INSTITUTE FOR DEFENSE ANALYSES

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MEMORANDUM FOR THE MEDICAL ADVISORY COUNCIL

FROM: Jesse Orlansky

SUBJECT: X-27 (AAP 0101)

"Assessment of Changes in the Sensitivity of the Otolith Mechanism and its Central Nervous Connections to Linear Accelerations as a Result of Prolonged Weightlessness," Ashton Graybiel and Earl F. Miller, December 1, 1965.

X-28 (AAP 0102)

"Effects upon Semicircular Canal Function of Rotation of Head/Body in Weightless Environment," Ashton Graybiel and Earl F. Miller, U.S. Naval Aerospace Medical Institute, Pensacola, Florida, December 1, 1965.

It is obvious that the otolith mechanism is one of the more relevant mechanisms which may be affected by the Weightless conditions of space flight. As such, this is a natural experiment and we are fortunate that the protocol deals directly with this issue. Furthermore, the experimenters are widely known for their competence in this problem. It is a pleasure, therefore, to endorse this experiment as a necessary one with full assurance that it will be conducted in an effective manner.

There are two qualifications which should be noted and which are pointed out by the authors: (1) Unanticipated accelerative or vibrational forces may constitute an important variable to contaminate the results of the experiment. The authors point out the requirement to record the presence of such unwanted conditions, if they occur. However, they do not point out the way in which the presence of such forces might make it difficult to interpret the results of the experiment. This item probably deserves some additional explanation. (2) The authors point out that the "Graybiel-Miller Litter-Chair," a necessary device for this experiment, must be developed within a time frame of about 24 months in order to be available for the study. While there is little doubt that this device is technically feasible, it must be pointed out that the experiment will obviously be limited if the Litter-Chair cannot be developed to meet the proposed schedule.

The experiment is well conceived and clearly described. It is a pleasure to endorse it to the MAC.

Experiment X-28 is closely related to X-27 and the comments made above apply equally well to this one. I also endorse X-28 for the AAP program.

I wish to draw attention to a novel type of arithmetic which was used in costing these two experiments. In X-27, the itemized costs total approximately $155,000 while the total in the same table is given as $226,000. On X-28 the specified items total $312,000 while the total is given as $520,000. I don't wish to draw attention to these items in a technical review since I suppose that some accountant can explain it. Don't ask me how. I notice also that figure 1, which illustrates the rotating chair, is inhabited by a female. More power to Graybiel and Miller for their contribution to space flight.

Except for these piquant touches, the proposals are excellent and I endorse them not only without reservation but, in fact, with admiration, bravo.

Jesse

Jesse Orlansky

JO:mh

BURTON K. MEYERS LECTURE

PRESENTATION TO

UNIVERSITY OF INDIANA

~~UNIVERSITY OF KENTUCKY~~

MEDICAL CENTER 30 MARCH 1966

~~EIGHTH ANNUAL RESEARCH CONFERENCE~~

INDIANAPOLIS, INDIANA

~~LEXINGTON~~, KENTUCKY

25 MARCH 1966

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Ladies and gentlemen, I am ~~indeed pleased with this opportunity~~ SINCERELY HONORED TO HAVE BEEN ASKED TO PRESENT THIS BURTON K. MEYERS LECTURE TO YOU TODAY. THE SUBJECT MATTER IS to ~~present to so distinguished a gathering a review of~~ a somewhat different form of medical research, the NASA program of in-flight medical investigation AND I ~~WOULD LIKE TO REVIEW~~ AM VERY PLEASED TO TRY TO REVIEW IT FOR YOU THIS NEXT HOUR. Space Medicine, like other forms of environmental medicine, differs from clinical medicine in that it deals with normal man in an abnormal environment. On the other hand, it shares with clinical medicine an abiding interest in the distinction between normal and abnormal human responses, the study of both, and the prevention and correction of undesirable physical or mental changes. It also shares with clinical medical research a commitment to the application of the principles of scientific objectivity in the separation of truth from superstition. I would like to begin this discussion by reviewing some of the important general concepts which form the framework of the program, then discuss the specifics of the Gemini experiments program, and finally describe our present thinking with respect to medical investigation in the Apollo program and beyond.

The fundamental issue ~~with which we are confronted~~ CONFRONTING US in launching man into space is the ability of man and machine to support prolonged manned space flight missions. The method elected by NASA Manned Space Flight to resolve this issue is what is known as the incremental approach, the extension of our manned space flight experience in step wise fashion to progressively longer duration and more complex missions. THE Medical information WE obtain~~ed~~ from flight crews during these missions can be thought of as consisting of two types.

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The first provides real time information concerning the welfare and safety of the crew, and is, ~~therefore~~ APPROPRIATELY ENOUGH, known as medical safety monitoring. Medical safety parameters consist of the ECG, respiration, temperature and blood pressure (and one should also add voice communication since this is recognized as an extremely important medical monitoring device). This type of information serves as the basis for immediate ~~and important~~ operational decisions on the part of ground based medical monitors, such as go - no go and flight abort decisions, and also therapeutic instructions which might have to be given the flight crew.

The second type of medical information is more fundamental in nature. Although it may be of less, or even little importance to the successful completion of the particular mission from which it is gathered, it is essential to the planning of subsequent missions and future space programs. It is to the second area that the medical experiments program is primarily addressed. It emphasizes the health, welfare, and safety of the astronauts on future missions. Its goal is to gain maximum insight into man's physiological and functional integrity as effected by prolonged existence in the space environment, and to determine how best his mission in space can be extended. Consistent with the incremental approach, it is incumbent upon the medical experiments program to take maximum advantage of each progressive mission to spot potential problem areas, establish quantitative trends, and be prepared with effective preventive measures.

The investigation of man's responses to space flight has four key (2)
objectives. These are to determine the human effects of space flight and the time course of these effects; the mechanisms by which these effects are manifested; means of predicting the onset and severity of these effects; and the most effective and practical means by which potentially untoward effects can be prevented ~~and/~~or corrected. These four objectives ~~fall~~ come under the general category of ~~the provision of~~ information to support man on progressively longer duration space flights. As our flight program procedes, however, we will be more & more able to accommodate a second major category of objectives--that of contributing information significant to scientific disciplines concerned with studies of human function.

Perhaps unique to any experiments which are to be accomplished in an (3)
operational setting is the requirement that it be feasible to accomplish them within the constraints of that operational setting, as well as the standard requirement that they have sufficient scientific merit. Proposed in-flight medical experiments are, therefore, first screened for scientific merit, i.e. from the standpoint of relative importance to our goals, validity and reliability of experimental design, etc.; and then evaluated from the point of view of technical and operational feasibility, i.e. the ability of spacecraft, flight crew, ground crew, and mission to accommodate them.

Mission constraints, upon which feasibility determinations are based, in general, arrange themselves into ~~two categories:~~ either engineering constraints, ~~and~~ or operational constraints. Among the more important of these are such technical or engineering factors as volume, weight, power, and telemetering or tape recording requirements; and such operational factors as ease of accomplishment by the flight crew, training requirements, flight crew time requirements, non-interference with other major mission objectives, and ground crew support requirements.

Of all of these, one of the most difficult is the very long lead time required for any experiment to be incorporated into a projected flight. Except in unusual instances, the deadline for acceptance of an experiment for a particular flight must precede that flight by approximately two years. This important consideration has made it necessary for us to prognosticate problems as well as solutions as realistically as possible far in advance of each flight.

Concerning the medical content of this program, this subject is perhaps (4)
most clearly outlined by calling upon a technique which we used successfully in one of our studies. The technique consists of first defining the gamut of environmental factors or stresses to which astronauts are exposed; then examining the potential effects of each of these stresses on each of the body functions and systems. By examining the interfaces between the two, areas of potential difficulty, the degree of likelihood of their appearance, and ~~their~~ severity as a function of duration of flight, can be identified and evaluated with relative simplicity and clarity.

(5)

Upon carefully reviewing a rather comprehensive list of potential stresses, one must conclude that virtually the only stress factor of space flight which cannot be duplicated in an earth environment is prolonged weightlessness. Consequently, the major stress effect problems which warrant in-flight medical experiments are weightlessness, itself, and combinations of it with other factors. It may be observed that even with respect to such little known conditions as ionizing radiation, magnetic field alterations, and the micrometeoroid hazard, once the environment is defined, these questions, complex as they may be, for the most part can be rather thoroughly studied on the ground. Upon reviewing a similar list of combined stresses which may be considered SYNERGISTIC ~~to have uniquely troublesome effects~~, all of these, at least during the course of our studies, have contained weightlessness as one of the factors in question.

(6)

Reviewing now the groups of body functions, it is perhaps safe to say that of the possible effects of prolonged weightlessness on man, those most seriously anticipated are cardiovascular deterioration, bone demineralization, muscular atrophy, and dehydration. With the exception of dehydration, all of these are disuse phenomena which have been observed repeatedly during bedrest and water immersion studies, as well as during many years of clinical observation. With respect to disuse phenomena, the consensus of current thinking is that overt manifestations, if they develop at all, would be most likely to occur during the multiple G stress of reentry or the sustained one G stress BACK ON EARTH ~~of terrestrial existence resumed upon landing~~, rather than during the period of exposure to weightlessness.

The phenomenon of dehydration has been observed in all manned space flights to date. Whereas in Mercury it might have been due in large measure to inadequacies of environmental control, the same has not been true of the Gemini series. Temperature and humidity control in the Gemini spacecraft has been excellent. Yet, dehydration continues to be demonstrated. This lends support to the concept that loss of body water is probably initiated by the redistribution of body fluids in the weightless state, and mediated, at least in part, by the Gauer and Henry reflex. To briefly explain this rationale, in weightlessness, blood is no longer drawn to the lower extremities by gravity. This allows a greater proportion of the total blood volume to circulate within the thorax. Stretch receptors in the auricles are then stimulated, which initiate a reflex mediated by the vagus, resulting in a decreased output of ADH by the posterior pituitary. Urinary output is thereby increased and total blood volume reduced with a resultant compensatory reduction of thoracic blood volume. As you will see, however, the Gauer and Henry reflex alone does not completely explain the Gemini findings with respect to water balance.

Although the four effects mentioned have received the greatest emphasis, other possible effects cannot be excluded from consideration, despite the fact that there have been no overt manifestations of them in any of our flights through Gemini 8, our most recent one. Among these are respiratory, vestibular, metabolic, and perastaltic effects, possible effects upon ciliary action with particular reference to the respiratory tract, effects upon alertness, and, of comprehensive importance, effects upon total performance. All of these warrant attention and study.

The evaluation of flight experimental data is contingent not only upon the accuracy of the in-flight data, itself, but also upon the validity and adequacy of the control or baseline data, with which it must be compared. For most in-flight medical experiments, the flight crew serve as their own controls, and baseline data then consists of astronaut information obtained during the process of medical selection, during centrifuge runs, pressure chamber runs, simulation and trainer activity, numerous physical examinations, and special pre-flight control studies for specific in-flight medical experiments.

An active program of ground based medical experiments involving non-astronaut subjects serves as an important source of additional baseline data. These experiments are designed to parallel some aspect or aspects of space flight in order to study their effects, or to distinguish specific factors as causative of effects which might have been observed during space flight. Some of these are bed rest studies in which absolute bed rest is used as a simulator of weightlessness. (At bed rest, the cardiovascular system is not required to support the weight of the column of blood, nor the musculoskeletal system the weight of the body in the long axis.) Bed rest studies provide a great variety of data concerning many of the body functions and systems. These studies also enable us to calibrate certain testing procedures and preventive techniques prior to their use during an actual mission. OTHER WTL. STUDIES UTILIZE H_2O IMMERSION & PARABOLIC AIRCRAFT FLIGHTS.

A rather unusual, but very pertinent direction of study is the medical monitoring of individuals under stress during sports events, such as skydiving, sports car racing, hockey, and even bull fighting. INTERESTINGLY ENOUGH, These studies have shown, among other things, that heart rates of normal individuals can rise beyond levels previously considered by many clinicians to be the top limit of normal without ill effect. These studies have also shown that tilt table responses in normal subjects can be as altered after a 12 hour sports car race as after a space flight, a fact which clearly demonstrates the importance of this type of information to maintaining perspective in interpreting space flight findings.

Turning now to the Gemini program, medical safety monitoring consists (8) of the same four measurements which were recorded during Project Mercury, i.e. temperature, blood pressure, ECG, and respiration. The equipment, however, has been somewhat modified. Gemini bioinstrumentation incorporates the use of miniaturized signal conditioners inserted into the circuit, and worn inside the pressure suit. These have been shown to result in an improved signal and a greater degree of accuracy and reproducibility of the records obtained. Shown here are the breadboards and final products of several signal conditioners. They are, in effect, small amplifiers placed close to the (9) source of the signal. This illustration is a close-up view of a typical signal conditioner.

The Gemini biomedical tape recorder is capable of recording seven (10) channels of information for a total of 100 hours. It is very lightweight and compact, measuring approximately 3 x 5 x 8 inches. It is used to record both medical experimental data and medical safety information.

The Gemini program consists of a series of 12 flights, the first two (11) of which were unmanned. Among its primary aims are to provide training in orbital rendezvous and docking, and experience with extravehicular activity. One of its major objectives was to determine the effects of prolonged space existence upon man. This has been accomplished by increments to the maximum duration flight of 14 days we saw in Gemini 7.

The Gemini in-flight medical experiments program consists of a total of eight experiments and ~~one~~ A GROUP OF operational procedures, formerly Experiment M-2.

This ~~is~~ consists of the tilt table ~~procedure~~ studies and evaluations of body fluid compartments, which, as ~~an~~ operational procedures, ~~was~~ were performed on most missions of the Gemini series. Of the remaining eight experiments, four are additional cardiovascular experiments, two are concerned with bone metabolism and electrolyte balance, one is an evaluation of sleep during flight, and the remaining one is an investigation of otolith function. Because Gemini 7 was the longest flight of the series, it was heavily medically oriented and carried all of the Gemini in-flight medical experiments and operational procedures.

Experiment M-1 is the evaluation of a countermeasure against cardio- (12)
vascular deconditioning as observed by the tilt table and other procedures. It consisted of the regularly cycled intermittent inflation and deflation of pneumatic cuffs about the thighs. The cuffs, which ~~are~~ were incorporated into the undergarment, were applied to one astronaut and the results of his cardiovascular evaluation were compared with those of the other. This method is based upon the work of Graveline who in 1961 demonstrated the effectiveness of similar cuffs about all four extremities in preventing the degradation of tilt table tolerance following water immersion. While he used an inflation pressure of 50 mm of mercury applied alternately one minute on and one minute off throughout the period of immersion ~~of his subjects~~, the procedure as used in Gemini applied a pressure of 80 mm of mercury, two minutes on and four minutes off. The inset photograph is a picture of one of Graveline's original subjects. The next slide illustrates the Gemini automatic programmer (13)
and oxygen bottle and the location of the inflatable cuffs. The technique is thought to mediate its effect by preventing or slowing the redistribution

of blood volume within the body, as well as by exercising the venous network of the lower extremities to maintain tone.

The experiment was flown on Gemini 5 and 7. On Gemini 5, a small leak developed in the system, and the oxygen supply was depleted after four days. ~~The system and method were improved for~~ CONSEQUENTLY, ON Gemini 7 ~~and~~ the equipment ~~is now~~ WAS operated from the cabin oxygen supply system rather than its own source. ~~Throughout the Gemini 5 flight~~ IN BOTH GEMINI 5 AND 7, the IN-FLIGHT cardiovascular responses of the ~~two astronauts~~ C-PILOT AND PILOT were not significantly different. I will discuss the post-flight evaluations in a moment.

Experiment M-2, the now operational tilt table procedures and body fluid studies, were performed pre- and post-flight on Gemini 4, 5, and 7. (14)
The tilt table procedure alone was performed on Gemini 3 and 6. The tilt table study is ~~essentially a cardiovascular~~ USED AS A provocative test designed to bring out incipient changes in cardiovascular responsiveness. A series of these tests are done pre-flight and post-flight in a manner somewhat similar to that used during the Mercury program for the Cooper flight, MA-9. In Gemini, however, the period of vertical tilt has been expanded from five ~~minutes~~ to fifteen minutes, the tilt board has been fitted with a saddle-like seat, and the introduction of the Flack test (A CALIBRATED VALSALVA MANEUVER) during tilt has been eliminated. This slide indicates how the Stokes litter was used as a tilt board during the Mercury program. In this procedure, the astronaut supported himself on his feet during the period of tilt. The next slide illustrates (15)
the Flack tester, ~~which is a~~ THE device used to perform a calibrated Valsalva maneuver. The subject, blowing into ~~it~~ THIS DEVICE with sufficient pressure to match

the red line on the piston to the red line on the cylinder exerts a pressure of 40 mm of mercury. As utilized during the Mercury program, the Flack test was introduced at the fourth minute of vertical tilt and the subject maintained the maneuver for 15 seconds to provide an additional cardiovascular stressor. The next slide illustrates the ~~use of the saddle~~ SADDLE tilt table ~~during a bed rest study~~. This is the table used in Gemini to eliminate use of the subject's legs for his support during tilt. Recent studies have indicated that this measure renders the test perceptably more sensitive by ~~obviating~~ PREVENTING the assistance given venous return by even this minimal activity of the lower extremities.

In conjunction with the tilt table studies performed on Gemini 4, 5, and 7, blood volume, plasma volume, and red blood cell mass determinations have also been made. In all of these, the RISA technique utilizing iodine 125 was used for determinations of plasma volume. In Gemini 4, blood volume was calculated from the hematocrit determination and plasma volume. Red cell mass estimates were made by subtraction of the plasma volume from the calculated blood volume. In Gemini 5, tagging of red cells with chromium 51 permitted a direct determination of red cell mass, as well as a determination of red cell survival. In Gemini 7, red blood cell tagging with labeled DFP was added in order to eliminate the problem of elution and better identify the cause of the diminution of red blood cell mass, i.e., whether based on a diminished production or augmented destruction of red blood cells.

DISCUSSION

M-3 is the exercise experiment performed with a bungee cord as in Project Mercury. It is an evoked response experiment whose purpose is to measure

cardiovascular responses to the same fixed stimulus, as the flight continues. As programmed in Gemini, the M-3 exercise is not a cardiovascular conditioning procedure although this will be explored in Apollo. The force required to stretch the cord is approximately 70 pounds, and the stretch distance is limited to about one foot. The work completed per full stretch is, therefore, approximately 70 foot pounds. Each exercise period has consisted of a single stretch per second for 30 seconds. Four such exercise periods were performed by each astronaut throughout each day on both Gemini 4 and Gemini 5. THEY WERE DONE TWICE A DAY ON GEMINI 7. As shown on the slide, in Gemini the cord is held by means of a loop about the feet rather than attached to the floor of the vehicle, as it was in Mercury simply to facilitate storage. This slide illustrates the use of (18)
the cord by an astronaut in the spacecraft.

In Gemini 4, 5, and 7, the flight crews showed no significant change in cardiovascular response to this exercise as the flight progressed, nor were there significant differences between in-flight responses and those obtained from similar measurements on the ground. The fact that this method as used does not appear to be exceptionally sensitive might render it valuable as a predictive device.

Experiment M-4 is the in-flight phonoelectrocardiogram. By recording (19)
the phonocardiogram simultaneously with the electrocardiogram, the intervals between electrical stimulus and a fixed point of myocardial response, as indicated by valve closure, are determined for each heart beat. By thus timing the events of mechanical systole, an indication of the status of the myocardium, and its responsiveness, is gained. Illustrated in this slide

is the microphone and signal conditioner used for the phonocardiogram. The next slide shows the approximate placement of this equipment on the astronaut.

This experiment, whose principal investigator is Dr. Carlos Valbona of the Texas Institute of Research and Rehabilitation in Houston, Texas, was flown on Gemini 4, 5, and 7.

M-5 is the analysis of body fluids for various hormonal assays and other determinations. Assays of particular interest are the steroids, catecholamines, and antidiuretic hormone. The experimental procedure calls for the analysis of both blood and urine samples pre- and post-flight, and of urine specimens obtained during flight. On Gemini 7, 75 cc urine specimens were collected from each mixture of two successive voidings and stored for post-flight analysis. Urinary output was determined by mixing the urine in the mixing bag with a fixed amount of ~~tritium~~ TRITIATED WATER before filling the specimen bag. Urinary output calculations are based upon the concentration of tritium in the specimen. This experiment was flown for the first time on Gemini 7. The equipment consists of a valve, tritium container, common mixing bag, and specimen bags. The remainder of the urine after sampling was dumped overboard. The next slide shows a specimen bag. You might find it of interest that even this small item of equipment must be flight qualified. Its most critical qualification test is its resistence to burst in a high vacuum environment, for obvious reasons.

Experiment M-6 is the measurement of bone density by means of a special x-ray technique which is performed pre-flight and post-flight. Shown here is the principal investigator of the experiment and the originator of the technique, Dr. Pauline Berry Mack of Texas Women's University.

Although the technique is highly specialized, it employs standard x-ray equipment and a metal wedge densitometer to determine the density of the os calcis and middle phalanx of the fifth finger before and after flight. A photo-scanner is used to determine bone density from the x-rays, and pre- and post-flight films are compared. A diminution of bone density was noted in both bones of all ~~four~~ Gemini 4, 5 AND 7 ~~and Gemini 5~~ astronauts but less prominently in the Gemini 7 crew. As would be anticipated, all of these values returnED to normal within a few weeks after the flight.

Experiment M-7 is the calcium balance study, perhaps more accurately described as A MINERAL ~~an electrolyte~~ balance study. It is a very closely controlled total intake and output study designed to identify changes in the mobilization and metabolism of calcium and other MINERALS ~~electrolytes~~, under weightless conditions. The principal investigators are Dr. G. Donald Whedon, Director of the National Institute of Arthritis and Metabolic Diseases, Dr. William Neuman of the University of Rochester Medical School, and Dr. Leo Lutwak of Cornell University Medical School. This experiment was flown for the first time on Gemini 7. Electrolytes which are being evaluated in addition to calcium are nitrogen, phosphorus, potassium, sodium, chloride, and magnesium. As the primary amino acid constituent of bone matrix, hydroxyproline output is also being assayed. Pictured here is the plastic fecal receptacle utilized in Gemini. Urine, feces, and sweat were carefully collected and analyses of these specimens and of flight food are currently in progress. (23)

Experiment M-8 was also flown for the first time on Gemini 7. It is an assessment of depth of sleep during weightless flight as measured by electroencephalography. The principal investigator is Dr. Peter Kelloway of Baylor (24)

University Medical School. Pictured here are the electrodes and signal conditioners for the bilateral parieto-occipital leads which ~~are to be~~ WERE recorded. The next slide illustrates the leads in position worn by one of our laboratory technicians at the Manned Spacecraft Center in Houston. As many of you are aware, depth of sleep has been directly correlated with a slowing of the electrical activity of the brain. On Gemini 7, these electrodes were worn by one astronaut for the first two days of flight AND THE FOUR STAGES OF SLEEP (EEG) WERE CLEARLY DEMONSTRATED. 25

Experiment M-9 is the otolith function experiment designed by Captain Ashton Graybiel and Dr. Earl Miller of the Naval School of Aviation Medicine, Pensacola, Florida. The otolith mechanism is primarily a sensor of linear acceleration. Since this is a gravity sensing and gravity dependent mechanism, the question of the possible development of changes in sensitivity of the otolith in the absence of gravity has been raised. This experiment is designed to evaluate otolith function by means of two methods, which ~~constitute~~ ARE the two parts of the experiment. The first is the determination of egocentric visual localization of the horizontal in flight. The equipment for this measurement has been incorporated into the equipment for another in-flight experiment. It consists of a light-proof goggle with a rotatable illuminated white line in front of one eye. During flight, the astronaut attempts to rotate the white line to what he considers the horizontal position, i.e., the position parallel with the pitch axis of the spacecraft. His ability to do this is a function of the integrity of otolith responsiveness. The position of the white line is read by the other astronaut by means of external calibrations on the surface of the actuating ring. The second part of the experiment consists of the measurement of ocular counter-rolling pre- and post-flight. This is done by tilting 26 27 the astronaut to the side in a very precise fashion. With this movement, the eyes normally rotate very slightly in the opposite direction in an attempt to maintain alignment with the horizon. The degree of counter-rolling reflects the sensitivity of the otolith mechanism. The amount of sideward tilt is an exact 50 degrees, hence the use of the frame. The head is held very still by supporting cushions while the camera which is fixed to the frame in front of the eyes takes a series of still pictures to enable the measurement of counter-rolling in minutes of arc. The counter-rolling frame is shown on this slide, and the next slide is a close up showing a better view of the position of the camera with the relation to the head.

This experiment was flown on Gemini 5 and Gemini 7. The data obtained show no evidence of otolith disturbance due to weightless flight of up to two weeks.

It should be noted that none of the Gemini flight crews to date have exhibited any overt manifestations in the form of symptoms or signs of adverse effects. The findings which have been discussed in this review of ~~the~~ Gemini ~~in-flight~~ medical ~~investigations~~ have been obtained from specific tests and laboratory measurements which have been performed for the purpose of obtaining trend information.

Most of these Gemini experiments will be repeated during the Apollo program since Apollo will offer the opportunity of obtaining physiological information from flight crew members who are mobile during their exposure to weightlessness. Additional medical investigations planned for the

Apollo program are a study of cytogenetic and immunological effects on blood elements, the use of exercise as a cardiovascular preventive measure, vectorcardiographic studies utilizing the Frank Lead system, in-flight measurements of metabolism, evaluation of lung volumes, a continuation of the red blood cell survival studies, and, depending upon its level of development, the use of the lower body negative pressure device pre and post flight. This device, shown in this illustration in a clearly non-flyable form, is being investigated by the Air Force School of Aviation Medicine. As its name implies, the principle involves the application of negative pressure to the lower portion of the body to increase the relative volume of blood in the lower extremeties. With respect to the circulatory system, this can be used as a kind of gravity substitute in flight, and therefore can be applied either as an in-flight tilt table test or as a cardiovascular preventive measure.

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OFF

The flight program currently envisioned as the follow-on to Apollo is the Apollo Applications Program. It entails the utilization of Apollo vehicles and technology for more prolonged and varied orbital missions and expanded lunar exploration. IT'S BASIC PURPOSE WILL BE SCIENTIFIC. Since this program is presently in the planning stage, it would be premature to launch into a detailed discussion of it. However, its medical potential as an extended duration orbiting research laboratory does bear a few important comments.

In-flight medical investigation for this flight program has two major aspects; on the one hand, a planned R&D program based primarily on a series of NASA initiated studies; on the other, medical and behavioral experiments proposed FOR FLIGHT BY PPLE. INVESTIGATORS OF THE SCIENTIFIC COMMUNITY ~~by the scientific body~~ of the United States and friendly foreign nations.

NASA initiated studies were begun in early 1963 and consisted of the work of in-house professional groups, industry, and a group of prominent consultants known as the Space Medicine Advisory Group. These efforts led to our presently planned research and development program. As currently viewed, the medical effort for this program falls into eight categories, namely, behavioral, neurological, cardiovascular, respiratory, metabolic, endocrine, hematological, and microbiological and immunological. Since clinical laboratory procedures will be performed on board the spacecraft, presently planned research and developmental efforts emphasize the development of microtechniques and clinical laboratory techniques which do not require the use of wet reagents. In addition, there will be a continuing effort toward the development and validation of new physiological measurement techniques and equipment improvement, further studies to define ranges of normal physiologic responses of man under dynamic conditions, and continued investigation of DATA STORAGE, COMPUTERIZATION, TRANSMISSION, AND DISPLAY. ~~the use of the computer and the improvement of display systems in the handling of medical data.~~ (30+31)

Looking now to the other aspect, the participation in the program by the scientific community, we have actively solicited this kind of activity on several occasions in the past, but until very recently, responses have been quite slow. Lately, there has been a noteable increase in the number of proposals received, and it is our intention to encourage this trend by continuing to improve our methods of communication with the scientific community. In keeping with this, I would like to take this opportunity to encourage anyone interested in designing and submitting an experiment which he considers pertinent, to procede actively to do so. The program of in-flight medical investigation is a national endeavor. As such, it is open to any professionally qualified individual in the United States, as well as those from friendly foreign nations.

Proposals for in-flight medical experiments are received by the Medical Science and Technology Division of Space Medicine in NASA Headquarters on a form which has been drawn up for that purpose. The review for scientific merit is accomplished by the NIH study section system, followed by a review from a programmatic perspective by a council of medical consultants to this division which is called the Medical Advisory Council. The appropriate forms and any further information you may require may be obtained by contacting our office, NASA Headquarters, Washington, D. C. I MIGHT ALSO TELL YOU AT THIS POINT THAT Should you wish to have a background of medical information obtained from our manned space flights to date, you are invited to write to the Deputy Director, Scientific and Technical Information Division, NASA Headquarters, Washington, D. C. 20546--Attention: Mr. Howard G. Alloway.

Permit me to conclude by saying that it has been my pleasure to present to you this account of the NASA program of in-flight medical investigation. I sincerely hope that you have found it to be of interest, and, even more, that it has stimulated some of you able investigators in the audience to profound thoughts, and active participation in the program.

LOOKING NOW TO THE OTHER ASPECT, THE PARTICIPATION IN THE PROGRAM BY THE SCIENTIFIC COMMUNITY, WE ARE VERY INTERESTED IN RECEIVING PROPOSALS FOR IN-FLIGHT MEDICAL & BEHAVIORAL EXPERIMENTS FROM ~~INVESTIGATORS &~~ RESEARCHERS ACTIVE IN THESE FIELDS. ~~THROUGHOUT THE COUNTRY.~~ THE PROGRAM OF INFLIGHT MEDICAL INVESTIGATION ~~IS CLEARLY A NATIONAL ENDEAVOR, AND~~ MUST MEET THE HIGH STANDARDS OF MEDICAL & BEHAVIORAL RESEARCH WHICH WE HAVE ACHIEVED IN OUR SCHOOLS & LABORATORIES THROUGHOUT THE COUNTRY. THIS EFFORT, THEREFORE, IS OPEN TO AND ACTIVELY INVITES ~~THE~~ ~~ALL~~ QUALIFIED INDIVIDUALS ~~IN THE U.S. AS WELL AS FRIENDLY FOREIGN NATIONS~~ TO ~~CONTRIBUTE THEIR IDEAS~~ SUBMIT THEIR PROPOSALS FOR ~~INFLIGHT MEDICAL~~ EXPERIMENTS WITH THE INTENTION OF BECOMING ACTIVE PRINCIPAL INVESTIGATORS. ~~IN THE PROGRAM.~~ RESPONSES TO DATE HAVE BEEN GOOD AND GAINING. WE, NASA, CONSIDER IT ONE OF OUR MAJOR RESPONSIBILITIES TO ENCOURAGE THIS TREND.

X
REVIEWS FOR SCIENTIFIC MERIT ARE ACCOMPLISHED BY THE NIH STUDY SECTION SYSTEM, FOLLOWED BY A ~~RE~~ SCIENTIFIC REVIEW FROM ~~THE~~ A PROGRAMMATIC PERSPECTIVE BY A ~~MEDICAL AD~~ COUNCIL OF MEDICAL CONSULTANTS TO NASA OMSF, WHICH IS CALLED THE MEDICAL ADVISORY COUNCIL.

(+ FURTHER INFO)

I WOULD LIKE TO CONCLUDE BY ~~AGAIN~~ THANKING YOU FOR THE OPPORTUNITY OF REVIEWING THIS ~~NEW ASPECT~~ AREA OF MEDICINE WITH YOU TODAY.

SUBSTITUTE

IN OUR R&D PROGRAM, ON THE OTHER HAND, WE WILL RELY HEAVILY ON ~~INDUSTRY TO~~ OUR ~~GREAT~~ INDUSTRIAL RESOURCES TO ADVANCE THE STATE OF THE ART IN BIOCHEMICAL & PHYSIOLOGICAL + DATA HANDLING TECHNIQUES & EQUIPMENT. IT IS IN THESE AREAS IN PARTICULAR THAT SIGNIFICANT ADVANCEMENTS APPLICABLE TO BOTH AEROSPACE MEDICINE AND CLINICAL MEDICINE ARE LIKELY TO BE MADE.

ARTICLE FOR
U. S. MEDICINE

S. P. VINOGRAD, M.D.
DECEMBER 19, 1966

Nineteen sixty-six was a year of significant advancement toward our national goal of landing man on the moon within this decade. While the unmanned Surveyor and Orbiter flights returned startlingly detailed photographic reports of the characteristics of the lunar surface, NASA Manned Space Flight completed the Gemini program with unqualified success. As the final precursor to the Apollo series and its target manned lunar landing mission, the Gemini program had as its major objectives the validation of man, machine, and supporting technology for long duration flight in excess of the requirements of the lunar landing mission; rendezvous and docking of two vehicles in earth orbit; the development of operational proficiency of both flight and ground crews; the conduct of experiments in space; extravehicular operations; on-board orbital navigation; the active control of the reentry flight path to achieve a precise landing point; and the investigation of operational variations and applications of alternative navigational backup modes. All of these objectives have now been achieved. All of them, too, bear out the importance of man as a highly skilled functional unit in this man-machine complex.

In Gemini, no overt signs or symptoms of physical or performance deterioration have been encountered. Yet, the careful measurement of specific body systems and functions has brought out subtle changes whose time courses and preventive requirements are the subject of continuing research since they have an important bearing on the planning of very long duration manned flights of the future.

Although Gemini 7, the 14-day flight of Col Frank Borman and Lt Col James Lovell, took place in December 1965, the evaluation of the medical data derived from that flight was an important 1966 space medical effort. Because of its long duration, this flight carried the full complement of medical experiments and medical operational procedures scheduled for the Gemini program. It was the first mission in the history of manned space flight which was designated a medical flight. Its successes are a memorable reflection of the cooperation, interest, and conscienciousness of its flight crew who carried out their heavy schedule of medical investigations under the severely constrained operational conditions of space flight, a far cry from the conveniences of an earth-based laboratory. Its successes are also a tribute to the principal investigators and associated scientific personnel from both the scientific community and NASA who planned and worked so carefully to derive valid data. Comparison of the Gemini 7 flight data with that obtained from Gemini 4 and 5 (the 4- and 8-day missions, respectively) has resulted in considerable clarification of the physiological occurrences which might be anticipated on longer duration space flight. Although the flights of Gemini 4 and 5 were less heavily endowed with medical experiments, we are similarly indebted to their flight crews, Astronauts McDivitt, White, Cooper, and Conrad, for their important roles in this effort.

Gemini was the first flight series to carry a pre-programmed group of in-flight medical experiments. This medical activity is now established as a program, called the program of in-flight medical experiments, whose present activity is currently centered about the planning and development of medical investigations for Apollo and beyond. It consists of a series of in-flight and pre- and post-flight medical measurement protocols designed to gain insight into man's physiological and functional integrity as affected by prolonged space flight.

In contradistinction to the medical operational effort, which emphasizes the welfare and safety of the flight crew during the actual mission, it places emphasis on the welfare and safety of the astronauts on future longer duration missions. During Gemini and Apollo, the objectives of this program are primarily operational in nature. They consist of the determination of the effects and time course of the effects of space flight on man, the mechanisms by which these effects are manifested, means of predicting their onset and severity, and the identification of the most effective preventive or corrective measures. Beyond Apollo, the medical experiments program will be able to accommodate a second category of objectives, the support of medical research which might be advanced by weightlessness or any of the other unique conditions of space flight.

This program is an open one which now includes and continues to encourage the participation of competent medical scientists throughout the country. Proposals for in-flight medical experiments and their associated ground-based research are reviewed for scientific merit by the NIH study section system followed by a second review by a group of outstanding consultants who are familiar with manned space flight, called the NASA Medical Advisory Council. Although the groundwork was begun more than a year earlier, the activity of the NIH study sections in rendering their highly competent and cooperative support to this program was another major landmark of the year 1966.

Gemini blood volume studies were carried out on the 4-, 8-, and 14-day flights. RHISA and Cr51 techniques were used pre and post flight for plasma volume and red cell mass determinations, respectively. Following flight, the red cell mass was decreased in all flight crew members. Although this decrease measured only 7% in one astronaut, the five other individuals showed losses ranging from 12-20%. The Gemini 4 and 5 results showed a good correlation with duration of flight. In Gemini 7, one astronaut showed an equivalent change to the 8-day crew measurements, while the other showed only the 7% change. Plasma volume measurements were slightly decreased following the 4- and 8-day flights with a resultant decrease in total blood volume in these two flight crews. Following the 14-day mission, however, both crew members showed an increase in plasma volume which compensated almost exactly for the red cell mass loss so that the blood volume showed no change over pre-flight measurements. It is currently held that the most probable reason for these changes in red cell mass is the hyperoxic environment (100% oxygen at 1/3 sea level total pressure), with decreased physical activity as a secondary factor. The blood volume changes are less well understood. The increase of plasma volume seen in the 14-day flight but not in the two earlier flights is explainable either as a compensatory response which took place as the duration of flight was extended, or by virtue of the alteration of certain of the human factors aspects of the Gemini 7 flight. Most notably, the Gemini 7 flight crew did not wear their pressure suits during most of their orbital flight with a resultant significant lessening of thermal stress. Of further interest is the fact that all of these flight crew members showed evidence of dehydration following flight as indicated by the post-flight weight loss which was in all instances almost immediately regained, or nearly so, with the imbibition of water after recovery. This and other indications of dehydration are of particular interest in the Gemini 7 flight crew whose blood volumes were unchanged and whose plasma volumes were increased. These blood volume and red cell studies are a team effort whose members include Dr. Craig Fischer, NASA Manned Spacecraft Center, Houston; Dr. Philip Johnson, Baylor University College of Medicine; and Dr. Charles Mengel, Ohio State University Medical School. Related ground-based research activity is a continuing NASA effort in these and other laboratories.

Pre- and post-flight tilt table studies, which utilize the tilt table as a measurable stimulus for the measurement of cardiovascular responsiveness, have been carried out pre and post flight during most of the Gemini missions. Until Gemini 7, a trend appeared to be emerging in which the degree and duration of alteration of tilt table response seem to correlate quite well with duration of flight. Following the 14-day flight, there was again an alteration of tilt table response which in one individual was less pronounced than those seen following Gemini 4 and 5, but which in the other individual was distinctly more pronounced. On the other hand, both Gemini 7 astronauts returned to their pre-flight levels in an unusually short time. Perhaps the most logical explanation for this improved recovery time relates to the fact that the blood volume was unaltered. The tilt table studies and all medical operational procedures were devised and implemented by a medical operations team under the direction of Dr. Charles A. Berry, Director of Medical Research and Operations, NASA Manned Spacecraft Center, Houston.

The effectiveness of rhythmically inflated thigh cuffs as a preventive measure to reduce changes in cardiovascular responsiveness during space flight was carried out as Experiment M001 aboard Gemini 5 and Gemini 7. In both instances, this device was worn by the pilots but not by the command pilots in order that post-flight tilt table and other responses could be compared. Although this method showed great promise in ground-based water immersion studies, its evaluation during space flight resulted in no favorable findings. This technique continues to be studied, in particular, the influence of alterations of cycle time and cuff pressures. However, the use of an elastic leotard-like garment currently appears to be better suited for flight. This is scheduled for evaluation in flight in the near future. The principal investigator of these experiments is Dr. Lawrence F. Dietlein, Chief, Biomedical Research Office, NASA Manned Spacecraft Center, Houston.

The evaluation of cardiovascular responsiveness in flight using bungee cord exercise as a calibrated stimulus was performed on Gemini 4, 5, and 7. Also carried on these flights was the phono-electrocardiogram experiment in which the timing of events of myocardial contraction was measured from simultaneous recordings of the phonocardiogram and electrocardiogram. Neither of these experiments demonstrated any changes unique to space flight within our maximal 14 days experience. The exercise regimen will be increased for this evaluation on future flights. Dr. Dietlein is the principal investigator of the exercise experiment while he and Dr. Carlos Vallbona of the Texas Institute of Research and Rehabilitation are co-investigators of the phono-electrocardiogram experiment.

Blood and urine examinations pre and post flight and the evaluation of urine specimens collected in flight were accomplished by Dr. Harry Lipscomb, Baylor University College of Medicine, and Dr. Elliott Harris, NASA Manned Spacecraft Center, Houston as Experiment M005. For many reasons, the collection of accurate aliquots of urine in flight is a far more difficult problem than was first apparent. However, this procedure was carried out on Gemini 7 with sufficient accuracy that correction factors based on a presumed constant creatinine output could be applied. The calculation of total urinary output from the aliquots (by a concentration-dilution technique) was of critical importance to the mineral balance experiment as well as to M005. In this experiment, electrolyte and water retention were observed immediately post flight, a further indication of dehydration. Plasma 17 hydroxycorticosteroids were elevated post flight but in-flight urinary outputs were normal, a finding which is consistent with the increased demands of reentry as compared with orbital flight. In addition, post-flight plasma uric acid levels were found to be slightly low, perhaps as a reflection of the low dietary intake of purines during flight.

A detailed mineral balance study was performed for the first time on Gemini 7. The principal investigators of this experiment are Dr. G. Donald Whedon, Director, NIAMD, NIH, Bethesda; Dr. Leo Lutwak, Cornell University Medical School; Dr. William Neuman, University of Rochester; and Dr. Paul LaChance, NASA Manned Spacecraft Center, Houston. This effort required a complete intake and output measurement of calcium, phosphorus, nitrogen, sodium, chloride, potassium, and magnesium. Output of hydroxyproline, the major amino acid constituent of bone matrix, was also measured. This was a highly complex experiment which required diligent effort on the part of the principal investigators and their team of ancillary personnel as well as the Gemini 7 flight and backup crews. The protocol included a ten-day pre-flight and two-day post-flight equilibration period as well as the 14-day in-flight experimental period. Despite all precautions, technical difficulties, such as inaccuracies in the urine sampling system, did occur. Yet, with the application of correction factors, acceptable curves were obtained. A mild negative calcium balance and a more pronounced negative nitrogen balance were demonstrated to have taken place during flight. This is consistent with the findings of the bone density experiment of Dr. Pauline Mack of Texas Women's University. In this experiment, three x-rays of one hand and foot of each astronaut were taken pre and post flight. Implying her own densitometric technique, she noted a demonstrable demineralization of both weight-bearing and nonweight-bearing bones. In the four- and eight-day flight crews, this occurred to approximately the same extent as that seen in weight-bearing bones after two weeks of bed rest. Paradoxically, the Gemini 7 changes, although again demonstrable, were less pronounced. Although the reasons for this apparent discrepancy are not entirely clear, the heavier in-flight exercise schedule adopted by the Gemini 7 astronauts is doubtless a significant factor.

The electroencephologographic analysis of sleep was also carried out aboard Gemini 7 by one flight crew member. Interpretable data was obtained for a period of a little over two days. The four stages of sleep were easily demonstrated, although "paradoxical" sleep could not be identified with certainty since electro-oculograms were not included. The principal investigator of this experiment was Dr. Peter Kellaway of Baylor University College of Medicine.

The investigation of vestibular otolith activity during weightless flight was the subject of an experiment by Dr. Ashton Graybiel and Dr. Earl Miller, Naval Aerospace Medical Institute, Pensacola. Pre and post flight ocular counter-rolling measurements were performed as an index of otolith responsiveness. In-flight measurements of the astronauts' ability to identify the horizontal axis of the spacecraft with vision obscured was used as an in-flight measurement of the integrity of the otolith system. These measurements were carried out on Gemini 5 and Gemini 7. In general, these data revealed no significant change in the otolith system in 14 days of space flight. Vestibular investigations will be continued into longer duration flights. Semicircular canal function has not yet been evaluated in weightless flight, but plans for in-flight research into their function, particularly as they are affected by Coriolis forces, are in being for the future.

Because of their relatively short durations and heavy operational schedules, the remaining Gemini flights after Gemini 7 did not carry medical experiments. Medical operational data has revealed no new or unanticipated findings except with respect to the Gemini 11 extravehicular activity. Although this problem is continuing to receive a great deal of attention and investigation, the most plausible explanation appears to be that the effort required to accomplish a task in a pressurized space suit without the assistance of gravity is much greater than was anticipated. This conclusion was well supported by the demonstration of successful task performance with the addition of restraining devices during the Gemini 12 EVA.

The Apollo program is scheduled to begin in 1967 and with it will come new opportunities for the addition of more data on the in-flight medical investigation begun in Gemini. With the Apollo Applications program, which we believe may follow, the entire scientific effort will be strongly emphasized and the scientific community will play a major role. Flight durations will be expanded, and crew task requirements will be more diversified. Consequently, the evaluation of man in the space environment will be intensified. With the increase in physical volume and weight capabilities of the vehicles, our ability to conduct valid investigation will also be augmented. The continuing and growing participation and support of our medical community in this national effort is, therefore, strongly encouraged.

D R A F T   II: May 19

Dear Colleague:

The National Aeronautics and Space Administration expects to complete, in this decade, a successful manned landing on the lunar surface. The Apollo program is designed to provide man the capability of operating in space and on the moon. The Apollo Application Program (A.A.P.) which follows the lunar landing will utilize this capability for the benefit of science.

~~For the medical research worker this provides an opportunity for a comprehensive analysis of~~ HUMAN ~~the~~ effects ~~of the space environment, on the astronaut.~~ THE MEDICAL ~~This~~ experimental program FOR AAP ENCOMPASSES ~~has~~ two major categories of objectives. The first~~, that of~~ IS TO provide ~~ing~~ information to support man on progressively longer duration space flights, ~~consists of the four objectives. These are to determine the effects, mechanisms, predictive means, and corrective measures with reference to the influence of space flight on the psychophysiological integrity of man. With the advent of the AAP program, the opportunity for in-flight investigation is expanded, and now can accommodate the~~ THE second ~~major category of objectives, that of~~ IS TO contribute ~~ing~~ information significant to scientific disciplines concerned with studies of human function. ~~This category of endeavor is inherent to the field of medicine and all of its branches as it is to the other biological and the physical sciences.~~ →

is thus offered
~~This offers~~ an excellent opportunity to increase the depths of medical understanding and to explore fields hitherto ~~so far~~ unaccessible. to the medical investigator. ~~To fulfill such a task satisfactorily,~~ NASA seeks the participation of medical investigators in many different fields on a timely basis.

Because of the long lead time, proposals for in-flight medical experiments, time is a critical factor. In-flight medical experiments must ~~should~~ be programmed at the earliest possible date.

If you have an experiment that you believe has merit, NASA invites you to submit a proposal. Guidelines and special forms for this purpose may be obtained from:

Sherman P. Vinograd, M. D.
Director, Medical Science and Technology
Space Medicine
Office of Manned Space Flight
NASA
Washington D.C. 20546

Sincerely,

George E. Mueller
Associate Administrator
for Manned Space Flight

VINOGRAD

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

Fred – Can you & Mac Link compose a letter similar to this re Medical Experiments? Might be a good approach.
[illegible]

IN REPLY REFER TO: SL(VRW:fw)

MAY 3 1966

Dear Colleague:

The National Aeronautics and Space Administration expects to complete, in this decade, a successful manned landing on the lunar surface and to have samples of the Moon returned to Earth. The returned samples will provide the first opportunity to determine, through a comprehensive analytical program, the composition of the Moon and evidence related to its origin.

Because the opportunity to submit proposals for analysis of lunar materials may not have come to the attention of some scientists, we are extending the deadline for submission of proposals to June 15, 1966. Equal consideration will be given to both new proposals and those that were submitted in response to previous announcements (June 1964, January 1965, and July 1965 issues of "Opportunities for Participation in Space Flight Investigations"). Proposals previously submitted may be amended during this extended period to reflect any changes in the proposed scope of investigations, designated investigators, or funding requirements. Proposals from laboratories that are prepared to undertake sample analysis by the Spring of 1968 will receive preferential consideration.

Proposals should adequately describe the scientific objectives and merit of the investigation, the competence and experience of the investigators, and the reputation and interest in the investigator's institution, especially from the viewpoint of whether the institution will provide the support needed to carry out the intended investigation. Proposals must designate the principal investigator, who will be responsible for the conduct of the actual analysis of the lunar material, and must include a description of his scientific competence and that of his co-investigators. In addition, proposals should describe the method of analysis, data to be obtained, type and amount of sample required, and any special requirements for sample preparation prior to shipment to the laboratory.

Instructions on the preparation of proposals, including requirements for funding and management, are contained in "Opportunities for Participation in Space Flight Investigations" NHB 8030.1, July 1965. Copies of this publication can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402, price 60 cents.

Twenty-five copies of the proposal are required for submittal to:

Director, Office of Grants & Research Contracts
Code SC
National Aeronautics & Space Administration
Washington, D. C. 20546

It is requested that twenty-five additional copies be forwarded to:

Mr. Verl R. Wilmarth
Chief of Planetology
Lunar and Planetary Programs
Office of Space Science
and Applications
National Aeronautics & Space Administration
Washington, D. C. 20546

Sincerely yours,

Homer E. Newell

Homer E. Newell
Associate Administrator for
Space Science and Applications

November 21, 1966

Report of *Ad Hoc* Sub-Committee of MAC
on the AAP Proposal of Dr. W. Dean Chiles, Wright-Patterson AFB

Dr. G. Donald Whedon, Chairman
Dr. Joseph Kubis
Dr. Jesse Orlansky
Dr. Edward J. McLaughlin (representing Space Medicine Staff)

The committee met with Dr. Chiles on November 18, 1966, in one of the offices in Space Medicine Division, NASA, from 9:10 a.m. to 11:40 a.m. for a "site visit" discussion of his proposal entitled, "Psychological Status of the On-Orbit Astronaut". Subsequently the committee had a 25 minute discussion of the proposal.

Dr. Chiles described his study primarily as an effort to learn from simultaneous performance of a series of tasks, more about "alertness" and how much of the subject's mental capacity he is able to use or muster, at various times of the day and under varying conditions at different times during the sequence of a space flight. Since man in practical life has many different tasks to perform and has to carry them out more or less concurrently, much more will be learned from a battery of tests which are "time shared" than from either single tests or even several tests run sequentially. Discussion brought out that in use of the tests of the type proposed, in the considerable experience to date with pilots, reliability from day to day was very good in the 90 to 120 minute test periods used, particularly for arithmetic, targeting and tracking tests, but that reliability had not been established for shorter test periods; in fact, shorter test periods of the 30 minute duration in the proposal have not been used except for two tests as part of the battery. There is apparently little relationship between the tests used and function as a pilot (validation). The sensitivity of the test battery now in use is reported as good; good and poor performers and good and poor performing days in a single subject can be detected. On inquiry as to the basis for selection of particular tests, it came out that although there had been some development, (that is, from experience certain tests have been changed or were discarded) the choice of tests is rather arbitrary; one important criterion for test selection is that tests which show <u>continuous</u> improvement in performance with training (that is, "do not reach an asymptote") are of no value. On inquiry with regard to "deterioration", under stress certain tests do receive priority over others by the subject.

The considerable weight and volume (and cost) of on-board equipment is due to the inclusion of computer equipment which contains the program of tests to be given the subject and also collects, stores and provides some relatively simple statistical treatment to the subject's response or "answers". These results are then to be telemetered to the ground; no on-board print-out equipment is planned.

In discussion of the budget, Dr. Chiles indicated that all of the funds requested for sub-contracts to manufacture hardware, none was for support of the research or test-observations to be carried out with the equipment. He is requesting one test unit for flight and of the 8 so-called "prototypes", two units would be used in training and in ground pre-flight tests, whereas 6 were intended for loan to other investigators. Dr. Chiles stated that the project could be done with one flight unit (Dr. McLaughlin: NASA requirement for two flight units, one merely being back-up, resulting in added cost of 50 - 60% for flight equipment), and one training or ground-test unit. The units proposed would differ from units currently in use only in the addition of a tracking test and in making a somewhat more compact and rugged package. A revised hardware cost estimate would be in the range of $600,000 to $800,000.

The plan of "research" operation, not particularly described in the proposal, is 1) to make a study of pilots, probably at Edwards AFB via contract to Douglas or some other company with Dr. Chiles as consultant, some of the work being done in his lab, and later 2) to carry out actual ground training, pre-flight testing and in-flight measurements under Dr. Chiles' direction. The budget requirement for the latter would be approximately $50,000 per flight, for the Edwards studies approximately $100,000 per year for 3 years.

Questioning with regard to the considerable period of 35 hours pre-flight training brought out that it takes 20 to 25 hours to come up to an asymptotic level of training and about 10 hours would be needed for collection of ground pre-flight data. A considerable part of the training could be done up to 6 months before flight but about 15 hours would need to be worked into the critical two months before launch. Thirty minutes, three times a day each day would provide a good window on circadian relationships, but this objective could probably be reached by two times a day two or three times a week if the time of day of test is varied. Dr. Chiles thought that time of test period might be cut to 20 minutes, although 30 minutes was much preferable, but all six tasks would need to be maintained.

<u>Committee Opinion and Recommendation</u>: The present proposal should not be recommended for approval. The committee felt that the approach of time-sharing multiple tests is sound and that the choice of tests was good, but that it was impossible to assume that current experience and conclusions of validity with respect to 1-1/2 to 4 hour test periods could be applied to test periods of 30 minutes; studies would have to be made of the usefulness and validity of "short" test periods. The committee recommends to MAC that Space Medicine staff take up with Dr. Chiles the possible submission of a proposal for ground-based (only) studies of the validity of short period testing with the type of testing proposed presently, presumably with pilots and perhaps students. Such a proposal would probably require 1) $500,000 for fabrication of two ground units suitable for the studies and 2) $100,000 per year for 3 years for support of the research.

The competence of Dr. Chiles in this field and his capacity to do the work was accepted.

IDA

December 2, 1966

Dr. E. J. McLaughlin
Secretary, Medical Advisory Council
Code MM
National Aeronautics & Space Administration
Washington, D. C. 20546

Dear Ed:

Don Whedon has made an accurate report of our discussion with Dean Chiles and I concur in his recommendations. Would Don consider adding the following paragraph at the end of the report, immediately preceding the recommendation, for explanatory purposes. It does not change the sense of the report.

> "It is worth noting that Dr. Chiles' work on a performance test battery for astronauts is the most advanced item currently available for this purpose. No other experimenter has worked on this problem for so long a period of time nor has brought a test battery to his stage of development. Bryce Hartman of the Air Force School of Aerospace Medicine developed a similar battery but Chile's battery has been more thoroughly tested. Edwin Fleishman of the American Institute for Research has started a fundamental study of the factors which should be represented in a performance test battery but he has not yet developed an actual test. As we know, Milton A. Grodsky of Martin Company, Baltimore, and others take an opposing point of view that the astronaut's status should be measured on operational tasks rather than on a test battery. No steps have been taken to resolve these alternative viewpoints."

Cordially,

Jesse Orlansky

JO:mh

WEIGHTLESSNESS AND MANNED SPACE FLIGHT

MEDICAL DATA TO DATE

ABSTRACT

PRESENTATION TO INSTITUTE OF ENVIRONMENTAL SCIENCES

S. P. VINOGRAD, M.D.

NOVEMBER 30, 1966

Medical data obtained from manned space flight to the end of the Gemini program is reviewed. These data are derived from in-flight medical experiments and from operational medical procedures. Observations include measurements of cardiovascular function, the musculoskeletal system, blood and blood volume, fluid and electrolyte balance, endocrine activity, sleep, and vestibular function.

Although data is still meager in some aspects, certain trends appear to be emerging. None of them have been associated with overt symptoms or signs of dysfunction in our flight crews.

Space flight medical data have shown a reduction of tilt table tolerance, decreased bone density, increased calcium and nitrogen output, dehydration, decreased red cell mass, and altered plasma volumes. Although single etiological factors are exceedingly difficult to identify, cardiovascular and musculoskeletal changes might logically be attributed primarily to a combination of weightlessness and relative inactivity. Decreased red cell mass, shortened red cell life span, and increased red cell fragility are thought to be most reasonably referable to both the high oxygen atmosphere and, again, to relative physical inactivity. Findings indicate that dehydration and altered plasma volume are not necessarily equatable. There is little question that both are relatable to thermal stress. At the same time, both changes may also reflect the influence of weightlessness on body fluid distribution.

MEDICAL ASPECTS OF ARTIFICIAL GRAVITY

IN

MANNED SPACE FLIGHT

An important problem confronting space medicine today is the so-called G-Decision. Does man need artificial gravity to fulfill his mission tasks while exposed to prolonged periods of weightlessness? The decision is important and urgent because it could have very fundamental effects on the design of spacecraft for long-duration missions. This paper is an analysis of known medical factors which must be considered in arriving at a final decision. The discussion is arranged in four sections: (1) Vestibular Effects, (2) Cardiovascular Effects, (3) Other Problems, and (4) Scientific Requirements.

1. VESTIBULAR EFFECTS OF WEIGHTLESSNESS: The vestibular organ consists of two parts: (1) the otolith organ which responds to position and to linear acceleration* and (2) the semicircular canals, which primarily responds to angular acceleration*. Anatomically, the two organs are closely related to having peripheral receptors in the same organ, a common blood and

*Linear acceleration refers to change of speed, while angular acceleration refers to change of direction with or without change of speed.

nerve supply and apparently a common representation in the Central Nervous System. However, functionally, the two senses are different. There is evidence that angular acceleration may also effect otolith function, but the sense of position appears to be limited to the otolith organ.

OTOLITH ORGAN

This organ consists of gelatinous material at the tip of hair-like cells (otolith) in two small fluid-filled chambers (utricle and saccule) of the inner ear. Otolith sensation is closely integrated in the brain with visual orientation sensations of position and movement from limbs, trunk, and neck, and with touch and pressure sensations from the skin.

There is continous tonic input to the Central Nervous System from the various receptor areas under earth conditions which is to some degree absent under weightless conditions. In Titov and some of the other Russian cosmonauts, there were reports of minor vestibular disturbances (nausea and disorientation) which may be attributed to the absence of normal otolith stimulation. The other cosmonauts and all American astronauts did not show signs of significant vestibular disturbances.

The possibility of recurrence of these mild vestibular disturbances in future space flight cannot be excluded. Apparently some people are sensitive to this kind of disturbance and at this time we have no selection methods to exclude them. There are also no reliable training methods to prevent these symptoms. However, the symptoms are not incapacitating and according to Dr. Graybiel's experience in the slow rotating room we may expect adaptation within a few days.

SEMICIRCULAR CANALS (SCC)

Angular acceleration effects the fluid (endolymph) in the semicircular canals of the inner ear. These are three canals arranged in orthogonal planes. Each canal contains a widening (ampulla) in which the receptor organ (cupula) is located.

Most disturbances of vestibular function (oculogravic illusion, oculogyral illusion, Coriolus effect) are due to angular acceleration (A. Graybiel, NASA SP-77, p. 217). These disturbances would not normally occur in space flight without effective angular acceleration such as spacecraft rotation. Therefore, they become important when a rotating source of artificial gravity is considered as can be seen from the following analysis:

Oculogravic illusion is an apparent displacement of the visual field (feeling of being tilted back, impression of objects in visual field rising) and is likely to occur when angular acceleration and gravity are acting in different planes. Since the gravity force component is not normally present in space flight, this condition is not applicable to the current discussion.

The oculogyral illusion is related to the oscillatory movement of the eyes during angular acceleration (nystagmus) and causes the illusion of fixed objects moving in the direction of the angular acceleration. It will, therefore, not normally occur in a non-rotating space vehicle, but it could occur if an on-board centrifuge is used or if the spacecraft is rotating about a short radius.

Coriolus effect is the motion sickness which may occur in a rotating field when on turning of the head, a pair of semicircular canals is suddenly brought into the plane of rotation.

VESTIBULAR RESPONSE - SUMMARY

There is no evidence indicating that the absence of gravity in space will cause any serious disturbances of vestibular function. Mild disturbances of balance and orientation were observed in the Russian cosmonauts. None of these reported disturbances, however, affected performance to a degree that would indicate a medical need of artificial gravity (NASA SP-77, 1965, p. 217). On prolonged space flight (months or years), the absence of positional tonic input could change the sensitivity of the respone to vestibular stimulation. Such a change of sensitivity would not affect astronaut performance in space as vestibular function is not required in a normal non-rotating spacecraft.

There is no reason or evidence indicating a disturbance of semicircular canal (SCC) function in space flight. However, SCC would play a major role in the selection of a suitable habitable gravitational environment in a rotating spacecraft. In this case, speed and radius of rotation must be based upon medical-engineering tradeoffs.

2. CARDIOVASCULAR FUNCTION:

BLOOD DISTRIBUTION

On earth, in the sitting or standing position, there is a marked gravitational gradient along the long axis of the human body. This affects blood distribution causing a shift of blood from the head and trunk to the legs. In the resting (prone or supine) position, the gravitational effect on blood distribution along the long axis of the body is eliminated. Blood distribution during weightlessness is largely equivalent to the earth-resting position. Therefore, human activity in weightlessness is imposed on an organism with a resting type of blood distribution. The physiological changes involved are the following:

VASCULAR TONUS:

On earth, man changes his position frequently (sitting, standing, lying down) and each change involves a shift of blood volume. This periodic filling and emptying of sectional vascular beds provides a stress factor which is essential to the maintenance of vascular tonus. The gravitational effect on vascular tonus is most pronounced in the leg area due to the marked differences of hydrostatic pressure in this area when changing position. Under weightless conditions, the clinical effects of loss of vascular tonus are enhanced by the loss of muscular tonus due to lack of activity. While in-flight performance will not be affected by the loss of vascular tonus, re-exposure of the body to an upright position in a gravitational field may cause excessive drainage of blood into the lower part of the body which could impair performance capability. This is the phenomena noted in post-flight tilt table response.

BLOOD PRESSURE, BLOOD VOLUME

The absence of normal gravity in space will cause a shift of blood from the legs to the chest and head. The regional blood distribution changes will be manifested on the arterial side as a pressure change with minimal volume change and on the venous side as volume change with minimal pressure change.

An increase of arterial pressure in the head and neck area due to the absence of gravity in space may affect the receptors in the great arteries (carotid body). The result could be an inhibition of heart rate and respiratory rate and possibly an increased responsiveness to cardiovascular stress. For example, the increase of heart rate in standard exercise may be greater than the increase obtained under corresponding conditions on earth (G.A. Chase: Aerospace Medicine, 37(12): 1232, 1966).

The increased blood volume in the great veins of the chest may inhibit the normal release of antidiuretic hormone from the pituitary gland causing an increased urinary water loss (Henry, Gauer Reflex), (C.A. Gilbert J. Appl. Physiology, 21(6): 1699, 1966).

Spaceflight observation as well as ground simulation indicate that the cardiovascular effects of weightlessness are not progressive, but are self-limited adjustment to the new environment.

PREVENTIVE AND CORRECTIVE PROCEDURES

If cardiovascular adaptation to space is permitted, performance may be impaired immediately after return to earth or when landing on some other planet. Elastic pressure on the legs by means of leotards appears to offer promise as a good protective device during this critical period though this is a temporary protection and not a correction of the underlying condition.

If it is considered necessary or desirable to prevent cardiovascular deconditioning during flight or to recondition the astronaut before re-entry, periodic application of negative pressure to the lower part of the body by means of a specially designed device may be adequate (McCally: Aerospace Medicine, 37(12); 1247, 1966).

3. OTHER EFFECTS OF WEIGHTLESSNESS:

RESPIRATION

Weightlessness causes some minor changes such as displacement of diaphragm and change of pulmonary blood flow which are not discussed here as they will not affect the "G-Decision."

MUSCLES AND BONES

Loss of muscle mass and decalcification of bones are not due directly to weightlessness, but to relative inactivity and can apparently be prevented by properly designed exercise. Special exercise equipment is being developed and procedures are being defined for use in spaceflight to prevent degeneration of antigravity muscles and of bony supporting structures.

MUSCULAR COORDINATION

Traditionally, the sense of position and movement is largely gravity dependent, however, muscular coordination did not pose any problems in short-duration flight and is less likely to do so with the prolonged adaptation during extended space flights.

WORK PERFORMANCE

Weightlessness obviously facilitates any task such as lifting where gravity normally plays a major inhibiting role. On the other hand, gravity provides a stabilizing factor for the human operator. In the absence of gravity stabilization, artificial restraint and support devices must be provided. The difficulty of providing completely adequate restraint may cause a decrease of efficiency (energy expenditure/work performed) in space, according to results of GT-XI and XII. However, it appears that the effect of weightlessness on efficiency can largely be controlled by adequate training, planning, and adequately designed restraints.

CELLULAR EFFECTS

On prolonged exposure to weightlessness, there may be some effect on cellular growth, repair and on genetic function. There may also be synergism with other stress factors such as radiation. At present, such concepts cannot be eliminated nor supported by adequate evidence.

DEBRIS, OPERATIONAL PROBLEMS

Aspiration of free floating debris in the space cabin was once considered a serious problem. However, no real problems were encountered in actual space flight.

Operationally, there is a human performance problem in weightlessness due to objects floating freely and due to the difficulty of handling fluids. A small gravitational force (0.1 g) could eliminate these difficulties without depriving the astronaut of the energy-saving effects of weightlessness. If the above become real problems, they might be adequately controlled by improved methods of ventilation and filtration.

4. SCIENTIFIC REQUIREMENTS:

Since the prime purpose of this paper is a review of possible operational medical requirements for artificial gravity in prolonged space missions, it is only secondarily directed to the use of artificial gravity as a research tool.

If long-duration orbital space flights are to be considered as valid simulations of interplanetary travel, the environment should be the same as that planned for use in interplanetary travel. Since rotation requirements for interplanetary travel would creat unique engineering design and operational problems, (re guidance and control, astronomical observation, etc) precursor orbital space flights should be used to define procedures which will assure man's safety in a non-rotating, zero-g, interplanetary space vehicle.

The medical scientist may, however, want one space vehicle with the capability of producing by rotation a 1-g gravitational field, with some other habitable part of the same space vehicle complex at 0-g. This would permit controlled study in depth of the effects of the effects of weightlessness and make it possible to separate other environmental factors from the effects of weightlessness. There is currently, however, no apparent need for applying these requirements to all space vehicles.

SUMMARY:

1. Vestibular function will not be a critical factor in making a decision whether artificial gravity is required, but it would be an important factor in the medical-engineering trade-off if rotation was required for other reasons.

2. According to presently available knowledge, the cardiovascular effects of weightlessness can be dealth with adequately without the help of artificial gravity. However, suitably induced artificial gravity could be beneficial to the cardiovascular system.

3. Deterioration of muscles and bones can apparently be prevented by properly designed exercise without the need of artificial gravity.

4. For ordinary maintenance tasks, a small gravitational force would be advantageous but cannot be considered a requirement.

5. The medical scientist would like ~~to provide~~ a precursor orbital space flight with the same gravitational environment as the one to be used for future interplanetary travel.

CONCLUSION:

~~According to~~ Based upon presently available evidence, weightlessness does not pose any medical problems which require routine use of artificial gravity. The occasional use of artificial gravity as a research tool in a space vehicle should be considered.

IMPLICATION FOR FUTURE SPACE FLIGHT

If man does not take an earth-gravity environment along into space, it is logical to expect that he will incur some physiological and/or psychological change caused by the absence of gravity. As noted above, some of these changes are known and predictable, others may only become apparent in some future space flight. NASA has a well defined program of medical experiments which uses an incremental approach to detect and measure early changes in man's function or performance. Where necessary, remedial procedures will be developed before proceeding to more prolonged space flight. Therefore, the conclusion that artificial gravity is not required under normal operational conditions is based on confidence in the medical experiments program.

DAILY BULLETIN

NEW YORK STATE ACADEMY OF GENERAL PRACTICE

NEW YORK HILTON — TUESDAY, APRIL 4, 1967 — FIRST EDITION

19th ANNUAL SCIENTIFIC ASSEMBLY *Rolls Out* THE RED CARPET

WELCOME

From The President

The American Academy of General Practice was the first medical organization to recognize that a physician's professional qualification does not end with his diplomacy or residency. Doctors can no longer remain status quo. Careful attention had to be given to his continued professional growth. One of the mediums open to a physician for his continued postgraduate education is conventions.

A convention is a great school for the study of the thoughts of the leaders in clinical medicine. At a convention one gains direction, enthusiasm and momentum. It also gives to the physicians an opportunity to become acquainted and involved in their organization and programs. As a respite from zealous attention to the scientific programs, one may socialize, make new acquaintances and renew old acquaintances.

As your President and spokesman on behalf of the New York State Academy of General Practice, I warmly welcome you to this Convention.

MAX CHEPLOVE, M.D.
President

ANNUAL BANQUET — WEDNESDAY 7 P.M. — TRIANON BALLROOM

DAILY BULLETIN

Official convention publication for the 19th Annual Scientific Assembly and Congress of Delegates, New York State Academy of General Practice, New York City, April 3, 4, 5, 6, 1967. The New York Hilton Hotel. First issue, Tuesday, April 4; Second issue, Wednesday, April 5; Third issue, Thursday, April 6.

1st Edition April 4, 1967

Martin Markowitz, M.D., Editor and Publisher

Bentley D. Merrim, M.D., Advertising

FROM YOUR EDITOR

Besides reporting the events and news items of the convention, it has occurred to us that the membership might be interested in getting a cross section of the thoughts and ideas that fill the minds of many of your A.G.P. members. Therefore, in this and in the following issues of the "Daily Bulletin" you will find an assortment of articles by many of your officers and county presidents as well as one by our national president Dr. Carroll L. Witten. Dr. John N. Edson, an outstanding clinician and educator, Director of Medicine at the Long Island College Hospital in Brooklyn has also favored us with an article.

MARTIN MARKOWITZ, M.D.

A most sincere welcome to CONVO 67. Our convention offers a diversified timely, interesting and instructive program of superior quality aimed directly at the general practitioner. As an innovation, it also offers your wife an interesting and exciting, long to be remembered three day experience while you are busy at the Convention.

Check our scientific and social menus. I am sure you will agree with your convention committee that they are superb. With your cooperation, we can make this convention, CONVO 67, outstanding. Show your wife the ladies program, direct her to the hospitality rooms on the 5th floor and I am sure she will be very busy for the duration.

Doctor, don't just go to the convention. Go to the convention to attend all the scientific assemblies, to see all the scientific exhibits, to greet and socialize with your fellow general practitioners from all over N. Y. State and even our neighboring states, to attend the G.P.'s prestige social affair of the year; the Banquet that honors our outgoing president, Max Cheplove, and of tremendous importance to see and hear all about the presentations of our technical exhibitors. Remember that your cooperation in visiting these technical exhibits, in discussing their products with the exhibitors and in expressing a sincere interest in their presentations is THEIR IDEA of a successful convention. This is a must if we are to encourage the year after year return of these high quality exhibitors and is a *must* if our conventions are to continue to be of high quality.

Please tell me how you enjoyed CONVO 67 before you leave.

GEORGE LIBERMAN
Chairman

GREETINGS FROM YOUR NEW PRESIDENT

The greatest honor one may receive is recognition by his peers. It is, therefore, with great humility and sincere pleasure that I accept the honor you have bestowed on me by electing me to serve as your President this coming year. This year promises to be very challenging and exciting and will require the whole hearted cooperation of all the officers and members of The Academy. I know I can count on their support.

I take this opportunity to welcome all of you to this Nineteenth Annual Scientific Assembly. From the lectures arranged, I am certain you will absorb a great deal of worth-while information which will help you function as good family physicians. From our several social functions, you will enjoy meeting friends and return home with fond memories of a very pleasant stay in our fun city.

A great deal of effort goes into the successful running of a meeting of this magnitude and many people must of necessity help in its planning. We were very fortunate in finally engaging Larry Kennedy as our Executive Secretary and his guidance and assistance has been invaluable.

Special appreciation must be given to Dr. George Liberman as Chairman and Dr. Leo Swirsky and Dr. Adrian Lamos as Co-Chairmen of this Scientific Assembly, for a fantastic job well done. To Mrs. George Liberman and her Co-Chairmen, Mrs. Leo Swirsky and Mrs. Theodore Tanenhaus our congratulations for the complete educational artistic and enjoyable plans for our ladies. They are certain to remember their visit here for a long time.

To all our sponsors and exhibitors goes our everlasting gratitude for making this meeting possible. To our guest speakers who have so generously given of their time and knowledge that we may increase our store of information to enable us to better serve our patients, our sincere thanks. To the Manager and staff of the Hilton Hotel, my great admiration for a job well done with politeness and dispatch. To everyone who has helped in any way, my personal thank you.

Lawrence Ames, M.D., *President*
New York State Academy of General Practice

FIRST DAY SCIENTIFIC SESSION AND PANEL

MORNING SESSION

SPACE MEDICINE

GEORGE LIBERMAN, M.D., *Chairman*

GREETINGS:

HOWARD J. BROWN, M.D.
Health Service Administrator for the City of New York

JOSEPH ROBINSON, M.D.
Chairman, Education Committee, N.Y.S.A.G.P.
AWARDS TO ESSAY WINNERS

ROBERT A. MOORE, M.D.
Medical Director National Fund for Medical Education
Former Dean, Downstate Medical Center
TRENDS IN MEDICAL EDUCATION

S. P. VINOGRAD, M.D.
Director of Medical Science and Technology in N.A.S.A.
INFLIGHT MEDICAL INVESTIGATION INTO MANNED SPACE FLIGHT

AFTERNOON SESSION

NUCLEAR MEDICINE

SAMUEL LIEBERMAN, M.D., *Chairman*

DAVID CHARKES, M.D.
Division of Nuclear Medicine, Temple University Hospital, Philadelphia, Pa.
PRESENT PRACTICAL USES OF RADIOISOTOPES IN THYROID DIAGNOSIS

LESTER LEVY, M.D.
Division of Nuclear Medicine, Long Island Jewish Hospital, New Hyde Park, N. Y.
OTHER USES IN RADIOISOTOPES IN ORGAN FUNCTION STUDIES

DRS. CHARKES AND LEVY
RADIOISOTOPES CYNTA SCANNING OF LIVER, BRAIN, LUNG, KIDNEY, BONE, HEART, ETC.
PRACTICAL DEMONSTRATIONS — QUESTIONS AND ANSWERS

FAMILY PRACTICE

JOHN N. EDSON, M.D.
Director of Medicine
Long Island College Hospital, Brooklyn, N. Y.
Including the Prospect Heights Hospital
Hospitals with an Integrated General Staff

Must the modern medical school produce nothing but medical scientists? Where are the Generalists of tomorrow that the progressive medical educator has designated as the new primary physician? Who *is*, going to replace the general practitioner whose ranks are thinning rapidly? These and many similar questions plague us every day.

Medical educators are aware of the shortcomings of the present program. In fact, at such schools as Harvard and Johns Hopkins, new curricula are being tried. Accelerated programs with more freedom of choice are now being offered, but only to unusually bright students. Actually, the subject material covered by these programs is very similar to that in the present curriculum.

The Report of the Ad Hoc Committee on Education for Family Practice of the Council on Medical Education of the American Medical Association begins to point the way. Each of you should read it, if you have not. Emphasis is placed on professional excellence along with a more humanistic approach to the family and its problems. The Committee implies that there must be excellence of training, including a residency in Internal Medicine and Pediatrics at least, and that to such a program should be added Community Medicine, Sociology, Social Psychology and Anthropology, as well. The program envisions 3-4 years of intern-residency training after medical school. One of the most important statements in the Report appears in the Appendix: "However, the crucial consideration is not how many facts the physician knows, but rather the principles and concepts he learns, his ability to find and use new information as it is developed and his skill in problem solving." To that statement should be added a skill in recognizing problems beyond his capacity.

The principles and goals of the Report are beyond reproach. However, it is doubtful that many medical students would be interested in such a program. Most students recognize the difficulties inherent in attaining excellence in one field, let alone two or more as well.

How can the problem be solved realistically? Here are some guide lines: 1) An evaluation should be made of the sociological and psychological motivations which turn a physician toward Family Practice rather than Medical Science for a career. 2) The patterns derived from such an evaluation should be applied to the admission of high school graduates, not college graduates, to a time accelerated program—time accelerated, but not fact accelerated, because the students probably will not be the "smartest" students according to present measurements. 3) A college and medical school curriculum should be devised which teaches science, humanities and medicine all together. For example, the consideration of sodium and potassium and the Donnan equilibrium across a semi-permeable membrane in a basic chemistry course should be related immediately to the nephron and to hemodialysis; or the conditional reflex in psychology should be related directly to family behavior. By such interweaving of basic science, humanities and medicine, the program can be much more dramatically taught; and the course can be shortened to 5-6 years. Such a time schedule would allow adequate time for a residency program within an eight year period. 4) The Academy of General Practice should be the motivating force toward such a program at all levels. You must concern yourselves with the education of your replacements as well as with the education of yourselves.

THE A.A.G.P. NEEDS EVERY G.P.
EVERY G.P. NEEDS THE A.A.G.P.

SIDNEY J. KOHLE, M.D.
Vice-Chairman of Membership
Chairman, 1968 Convention

During the past year the N.Y.S.A.G.P. has increased in size by many hundreds of new members and, as Vice-Chairman of Membership and Chairman of the 1968 Convention, I look forward, with a great deal of pleasure, to meeting many of these new members at our conventions.

The Scientific Program of the 1967 Assembly is an excellent one and a good example of one of the many services the N.Y.S.A.G.P. performs for its members.

For years our organization has been trying to convince non-member G.P.'s of the importance of Membership so they could participate in a strong collective voice, protecting their own interests in the medical world. The N.Y.S.A.G.P. has been successful in preventing loss of hospital privileges and even restoring some privileges that had already been lost.

It is with mixed emotions that we note that some of our new members have joined because they now see the hand writing on the wall.

A problem has arisen that may pose a financial threat to non-member G.P.'s. The Health Service Administration of New York City set up the following requirements for Certification of G.P.'s to treat Medicaid patients, (or at least to get paid for treating Medicaid patients):

1. Applicant must hold current appointment in a voluntary or a municipal hospital approved for internship training, or
2. Applicant must be a member in good standing of the American Academy of General Practitioners, or
3. Present evidence of having completed during calendar year 1965, 50 hours of post-graduate education approved by the A.A.G.P. or other appropriate professional body, or
4. Present evidence of having completed a total of 100 hours of post-graduate medical education approved by the A.A.G.P. or other appropriate professional body from January 1, 1961 to October 1, 1966.

General Practitioners who are not qualified as above will be allowed to treat Medicaid patients for a period of six months from October, 1966. If they have not qualified by then they will not be certified to continue treating Medicaid patients.

Commissioner of Health Ingraham has accepted these New York City qualifications and has endorsed them for the entire State.

If the above requirements are adhered to it can readily be seen why it would be to ones advantage to become a member of the N.Y.S.A.G.P.

We welcome this influx of new members into our organization, a larger enrollment will be most helpful. The G.P.'s position in Medicine is not static and we need a strong united voice to protect our interests. Never before was the motto more true,

"The A.A.G.P. need every G.P. and every
G.P. needs the A.A.G.P."

Before I conclude, I would like to take this opportunity to announce that we have

REFLECTIONS ON CONVENTION GOING— FEMININE VIEWPOINT

PEARL LIBERMAN

Chairman, Ladies Convention Committee

It seems to me that in the specialized existence of being a "Doctor's Wife," there are dimensions added by distaff involvement with a medical convention.

Because convention going is relatively a new part of our life (some four years), I have a definite point of view.

Of course, there are various kinds of convention going, — in town — out of town — or in town but hotel residence for the duration. No matter which you are involved in, there is in all of them a basic rare ingredient — that much maligned thing called "togetherness."

Whether you come by car, or by plane, or even by subway together, there are golden, stolen hours — completely out of character to your day in and day out life.

A sudden confrontation with your doctor in the lobby or in a meeting room — result: an unexpected invitation to lunch or for cocktails; a few quiet minutes of talk between meetings; the theatre on a night normally dedicated to office hours — all these have the sweet flavor of the spontaneous and unplanned.

Then there is the business at hand—togetherness of exhibit visiting and even the occasional lecture for two. But when the lecture is beyond the interest or comprehension of the doctor's wife, there is yet another kind of togetherness — the doctor's wife to doctor's wife.

Old friends, new friends, old viewpoints, new viewpoints, professional, social, to help in the office, recipes, advice, children, office hours, shopping, gallery hopping, not to help in the office, hours of female talk, more hours of doctors' wife talk — the constant wonder of the universality of experience, upstate, downstate, all around the state.

Then, the icing on the cake — black tie, gown, tinkle of ice and more talk, dancing, good food and good talk, a little politicking, future dates, farewells.

Again, the lovely hours of the trip home — the who did you see, what did you learn, was it a rest (definition of a rest: any change of activity), was it worth it?

"See you again next year."

Pearl Liberman, *Chairman*
Ladies Convention Committee

---

a special treat in store for our members. We are holding our next, the 20th, N.S.A.G.P. Convention May 5-9, 1968, (Scientific Assembly May 7-9), at the Concord, the World's Largest Resort Hotel.

We will have an excellent Scientific Program and in addition we can enjoy the many facilities of this fabulous resort. Our members will receive a considerable group reduction from the regular hotel daily rate. There will be free golf (on two courses). There will be complimentary Cocktail Parties, there will be no extra charge for the Banquet, and the food and entertainment at the hotel is unsurpassed. We will all have a wonderful time.

Note the dates and plan to enjoy a convention and vacation at the same time.

FAMILY DOCTO

N. Y. S. PROCLAM

As a new father, Governor Nelson A. Rockefeller was apparently in a good—should we say Happy?—state of mind when he proclaimed the week of April 2-8 as Family Doctor Week. For in it he notes that: "It is not uncommon for a family doctor to deliver a baby whose father or mother he saw through birth a generation earlier."

Read, in its entirety, the proclamation is an interesting and pertinent document in suppport of "the family doctor, known also as

It st
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fragme
care."

P R O C L A M A T I O N

State of New York

Executive Chamber

When illness strikes, the very presence of the family doctor brings comfort. He eases not only the pain and suffering but also the doubts, anxieties and uncertainties.

The family doctor, known also as the general practitioner, can be more than a healer. He can be a medical advisor and personal friend of the family. It is not uncommon for the family doctor to deliver a baby whose father or mother he saw through birth a generation earlier.

Despite the increase in specialization in this era of complex medical science, there are still more than 2,000 general practitioners in New York State. It is they who offset any trend toward fragmented and depersonalized medical care. It is they who serve as the vital unifying element in the overall spectrum of health facilities in a community.

Although the family doctor may be called upon at any hour of the day, and although we deeply prize his compassionate care when illness strikes, we are inclined amid the pressures of normal daily life to forget the dedicated service he stands ever ready to provide.

NOW, THEREFORE, I, Nelson A. Rockefeller, Governor of the State of New York, do hereby proclaim the week of April 2-8, 1967, as

The family doctor, known also as the general practitioner, can be more than a healer. He can be a medical advisor and personal friend of the family. It is not uncommon for the family doctor to deliver a baby whose father or mother he saw through birth a generation earlier.

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NOW, THEREFORE, I, Nelson A. Rockefeller, Governor of the State of New York, do hereby proclaim the week of April 2-8, 1967, as

FAMILY DOCTOR WEEK

in New York State.

G I V E N under my hand and the Privy Seal of the State at the Capitol in the City of Albany this thirteenth day of February in the year of our Lord one thousand nine hundred and sixty-seven.

BY THE GOVERNOR

Alton G. Marshall
Secretary to the Governor

Nelson A. Rockefeller

FAMILY DOCTOR WEEK

N. Y. S. PROCLAMATION

...or to deliver a baby whose ...her he saw through birth a ...lier." ...s entirety, the proclamation ...ng and pertinent document ...f "the family doctor, known also as the general practitioner."

It states that "Despite the increase in specialization . . . it is they (the general practitioners) who offset any trend toward fragmented and depersonalized medical care."

He concludes with a reminder, of which we are fully aware; that people "are inclined . . to forget the dedicated service he stands ever ready to provide."

Thank you, Governor Rockefeller.

CLEMENT BOCCALINI, M.D.

BANQUET

WEDNESDAY NIGHT, APRIL 5TH

Trianon Ballroom

Be There — Your Friends Will Be

Cocktails . . . 7:30 P.M.

Toastmaster .... GEORGE LIBERMAN, M.D.
Convention Chairman

THE NATIONAL ANTHEM

Invocation .... RIGHT REVEREND RAYMOND P. RIGNEY
Superintendent of Schools
Archdiocese of New York City

Greetings .... CARROLL J. WITTEN, M.D.
President, American Academy of General Practice

Retiring President's Remarks .... MAX CHEPLOVE, M.D.

President's Remarks .... LAWRENCE AMES, M.D.

Entertainment and Music by:

LESTER BRAUN & HIS SOCIETY ORCHESTRA

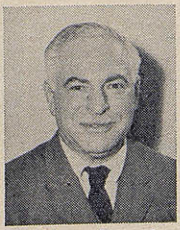
Dress Optional

M. THEODORE TANENHAUS, M.D.
Banquet Chairman

TICKETS AVAILABLE AT REGISTRATION DESK

or from your Banquet Chairman

AN ARMY TRAVELS ON ITS STOMACH — A CONVENTION ON ITS EDUCATIONAL GRANTS AND TECHNICAL EXHIBITS



M. Theo. Tanenhaus
Banquet Chairman

PRESIDENT'S BANQUET

The G.P. Affair of the Year

The outstanding "Fun Happening" and Prestige Affair of our Nineteenth Annual Convention will be the Reception-Dinner Dance honoring our retiring President, Dr. Max Cheplove, and our President-elect, Dr. Lawrence Ames.

This will be held in the beautiful and lavish Trianon Ballroom on Wednesday, April 5th. Cocktails unlimited will be served starting at 7 P.M., dinner and dancing at 8 P.M., to the rhythmic, tantalizing and gliding music of Lester Braun's Society orchestra.

We remind all of you, and especially your wives, of the entertaining and delightful social evening.

This is our Prestige Affair — with a multitude of bonuses — which includes a gourmet meal — all this for only $17.50 a ticket — dress optional.

Please contact the Banquet Chairman, Ted Tanenhaus, for your tickets and table reservations.

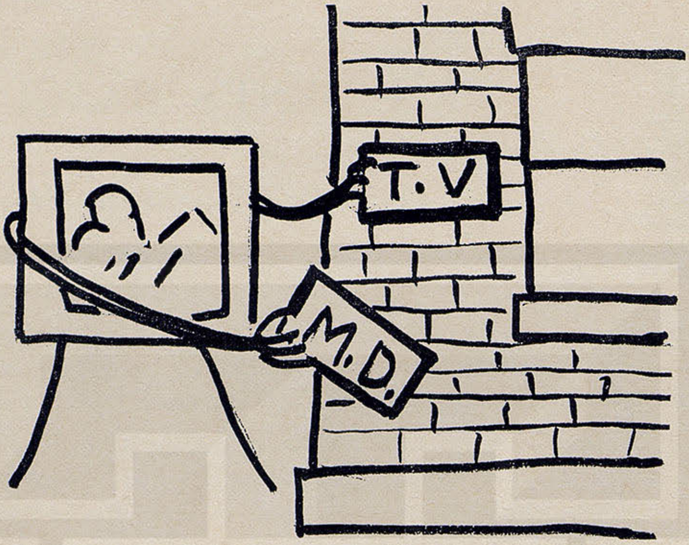
SCIENTIFIC EXHIBITS

Your Scientific Exhibits have been carefully selected and screened by your Scientific Exhibit Committee. They bring to you the latest in scientific achievement and are a revue of many of the latest developments in medicine, which may have escaped your attention while you are engaged in your busy practice. Here at the Scientific Assembly you will have ample opportunity to leisurely examine these exhibits and what is more important you will have the chance to question first hand those who are responsible for these latest medical gems.

TECHNICAL EXHIBITS

Technical Exhibits are the life blood of any Assembly; treat them as such. As you walk, not run, down the spacious aisles, remember that these people are here for a purpose. You are here to learn; they are here to show and tell you all about the products made expressly for use in your practice. This is your opportunity to correlate and evaluate the product and the claims made before you put them into practical use. We have made "MEDICAL SHOPPING" easy for you, by having everything of value under one roof, in one place. You can easily say, "Thank you for your support," by stopping at all exhibits.

VISIT AND REGISTER AT ALL SCIENTIFIC AND TECHNICAL EXHIBITS



T.V. REPLACES M.D.

Doctors, listen to my call
Tear your shingles off the wall
No need to show off your M.D.
To take your place there's now T.V.

If you think my words disturbing
Turn on your set and hear the blurbing
You'll find there's not a single ill
For which they do not have a pill.

Backache ills,—take Doan's Pills
Insomnia wrecks,—there's Sominex
For headaches brethren,—take Excedrin
Nervous,—Compoz; Sleepy,—NoDoz
No need sufferin,—just take Bufferin

If you wish to cough no more
Rush and get Vick's 44
Itching, bleeding from the rear
Relax pals! Preparation-H is here.

And so on and on it goes
To cure all ills from head to toes

Now, Doctor, I'm sure you'll agree
That there's no need for you and me
Though our motives are commendable
It's plain to see we are expendable.

Martin Markowitz, M.D.
Brooklyn, N. Y.

PAST-PRESENT-FUTURE

Samuel Lieberman, M.D.
Bronx, N. Y.

It perhaps ill befits the youngest? of the Elder Statesmen of NYSAGP to philosophize, but pardon my sclerosis. We who are of the Academy these past years have reason to be proud of our accomplishments. To us was bequeathed the laurel of Post-Graduate Education, by our founders, and with it the stamp of a Doctor who made every effort to keep abreast of the times and deliver to his patients the best possible medical care. We have reason to be proud of that heritage for it has placed upon us a badge of honor shared by no other Medical Group. We have reaped our reward from the past.

The present finds us in a rapidly, ever changing stream of Medical Practice, with a Fourth Party now involved in our destiny, namely, Government, both Federal and State. There has been placed upon our practice certain restrictions, some of which we have earned and some which we inherited as a result of our prior co-operation with the Third Party in Medical Practice. We may justly be proud that the State has recognized that membership in the Academy of General Practice is a mark of distinction and qualification for participation in the Medicaid Program. For the role that third parties have played we owe no thanks. As a reward for our participation in their plans and for acting as Co-insurers along with them, in providing care to those in limited income groups, we have had our co-operating fees submitted as usual and customary fees of the area. Perhaps we are indebted to them; for awakened by their chicanery we have in a much larger measure refused to participate in their new plans for the present and future.

The present has also brought us a large influx of new members, who here-to-fore were not interested in our aims but now faced with the wish to take care of many of their patients who come within the Medicaid scope have joined in our post-graduate education efforts. A hearty welcome to all of these Johnny-come-lately's; may they long stay with us and benefit from association with us despite the fact that certain education restrictions may soon be removed by the State.

The future? All reports point to a fact which has long been known to us. There is to-day a greater need than before for a doctor who can give continuing care to the patient and the family. Suddenly it has been discovered that the G.P. is really needed even though some have attempted to give him another name, to define the limits of his practice, and to point out that he needs specialization in the field of general practice. The PAST and PRESENT have shown, the FUTURE will substantiate, that there is and always will be a place for the G.P., no matter what he is called. For sure, he will never be relegated to limbo, families will always seek him out, — for nobody loves him but the people he treats.

Famous Caricature Artist to Sketch Convention Visitors

Joseph Kaliff, caricaturist extraordinaire, will be available thru the courtesy of Sandoz Pharmaceuticals on Wednesday, April 5, from 10:00 A.M. to 5 P.M. to sketch visitors to our convention.

To give you some idea of the "league" in which Mr. Kaliff travels the following are some of his credentials:

He has sketched four presidents — F. D. R., Truman, Eisenhower, J. F. K. Also—Jackie Kennedy, Stevenson, Einstein. His work has appeared in Time, Life, Look, Saturday Evening Post and Good Housekeeping. Arrangements for your free caricature can be made at the Sandoz Pharmaceutical Booth #7.

MEDICAL ADVISORY COUNCIL

MEETING AGENDA

22 & 23 September 1966
San Antonio, Texas

I. Announcements: S. P. Vinograd, M.D.

II. OMSF Experiment Processing Procedures and Requirements:
Mr. William Armstrong, Executive Secretary, MSFEB

III. Review of Medical Experiment Proposals:

a. MO50 - Metabolic Activity
b. MO51 - Cardiovascular Function Assessment
c. MO52 - Bone and Muscle Changes
d. MO18 - Vectorcardiogram
e. MO53 - Human Vestibular Function
f. MO54 - Neurological Study (EEG)
g. MO55 - Time and Motion Study
h. MO23 - LBNP (for AS205)

IV. Protocol for October Chamber Study

V. Pauline Mack and Cox Coronary Institute Proposal

VI. Garrett Proposal of Three Metabolic Experiments

VII. Review of Pre-Proposal by Dr. Hans Zinsser (Urinary Stone Precursors)

VIII. Discussion of Dr. Mueller's Two Questions and Letter. Comments Following Review of Gemini 7 Medical Experimental Findings.

+ 2 Questions

+ MAC Membership

Elector Board ...?

NASA HEADQUARTERS ROUTING SLIP

	CODE	NAME (if necessary)		
				ACTION
				APPROVAL
1.		Dr. Vinograd		CONCURRENCE
				FILE
2.		McClary	✓	INFORMATION
				INVESTIGATE AND ADVISE
3.				NOTE AND FORWARD
				NOTE AND RETURN
4.				PER REQUEST
				RECOMMENDATION
5.				SEE ME
				SIGNATURE
6.				REPLY FOR SIGNATURE OF:
7.				

REMARKS:

FROM: CODE: MN NAME: Doris DATE: 8/31/66

NASA Form 26 (Rev. July 1959)

U.S. GOVERNMENT PRINTING OFFICE : 1959 OF—513026

MM August 29, 1966

Dr. George D. Zuidema
Chairman, Department of Surgery
Johns Hopkins University
Baltimore, Maryland

Dear George:

At the termination of the Gemini medical experiments review, Dr. George Mueller asked two question, namely;

a. Are we using the best set of measurements of bodily functions to determine the degree and kind of adaptation to the space environment?

b. In what direction should we go in our experiment development to better observe human systems, states, and performance?

As a member of the Science and Technology Advisory Committee who attended the presentation, I would appreciate your answers to these questions.

Sincerely,

Original Signed By:
Jack Bollerud, Brig Gen, USAF, MC

Jack Bollerud
Brigadier General, USAF, MC
Acting Director, Space Medicine
Manned Space Flight

JBollerud:djc:8/29/66

same letter to: William H. Sweet, M.D.
Chairman, Department of ~~XXXX~~ Neurosurgery
Massachusetts General Hospital
Boston, Massachusetts

MM August 29, 1966

Dr. Lawrence F. Dietlein
Chief, Biomedical Research Office
Code: DB
Manned Spacecraft Center
Houston, Texas

Dear Dr. Dietlein:

At the termination of the Gemini Medical Experiments Review, Dr. George Mueller asked two questions, namely;

a. Are we using the best set of measurements of bodily functions to determine the degree and kind of adaptation to the space environment?

b. In what direction should we go in our experiment development to better observe human systems, states, and performance?

As a member of our experiments team I would like your answers to these questions.

I also wish to personally thank you for attending the meeting at the Kennedy Space Center and wish to apologize for the numerous changes in schedule. Your presence and well prepared presentation was appreciated.

Sincerely,

Original Signed By:
Jack Bollerud, Brig Gen, USAF, MC

Jack Bollerud
Brigadier General, USAF, MC
Acting Director, Space Medicine
Manned Space Flight

The above letter sent to the following people:

Dr. Robert L. Maulsby
Dr. Leo Lutwak
Captain Ashton Graybiel
Dr. Charles A. Berry
Dr. Pauline Beery Mack
Dr. Harry S. Lipscomb

JBollerud:djc:8/29/66

PROTOCOL

FOR

A 60-DAY ATMOSPHERIC VALIDATION AND

EXPERIMENTS SIMULATION STUDY

USING 100% O_2 AT A PRESSURE OF 258 mm Hg

OUTLINE

I. Purpose

As the mission duration of United States manned space flight increases, it is necessary to further verify the physiological suitability of the current spacecraft atmosphere. Therefore, the main purpose of this experiment is to validdate a 60-day human exposure to 100% O_2 at a total pressure of 258 mm Hg.

Since many of the physiological parameters necessary for this validation are investigated by inflight biomedical experiments that have already been designed for Saturn IVB, this study will make use of these biomedical procedures whenever possible. This will provide a validation of these procedures as well as an additional source of baseline data for the evaluation of inflight responses. To further aid this evaluation one-half of the control and on-half of the experimental subjects will be exposed to complete bedrest.

II. Experimental design

A. Overall

The independent variables in this experiment are 100% O_2 at a pressure of 258 mm Hg and bedrest. The dependent variables are a series of biomedical measurements designed to evaluate the physiological response to the two independent variables. Control data for the 100% O_2 atmosphere is to be obtained in two ways: 1) by having a control group of subjects who will not be exposed to the 100% O_2 environment, and 2) by obtaining baseline and postexposure data on the experimental subjects. Control data for bedrest is also to be obtained in two ways: 1) one-half of the subjects will not be exposed to bedrest, and 2) by obtaining pre- and post-bedrest data on the subjects who are exposed to bedrest.

A summary of the experimental design is shown in Figure 1.

B. Subjects

A total of 8 subjects, 4 control and 4 experimental, will participate in this study. Each subject is to be selected by a complete physiological and psychological evaluation. Because of the necessarily small n, an additional criterion for the selection of subjects should be the pairing of subjects between the control and experimental groups.

C. Experimental periods

This study will be comprised of 3 experimental periods for both the control and experimental groups: 1) a pre-experimental period of 14 days for training, acclimatization, and obtaining baseline data, 2) a 60-day experimental period during which the 4 experimental subjects (2 ambulatory and 2 bedrest) will be exposed to a 100% O_2 atmosphere at a pressure of 258 mm Hg while the 4 control (2 ambulatory and 2 bedrest) will remain at normal atmosphere and pressure, and 3) an 8-day post-experimental period.

D. Daily schedule

As it is desirable to keep the effects of abnormal scheduling to a minimum, a normal 16:8, L:D (lights on 0600, lights off 2200) schedule is to be used for the duration of the study. In addition the activity schedule of each day will remain as comparable as possible. The lights-on portion of each 24-hour period will be divided with respect to 5 major types of activity: biomedical measurements, meals, psychological evaluation, and free time.

Since the experimental and control subjects will follow identical routines, it is planned to have the measurement of paired control and experimental subjects occur simultaneously. Subjects not being measured would be allowed to pursue the activity of their choice unless it would interfere with a subsequent measurement.

The same performance tasks are to be given three times every day to each subject. A summary of the daily schedule is shown in Figure 2.

Figure 1

SUMMARY OF EXPERIMENTAL DESIGN

Control Group

N = 2	Normal Atmosphere No Bedrest	Normal Atmosphere, No Bedrest	Normal Atmosphere No Bedrest
N = 2	Normal Atmosphere No Bedrest	Normal Atmosphere - Bedrest	Normal Atmosphere No Bedrest

Experimental Group

N = 2	Normal Atmosphere No Bedrest	100% O_2 at 258 mm Hg, No Bedrest	Normal Atmosphere No Bedrest
N = 2	Normal Atmosphere No Bedrest	100% O_2 at 258 mm Hg - Bedrest	Normal Atmosphere No Bedrest
	PRE-EXPERIMENTAL PERIOD 14 DAYS	EXPERIMENTAL PERIOD 60 DAYS	POST-EXPERIMENTAL PERIOD 8 DAYS

Figure 2

Hours	Sleep	Meals	Medical	Perfor.	Psych.	Daily Log & Eval.	Free Time
0100	X						
0200	X						
0300	X						
0400	X						
0500	X						
0600			X	X			X
0700			X	X			X
0800		X					
0900			X	X			X
1000			X	X			X
1100					X		
1200		X					
1300			X	X			X
1400			X	X			X
1500			X	X			X
1600			X	X			X
1700		X					
1800			X	X			X
1900			X	X			X
2000							X
2100						X	
2200	X						
2300	X						
2400	X						

III. Environmental chambers

A. Configuration

A separate environmental chamber must be provided for the control and experimental groups, with each chamber of sufficient size to accommodate 4 subjects, 2 of which will be exposed to bedrest. Adequate area must also be provided in each chamber for equipment needed for the biomedical measurements and psychophysiological testing.

One of the environmental chambers must be capable of maintaining a gas atmosphere at outlined in the following section. Lighting intensity and control should be the same in both chambers.

B. Gas environment

During the pre- and postexperimental periods the gas environment for both the control and experimental subjects should be of normal composition and pressure. An atmosphere of 100% O_2 at a pressure of 258 mm Hg is to be provided for the experimental subjects during the 60-day experimental period. There should be adequate means of sampling and controlling the atmosphere at this level. Atmospheric monitoring for physiological purposes will be described in more detail in section IV.A. Trace contaminants and CO_2 should be removed using LiOH and charcoal.

C. Thermal environment

The temperature should be controlled at 75° F, $\pm 5^{\circ}$ F, for both the control and experimental subjects during the entire study. The humidity should be controlled at 40-70%.

IV. Physiological atmospheric validation

A. Atmospheric monitoring

In order to evaluate the physiological response to the experimental atmosphere, both major and minor constituents must be measured. Provision should be made for continuous monitoring of the following gases: CO_2, O_2, CO, H_2, CH_4, and N_2. If continuous monitoring of any of these gases is not possible, a grab sample taken no less than every two hours would be satisfactory.

In addition, cryogenic trapping of trace contaminants should be done continuously starting 7 days before any subjects enter the chamber. The sampling should be accomplished using two sets of cryogenic traps changed every 10 hours. The generation rates of any trace contaminants are to be calculated.

B. Metabolic and respiratory function

To test for any basic changes of metabolism, the basal metabolic rate is to be measured. This measurement is to be done on fasting, recumbent subjects immediately after arousal. The following parameters should also be obtained at the same time: expiratory minute volume ($\dot{V}_E$), inspiratory minute volume (V_I), carbon dioxide production (V_{CO_2}), respiratory gas exchange ratio (R), and alveolar gas tensions. In addition, blood pCO_2, PO_2, and pH are to be determined.

The schedule for data collection of these variables is:

Pre-experimental	-7, -1
Experimental	1X/4 Days
Post-experimental	ASAP

Pulmonary function is to be evaluated with respect to ventilation capacities and diffusion capacities. Standard spirometric techniques are to provide the following measurements: forced vital capacity, lung volumes, and maximum expiratory air flows. These measurements are to be obtained during the pre-experimental period at -7 and -1 days. During the experimental period they are to be measured 1X/4 days, and during the post-experimental period at ASAP, +1, +3, and +5 days.

Diffusion capacity, airway resistance, and pulmonary volume/pressure curves should be measured at -3 and immediately before the experimental period as well as immediately after the experimental period and +3 days.

In addition, chest Xrays (PA and lateral) should be done at -1 days and ASAP after the experimental period.

C. Cardiovascular

The cardiovascular validation of the 100% O_2 atmosphere is to be determined by hematological parameters. The majority of this evaluation is to be obtained in Saturn IVB experiments as outlined in section V.A.3. In addition, selected blood enzyme response is to be evaluated.

Blood obtained from the subjects by venipuncture is to be analyzed for serum enzymes and LDH isozymes. In addition to 4 samples each during pre- and post-experimental periods, one blood sample per week during the experimental period is to be analyzed.

D. Renal and endocrine

The assessment of renal and endocrine systems will be accomplished by the blood and urine chemistries as part of the bioassay of body fluids experiment as outlined in section V.C.

E. Bacteriologic evaluation

Nasal, throat, and samples are to be collected from each subject during the pre-experimental period at -10, -7, -4, and -1 days; during the experimental period, 2X/every week; and, during the post-experimental period at +1, +2, and +7 days. These samples are to be subjected to bacteriological analyses to determine any significant alterations in the aerobic microflora.

V. Validation of Saturn IVB inflight biomedical experiments

A. Cardiovascular

1. Lower body negative pressure, tilt table, and phonocardi-cardiogram

a. Purpose

The detection of space flight cardiovascular deconditioning (alterations in cardiovascular function which degrades the performance of the cardiovascular system) and the establishment of a time course of events that may be related to changes in cardiovascular function during a suited and non-suited space flight constitute the purpose of this type of investigation.

b. Equipment and instrumentation requirements

Equipment: 2 Lower body negative pressure devices, 2 automatic blood pressure cuffs with recording, 2 cardio-tachometers, 2 phonocardiograms (20-40 cps bandpass).

Instrumentation of subjects: Respiration, standard NASA ECG, phonocardiogram.

c. Requirements and procedures for collection of data

1) Tilt table tests are to be conducted in accordance with standard NASA operating procedures.

2) Lower body negative pressure tests are to be conducted on fasting subjects early in the morning. Respiration, phonocardiogram, and ECG are to be measured continuously from 5 minutes pre-exposure to 5 minutes post-exposure. The negative pressure device is to be kept at -30 mm Hg for 15 minutes.

d. Schedule of data collection

Lower body negative pressure:

Pre-experimental	-9, -2 days, -12 hours
Experimental	1X/7 days
Post-experimental	+12 hours, +3,+4,+6 days

Passive tilt table:

Pre-experimental	-10, -3 days, -24 hours
Experimental	(None)
Post-experimental	ASAP, +24 hours, +3,+5 days

2. Response to exercise

a. Purpose

The purpose of this investigation is to determine the crews' cardiovascular status by measuring their heart rate increase during a quantitated exercise load and and the time required following exercise for their heart rate to return to resting levels.

b. Requirements and procedures for collection of data

These measurements are to be obtained using standard laboratory ergometry techniques.

c. Schedule of data collection

Pre-experimental	-8, -4, -2 days
Experimental	(None)
Post-experimental	+3 days after tilt table, +6 days after lower body negative pressure

3. Hematology

a. Purpose

The purpose of this investigation is to delineate the alterations in plasma volume and red blood cell mass that occur during prolonged space flights.

b. Procedure and requirements

All determinations of plasma volume and red cell mass are preceded by a 15-minute recumbent interval. Background blood samples are obtained prior to each radioisotope series to correct for any previously injected radioactivity. All plasma measurements are accomplished with iodinated human serum albumin tagged with I^{125}. The radioactive albumin is diluted with normal saline to a concentration of 0.4 microcuries preflight and 0.8 microcuries postflight and placed in multiinjection bottles. For all preflight plasma volume determinations, 2 microcuries of I^{125} as iodinated human albumin, are injected whereas postflight 5 microcuries are used. Fifteen minutes equilibration times are adhered to throughout the series. All blood is drawn from antecubital veins into heparinized syringes. The whole blood samples are then centrifuged, the plasma removed, and 2, 1 ml aliquots from each sample pipetted into counting tubes. Standards are prepared by diluting 2 or 5 microcuries of radioactive albumin in 1 liter of tap water. Non-radioactive albumin has been previously added to each standard liter volumetric flask to prevent adsorption of the radioisotope by the glass. The standard aliquots are immediately pipetted for subsequent counting. All I.V. injections are made using disposable plastic syringes, and the same type of syringe is used in preparing all standards. Nearly all residual radioactivity in the dose syringes is removed by irrigating them with 2 ml of water which is then counted. The infinite, total body radiation exposure per astronaut, for the entire plasma volume series, is approximately 2.5 mrem.

The red cell mass determinations are performed by adding a 15 ml aliquot of the astronaut's blood to 5 ml of ACD solution contained in a Unitag Bag. To this solution, 100 microcuries of sodium chromate ($Cr^{51}P$) are added. After an incubation period of 10 to 12 minutes at room temperature, 100 mg of ascorbic acid is injected into the bag to terminate the tagging process. After thorough mixing, a 10 ml aliquot of the incubate is re-injected into the astronaut from whom the blood was drawn. The remaining incubate is retained for the preparation of standards. A venous blood sample is obtained after allowing an in vivo mixing time of exactly 15 minutes from which a hematocrit is obtained and duplicate aliquots of whole blood and plasma are submitted for radioisotope determination. The blood remaining in the Unitag Bag is used for determining the incubate hematocrit and pipetting duplicate 1 ml aliquots into counting tubes. The remainder of the incubate is then centrifuged, the plasma removed, and 2, 1 ml aliquots of the plasma pipetted into counting tubes.

The erythrocyte survival half-times are measured from the disappearance of chromium tagged red cells and are corrected for changes in red cell mass. A sample obtained 24 hours after the injection of the radioactive cells is used as the zero time for each survival determination. This prolonged mixing time is used to allow removal of cells inadvertently injured during the tagging procedure. The total radiation dose delivered per astronaut, for the entire Cr^{51} red blood cell mass determination series, is about 84.8 mrem.

All samples are counted in an automatic scintillation well detector using a pulse height analyzing scaler to separate the energy peaks of I^{125} (.035 - .0275) from that of Cr^{51} (0.323). Sufficient counts are collected to reduce the counting error to less than 0.5 percent. For each astronaut the predicted normal red cell mass and plasma volume are derived from the nomogram of Hidalgo et al, for I^{131} human serum albumin blood volume (B.V.). Preflight weights and heights are used in determining the blood volumes from the nomogram.

c. Schedule of data collection

Pre-experimental	-14, -6, -1 days
Experimental	1X/7 days
Post-experimental	ASAP, +7, +14 days

B. Metabolic

1. Purpose

The purpose of the Saturn IVB experiment is twofold: first, to determine if man's metabolic effectiveness in doing mechanical work is progressibely altered by the exposure to the space environment; and, to determine the metabolic cost of identical operational activities when man is deprived of the benefits of earth gravity as compared to the cost on earth.

Much is known about the relationships between the rate of doing work utilizing muscular effort and the expenditure of energy in chemical processes which make possible muscular contraction. Thus far, all of this information pertains to measurements done on the surface of the earth and under the influence of the force of gravity; a force which grossly modifies the requirements for energy expenditure by acting on the mass of the body and requiring compensatory muscular efforts to maintain body posture and mobility in the gravitational field.

When the force of gravity is absent, as during weightless flight, it might be presumed that the rate of expenditure of metabolic energy will be reduced. In fact, one might predict that the muscle systems which have developed in response to the gravitational force would atrophy and weaken. Evidence for this stems from the well-known observations that human subjects who remain immobile and do not use their "anti-gravity muscles" do experience some loss of muscle mass and muscle strength. Crude measurements of metabolic rates in Gemini astronauts have suggested that the rate of energy expenditure is below the predicted level. Thus, it appears that the resting metabolic rates will be somewhat less under weightlessness conditions than here on earth. It follows also, then, that it would be desirable to measure man's thermal efficiency inflight for comparison with the corresponding work outputs on earth.

To obtain this comparison, it would be necessary to measure man's metabolic rate as related to this work output. This can be done by measuring the metabolic rate for man for various work outputs using a well calibrated work output device such as an ergometer to provide reproducible levels of work. This relationship of metabolic costs to work output could then be compared to a similar curve for 1 G earth conditions.

The metabolic costs of doing identical tasks on earth and in space will be different because the effects of gravity assist in performing a task by providing frictional contact. Take away the gravitational environment, deprive the subject of his normal relation with frictional contact between his body and his work platform, and the result is that the efficiency with which useful work may be performed becomes problematical. Obviously, the effectiveness with which the worker is restrained and supported in the space environment will affect his efficiency in doing work as compared to doing the same work on earth. It then appears necessary also that we must measure man's metabolic costs for doing normal operational tasks using identical, or as nearly identical support as possible, in both flight and earth conditions. The metabolic costs of doing these tasks could then be compared to determine whether large differences exist.

In the planning of future long duration missions, information must be obtained relative to metabolic heat production (an index of the rate of conversion of chemical energy into mechanical energy) during various phases of the mission, i.e., during rest, exercise, and required mission activities. This information is essentail from a logistics resupply viewpoint and is mandatory for a realistic design of environmental control systems. It is reflected in the problems of providing oxygen, carbon dioxide removal systems, and provisions of food as the primary source of energy for the pool of metabolic products that is converted into mechanical energy by contraction of the muscle cells and for maintenance of all physiological functions.

To date, metabolic measurement during U. S. flights has been limited to the determination of the total carbon dioxide production by the chenical analysis of the amount of lithium carbonate formed by the reaction between carbon dioxide and lithium hydroxide. This method, although of value in determining average heat production rate for crewmen during space flight, does not provide insight into transitory (peak) energy expenditures associated with performance of work in space.

There has been a continuing ground-based program to ascertain the metabolic cost of working under conditions that could not precisely simulate the environment of space, but could be done with equipment and work programs resembling those used in flight. This program has included studies to determine both the metabolic contribution of the pressurized spacesuits and that of subgravity environments. The validity of these ground-based studies is not known and cannot be determined until metabolic measurements are made during an actual space mission.

There has been defeloped, but as yet not used inflight, a device to measure the rate of metabolic expenditure by indirect calorimetry. This method is based on the principle that the rate of conversion of chemical energy in metabolizing cells which comprise the whole body may be estimated by measuring the by-products of metabolism that are caused to occur as a result of burning (oxidation) of energy producing substances taken in the food, namely fats, proteins, and carbohydrates. For example, the stoichiometric relationship between the oxidation of a combination of food products and the production of carbon dioxide in the expired air can be estimated with considerable accuracy. Thus, to measure the amount of carbon dioxide produced in a given period of time gives an estimate of the rate of oxidation. The apparatus now developed is similar to the common laboratory device which measures the volume per unit of time of expired air, and in the same instrument is provided a means of chemically determining the concentration of carbon dioxide produced in that period of time.

The rate of metabolism may also be estimated by measuring the amount of oxygen utilized by metabolizing cells in a unit time. The energy produced by oxidation of foodstuffs by a known quantity of oxygen can be estimated with sufficient accuracy. Thus, measurement of oxygen utilization and application of knowledge that one liter of oxygen when burned with a combination of foodstuffs in a mixed diet results in the liberation of approximately 5 kilocalories of energy provide another means of estimating metabolic rate. The apparatus described above may be used to make both these measurements discussed and therefore has been proposed for the experiment.

2. Equipment and instrumentation

   a. Equipment: 2 Calibrated bicycle ergometers, 2 flight gas metabolic rate devices.

   b. Instrumentation of subjects: ECG, respiration, rectal temperature.

3. Requirements and procedures for collection of data

   a. Post-absorptive, same time of day.

   b. Collect 15 minutes resting data, 15 minutes exercise data, and until H.R. returns to normal.

   c. Record ECG, respiration, and temperature continuously from 4 minutes before experiment to end of experiment.

4. Schedule of data collection

Pre-experimental	-6, -3 days
Experimental	1X/7 days
Post-experimental	ASAP

C. Bioassay of body fluids

1. Purpose

It is the purpose of these measurements to determine the metabolic cost of manned space flight by the analysis of biological fluids. Results of the analyses are used as an indication of astronaut physiological status. Where changes are found to occur, efforts are made to elucidate the mechanisms producing these changes and assess their significance relative to space flight.

The measurements are divided into three parts. The first part, consisting of the preflight collection of two timed urine samples and two blood samples from each crewman, establishes the baseline values for the individual astronaut. The second portion of the measurements assesses the physiological status of the crewmen as observed by analysis of the urine samples collected during flight. The final portion of the measurements, utilizing a 48-hour urine sampling period and blood samples collected immediately postflight, establishes the rate of return to baseline preflight values.

The biochemical determinations may be grouped into several profiles, each of which provides information concerning the effect of space flight on one or more of man's physiological systems.

The first profile, water and electrolyte balance, is related to an examination of the weight loss which occurs during flight and the mechanisms involved in this loss. To this end the levels of sodium, potassium and chloride in the plasma are measured preflight and postflight, and the rates of excretion of these electrolytes in the urine are observed in all three phases of the measurements. Total plasma protein concentrations, measured both preflight and postflight, are used to indicate possible dehydration. Water intake and urine output are measured to determine whether the primary loss of weight is due to sweat and insensible losses or to changes in renal function.

To support the water and electrolyte balance aspects of the measurements and to provide an indication of mechanisms involved, the hormones vasopressin (antidiuretic hormone) and aldosterone are measured in the urine. The production of antidiuretic hormone is responsive to blood volume changes in the thorax, and it is postulated that, as in recumbency, zero-G would produce an increase in the thoracic blood volume. This in turn would induce a decrease in the secretion of antidiuretic hormone and a resultant increase in the urinary output.

Aldosterone, a hormone produced by the adrenal cortex, is also posture responsive and controls the renal tubular reabsorption of sodium. Its secretion is decreased in recumbency and increased in an erect position. An increase in its secretion results in decreased urinary sodium, while decreased production results in increased urinary sodium.

It is implicit in the above that knowledge of total urine production is essential to an evaluation of the data. The volume of urine and concentrations of the various components in it are not constant through the course of a 24-hour period. It would be impossible, therefore, to estimate water, electrolyte or hormone output on the basis of a single sample, even if the total volume of the sample were known.

The second profile involves the estimation of the physiological cost of maintaining a given level of performance during space flight. This could be considered a measure of the effects of stress during space flight. To this end, two groups of hormones are assayed. The first, 17-hydroxycorticosteroids, provides a measure of long term stress response. The second, the catecholamines, provides a measure of short term, or emergency, responses. The measurement of these parameters will provide us with an objective long term evaluation of the cost of space flight. With a sufficiently large sample, individual variations and responses will be eliminated from the evaluation.

The third profile constitutes a continuing evaluation of the effects of space flight on bone demineralization. Calcium, magnesium, phosphate, and hydroxyproline are measured in plasma and urine preflight and postflight, and are measured in urine obtained inflight. Changes in the status of bone mineralization may be accompanied by alterations in the ratio of bound to unbound calcium in the plasma. This ratio can be approximated from an estimate of plasma protein and calcium. It would also be anticipated that there would be an increase in urinary calcium, phosphate and magnesium with demineralization. In addition, demineralization of bone is accompanied by an increased excretion of hydroxyproline. This amino acid is unique to collagen. It is presumed, therefore, that the increased excretion of hydroxyproline accompanying demineralization results from a dissolution of the bone matrix.

The fourth group, or profile, may be related to protein metabolism and tissue status. Urinary urea is proportional to protein intake and tissue metabolism, while alpha amino nitrogen increases may be related to destructive tissue changes. Creatinine excretion is a function of muscle mass, and for a given individual is essentially constant over a 24-hour period irrespective of diet, urine volume or exercise. Decreases of creatinine excretion, however, are associated with loss of muscle tone and activity.

2. Equipment: Freezers for urine and blood samples, urine collection and sample bottles, 2 pH meters, equipment necessary to determine specific gravity, protein, glucose and ketone bodies.

3. Requirements and procedures for data collection

   a. Record time and volume of each voiding.
   b. Prior to freezing urine samples, determine pH, specific gravity, protein, osmolarity, glucose, and ketone bodies.
   c. Label and freeze sample.
   d. 35 cc blood.

4. Schedule of data collection

   a. Urine: All voiding pre-experimental, experimental, and post-experimental for all subjects.
   b. Blood: Same collection as for hematology.

D. Calcium balance

1. Purpose

Assessment of the alteration in musculoskeletal status during orbital space flight is the primary objective of this Saturn IVB experiment. Concomitant objectives are evaluation of water, electrolyte, and possible steroid changes.

Investigators have long recognized that chronic confinement may result in metabolic alterations such as losses of calcium and phosphorus to the point of osteoperosis, urinary tract stone formation, and loss of muscle mass and strength. Several bedrest-immobilization studies have shown that in healthy young adults urinary calcium excretion increases two-to threefold within five weeks after confinement. The same individuals may enter into a state of negative nitrogen balance (output exceeds intake). Quantitative Xray studies of the bones have demonstrated concomitant demineralization with bedrest-immobilization.

The preceding observations have led some investigators to predict that prolonged exposure to both confinement and weightlessness during space flight can eventually produce deletorious alterations in the physiological and biochemical integrity of the flight crew. As of the time of preparation of this form, Gemini pre- and postflight Xrays have suggested loss of mineral from peripheral bones, and the Gemini M-7 experiment has demonstrated a trend for negative metabolism changes which may have been ameliorated by inflight exercise.

The proposed experiment is designed to provide data which will define more specifically the problem of bone and muscle catabolism and its magnitude. The results will provide further evidence bearing on the effects of prolonged exposure to combined confinement and weightlessness. If significant metabolic changes take place, they will permit an educated extrapolation of the alterations to be expected on longer flights and will stimulate efforts to devise methods or procedures to counteract or ameliorate these undesirable effects. The Saturn IVB experiment will examine changes over periods of 30 to 45 days of flight and the influence of operational and controlled physiological procedures (i.e., exercise) on these changes.

Sever untoward effects are not expected during the Saturn IVB missions; however, it is mandatory that factual data on a sufficient population and over increasing flight duration be collected if data are to be available to predict flight safety of longer missions and to develop and test preventive measures which may ameliorate the degree and duration of mineral and nitrogen depletion. Therefore, it is the purpose of this inflight experiment to provide, within the limits of operational constraints and without jeopardizing the safety of the crew, data on calcium, nitrogen, electrolyte and steroid excretion during prolonged space missions. The information collected will be compared with pre- and postflight ground based control data collected on the crew.

2. Requirements and procedures for collection of data

   a. Special formula food starting 5 days before experimental period for all subjects.
   b. Each subject to be weighed daily after emptying bladder in morning.
   c. Complete record of food and water intake.
   d. All urine samples (see bioassay of body fluids, section V.D.) and feces to be collected.

3. Schedule for collection of data

   Daily from -10 days to +10 days.

E. Bone demineralization

1. Purpose

(See purpose, section V.D.)

2. Equipment: Xray machine.

3. Requirements and procedures for collection of data: Xray of hand and foot.

4. Schedule of data collection

Pre-experimental	-10, -3, -1 days for all subjects
Experimental	At 30 days of experimental period for all control subjects
Post-experimental	+1, +4 days, +2 weeks

VI. General requirements

A. Initiation and completion dates

B. MSC assistance

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DG

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INERT GASES

Wallace O. Fenn

INTRODUCTION

Man can survive in spite of large variations in the composition and pressure of the inspired air, the partial pressures of oxygen and carbon dioxide being the most critical. The optimum composition is not necessarily the same for launch, re-entry, in-flight maintenance, or extra-vehicular activities. The selection of the best mixture is also complicated by engineering and environmental factors not directly related to the physiology of the astronaut. This chapter will endeavor to consider all of these factors, with special reference to the physiology of the man himself. The particular problem of the best partial pressure of oxygen is considered elsewhere in this report. The Committee recommends that for prolonged use the oxygen tension of the inspired gas in the space ship should be no higher than that found in air at sea level when both atmospheres are saturated with water vapor at 37°C. Starting with this as a basis, the amount and nature of the inert gas to be added must be decided. We hope to predict on the basis of the information now available just what the physiological risks may be and what emergencies might be encountered in a space mission with different gases in the various circumstances.

PHYSIOLOGY OF THE INERT GASES

Before considering the advantages and disadvantages of adding inert gases to the atmosphere of the space capsule a brief review of the physiology of the inert gases is in order. Under normal conditions the only inert gas of any importance is nitrogen.

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Nitrogen gas, when inhaled, can always be recovered as nitrogen gas either in the excreta or the expired air. It can, however, have some physiological effects even at the concentration found in air. In a sufficiently high concentration of 3 or more atmospheres it has a narcotic effect that is well recognized by deep-sea divers and has been demonstrated in many laboratory studies. Synapses are more sensitive to nitrogen narcosis than isolated nerves and muscles (Marshall, 1951). In Drosophila, at least, high pressures of nitrogen are more narcotic in the presence of 1 atm than in 1/5 atm of oxygen. (Fenn. 1965) The same is true of xenon and argon but helium has a narcotic effect only in very high concentrations. Similarly, the inhibitory effect of the narcotic inert gases on the growth of Streptococcus faecalis is greater in the presence of 1 atm of oxygen than in a strictly anaerobic environment (Fenn, unpublished observations). Mice and men are more sensitive to nitrogen narcosis than paramecia and insects, possibly because the CO_2 tension is higher in mammals.

Nitrogen narcosis is attributed to the physical effect of a sufficient number of molecules of N_2 in solution in the water, proteins, or lipids of the body cells, especially those in the brain. This narcotic state develops very quickly, apparently as soon as a threshold concentration of nitrogen in the tissues is attained, and without any time factor that anyone has yet measured. There may be secondary effects that depend upon the product of time and concentration, but if so, they have not yet been identified. Such secondary results might even affect the life-span or any of the physiological processes in the body, but there is no evidence yet of any such effects. There is also no evidence of adaptation to high concentrations of nitrogen, although the development of increased tolerance to some other narcotics has been demonstrated. So far as we know now, the body reacts to a second exposure to high pressures of nitrogen exactly as it does to its first exposure, with neither increased tolerance nor increased sensitivity.

There is at present no good evidence that the nitrogen which we inhale plays any essential role. At least for short periods of a few weeks men and other animals tolerate a nitrogen-free atmosphere without any untoward effects so long as the oxygen tension does not exceed the normal value. Fruit flies have also tolerated such nitrogen-free environments without obvious decrement in their life span. In *Neurospora*, however, Schreiner *et al*. (1962) have shown that growth is accelerated when helium is substituted for nitrogen; the growth rates were inversely proportional to the square roots of the molecular weights of the gases. Under high pressures nitrogen was unusual in being less inhibitory to growth than helium (Schreiner, 1965). These experiments do suggest that even at 0.8 atm pressure the inert gases may have some effect.

It was reported by Volskii (1960) and confirmed at least partially by Allen (1963) that chick embryos do not hatch normally if the nitrogen of the air is replaced by helium. This conclusion, however, was not confirmed by further work in the Soviet Union by Savin (1965), who reported that development was normal provided the eggs were properly cared for. It is doubtful at present, therefore, whether any effect of sea-level nitrogen can be deduced from this work. Further, South and Cook (1954) reported some inhibition of oxygen consumption and some acceleration of anaerobic glycolysis of mammalian tissue slices by N_2 compared to helium at 0.8 atm, but recent efforts by Rodgers (1966) failed to confirm these findings. Finally, MacHattie and Rahn (1960) have raised a litter of mice successfully at 1/5 atm of 100 per cent oxygen without ever permitting any significant amounts of N_2 to enter the lung. Again, there remains no reliable evidence that sea-level N_2 is physiologically active.

REASONS FOR AND AGAINST INCLUSION OF INERT GASES IN SPACE CAPSULES

Advantages of including inert gases are:

1. Less danger of fire,
2. Atelectasis of the lung inhibited,
3. Possible but still unproved effects of low pressures of nitrogen for long periods,
4. Engineering requirements for the ventilation system.

The disadvantages of including inert gases are:

1. A double monitoring system needed to stabilize the atmosphere,
2. Extra cost of carrying a supply of inert gas to replace gas lost by leakage,
3. Danger of developing the bends.

These arguments will be considered in turn, beginning with the factor considered by the Committee to be of first importance: the danger of fire.

ADVANTAGES OF ADDING INERT GAS

1. Inert gases and the hazards of fire. It seems to be impossible to rule out completely the danger of fire in a space capsule. It is possible,

however, to reduce substantially the chances of a dangerous fire without seriously incapacitating the astronaut. Unfortunately, for engineering reasons, it is desirable to reduce the total cabin pressure so that the percentage of oxygen is increased, perhaps to 100 per cent, and this increases the fire hazard (Clamann, 1965; Hall and Fang, 1963; Roth, 1964). In a pure oxygen atmosphere at 5 psi, fires have burned with unexpected speed, so that the temperature rises very quickly to very high levels. At a sufficient temperature even stainless steel will burn (Parker _et al_., 1964). Under such circumstances the usual fire-fighting methods are useless. In a space capsule the process is to some extent self-limiting if the O_2 supply is automatically turned off, because there is a limited supply of oxygen and when that is used up the fire will stop. In the meantime, however, very high temperatures and pressures have been generated and noxious gases may be produced. Events develop so rapidly that there may be hardly time to institute any fire-fighting procedures and even less to get into a space suit. It is extremely doubtful that an astronaut could survive if the fire started in a shirt-sleeve situation.

To our knowledge there have been no serious efforts to incorporate in space vehicles appropriate methods for fighting oxygen fires, and without them, the situation is hazardous for the astronaut. Apparently the only method now envisaged is to decompress the whole capsule immediately (Space Science Board, 1965), and this is a safe procedure only if the astronauts are already in their space suits. If the atmosphere is dumped promptly enough, a single astronaut, in his suit, might conceivably be able to cool the burned location and recompress the capsule quickly enough to permit the resuscitation of his anoxic comrades, but the chances of success in such a venture seem very slim indeed. Several fires have already developed in simulated space flights despite precautions which seemed adequate at the time. It is perhaps impossible to anticipate every contingency; any local heating from electrical apparatus, meteoroid impact, inadvertent focusing of the sun's rays, or electrostatic spark might start a fire.

In a gravity-free environment the danger of fire is somewhat diminished because there is no convection to bring a fresh supply of oxygen to the flame, and the available oxygen may be largely replaced by carbon dioxide and water vapor. Under such conditions a candle burns with a small, round flame rather than the familiar elongated flame (Clamann, 1965). Tests in gravity-free parabolic airplane flights have shown, however, that the candle, at 100 per cent O_2 in 5 psi, is not extinguished thereby, at least not in the short period of weightlessness (28 sec) available for such experiments (Hall, 1964). This gravity-free factor is naturally most effective in a completely static atmosphere; it may be supposed that in a space vehicle the currents of gas produced by the ventilating system, and the movements of the astronauts in their efforts to escape from or to extinguish the fire, might stir up the atmosphere sufficiently to neutralize the protective effect of the gravity-free environment. On the whole, more studies of fires in such an environment would be exceedingly helpful in appraising the fire hazards to be expected.

Every possible precaution should be taken to minimize the chance of ignition, to slow the rate of burning and to install in the vehicle the most effective fire extinguishing measures. One method that might be considered is a stream of any inert gas, since even helium is as "heavy" as carbon dioxide in a gravity-free situation and much less toxic. Quick automatic pressurization of the whole capsule (up to its maximum pressure tolerance) with nitrogen might also permit use of more familiar fire-fighting methods and reduce the conflagration to manageable dimensions.

An excellent and very comprehensive review of fire hazards and methods of extinguishing fires has been made by Roth (1964), but several fires have occurred more recently and the danger of fire might now be given even more weight than the author gave it at that time. Since that report, further studies have been made by Parker *et al*. (1964) and Huggett *et al*. (1964, 1965). All of these and other authors agree that the presence of an inert gas and a decrease in oxygen partial pressure slow the rate of burning and the energy required for ignition, although the results vary somewhat with different combustible materials. Helium and nitrogen appear to be the inert gases of choice, although neon might serve equally well. Helium requires less ignition energy than nitrogen, but nitrogen seems more effective in retarding the spread of fire in spite of the higher thermal conductivity of the helium. On the whole, nitrogen seems slightly preferable. A jet of nitrogen gas mixed with water could be effective by cooling the burning surface and surrounding the flame with oxygen-free water vapor and nitrogen. Water should not be used for this purpose, however, without due consideration of the damage to the lung that results from inhaling hot steam at a temperature which would be innocuous in a dry gas. Pressurization with nitrogen could be continued to the limit of the pressure tolerance of the vehicle without physiological hazards. Meanwhile, the fire itself would reduce the oxygen tension if the cabin supply were turned off, and the astronauts could use oxygen masks from a separate system. Whatever method proves most feasible, this Committee strongly recommends that a fire extinguishing system be installed in space vehicles.

Mention should be made also of the possibility of fire in a space suit ventilated by oxygen. One such fire has already been experienced during an ejection from a disabled ~~X-15~~ high performance airplane (Yeager, 1965). One would conclude that a suit should be ventilated with water or nitrogen rather than a combustible mixture.

2. Prevention of atelectasis by inert gases. The physiology of atelectasis is considered in more detail in Working Paper A4 [Permutt]. Here it is only necessary to state that even in normal breathing any small branch of the airway may become occluded by fluid or mucus, thus trapping some gas beyond that point. If that gas contains only O_2 and CO_2 it is absorbed by the blood within a few minutes, and that part of the airway will collapse gas-free. If the collapse is sufficiently widespread it can be detected as a decrease in the vital capacity, a condition often observed in aviators breathing 100 per cent oxygen mixtures (Ernsting, 1960; 1965). This collapse can usually be opened up again easily by a few deep breaths, but it may last for 24 hours in spite of all efforts to correct it (DuBois *et al.*, 1966). Trapped gas of this sort disappears more rapidly at high altitudes or low pressures because there is less gas to absorb. The tendency toward

trapping of gas is also favored by breathing at low lung volumes and by exposure to high G forces. The presence of any inert gas greatly delays the absorption of trapped gas. Owing to its lower solubility, helium provides more delay than nitrogen. In general, trapped gas disappears rapidly at first but soon much more slowly and at a constant composition. At this point every gas in the mixture attains a concentration just enough higher than that in the venous blood entering the lung so that it is absorbed at a rate proportional to its own percentage concentration Thus, the composition of the trapped gas remains constant after this point, until all the gas has disappeared (Rahn and Farhi, 1963). Such atelectatic areas are useless for gas exchange and tend to lower the oxygen saturation of the arterial blood.

A similar situation obtains in the inner ear. Astronauts breathing 100 per cent oxygen mixtures find it necessary to clear their ears frequently, and may even have to be awakened at intervals during the night for that purpose. While neither of these effects is usually very serious, it is at least an annoyance and can be avoided by even small amounts of any inert gas.

3. <u>Possible effects of low pressures of nitrogen for long periods</u>. This problem has already been discussed and it is evident that further experiments are required. To determine conclusively whether any such effects exist, it would be necessary to keep animals in a nitrogen-free atmosphere at normal oxygen pressures for their full life span, or for several generations. It would also be useful to carry out this experiment at different oxygen tensions to discover whether the life span is longest at the oxygen tension of air or at some slightly higher or lower tension.

In *Drosophila*, at least (Fenn, unpublished observations), the partial pressure of air seems to be optimum, although there are probably no statistically significant differences between 0.1 and 0.25 atm. It is well known, however, that nitrogen does have physiological effects at higher pressures and an extrapolation to a pressure for no-effect is subject to considerable error. Lacking good evidence to the contrary, therefore, it might be wise to include some nitrogen in the cabin atmosphere; from this point of view, a non-narcotic gas like helium would not be expected to serve the same purpose.

4. Engineering requirements for the ventilation system. It is reported that the weight of the blower needed for ventilation in the capsule increases markedly with decrease in pressure. A study carried out by Parker *et al*. (1964) indicates that the total required weight of the capsule reaches a minimum at a pressure of about 7.5 psi rather than 3.5 psi. It is thus for weight considerations that engineers have recommended the inclusion of an inert gas. If other ways of cooling could be found to avoid this large weight penalty, the conclusion might be quite different.

DISADVANTAGES OF ADDING INERT GAS

The principal disadvantage of including an inert gas is that it seems to be an unnecessary added expense. It requires a store of nitrogen or helium large enough to replace all the inert gas lost by leakage, an amount that could equal 30 per cent of the oxygen consumed by the astronaut. Total weight is thus greatly increased and a double monitoring system, with an oxygen sensor to keep the pO_2 constant and a total pressure system to control the addition of inert gas, is also required. This, of course, can easily be done but it does add to the total weight and the total cost.

The only real physiological disadvantage to the inclusion of an inert gas is the danger of producing bends when the pressure is reduced for extra-vehicular activities. This danger could, of course, be reduced by breathing 100 per cent oxygen for 3 hr before making the transition from, say, 7 psi of a 50-50 nitrogen-oxygen mixture to 3.5 psi of 100 per cent oxygen. One would expect this procedure to be reasonably safe since the total pressure is not reduced to less than about 60 per cent of the inert gas pressure, but in practice it has been found that about 5 per cent of the astronauts do develop bends under these conditions (Parker, et al.,1964). Most cases of the bends could be treated satisfactorily by returning the victim to the original atmosphere at 7 psi until more of the nitrogen could be removed by more prolonged breathing of pure oxygen, but the bends sometimes lead to difficulties not easily treated in a space capsule.

It might be pointed out also that with a pressure lower than 7 psi, the tendency to develop the bends on launch is increased if the preliminary period of de-nitrogenation by breathing oxygen were not continued for the full 3 hours usually considered necessary. This might be listed, therefore, as one of the advantages rather than a disadvantage of including an inert gas in the capsule atmosphere.

This Committee believes that the advantages of including an inert gas definitely outweigh the disadvantages, and strongly recommends an inert gas-oxygen mixture for long term flights. The only problem remaining then, is the selection of a suitable gas for this purpose, and the determination of the optimum pressure of the chosen gas.

SELECTION OF BEST INERT GAS FOR USE IN SPACE SHIPS

There is no apparent reason to use any gas other than nitrogen. There are certainly no advantages to argon, xenon or SF_6, and not enough is known as yet about the physiological effects of neon. If absence of N_2 (as such) is likely to be a hazard for long term flights, then helium presumably could not be a substitute. Nitrogen is somewhat better than helium in controlling fires. Helium, on the other hand, is said to be less likely to cause bends since its low solubility and more rapid diffusion should permit more rapid elimination from the body. This notion is not borne out in the experience of divers, however. (See Roth, 1965, for references.) Helium is certainly non-toxic and has been found to be no worse than nitrogen in respect to speech intelligibility at low pressures, and perhaps even slightly better because of the lower noise level (Cooke and Beard, 1965).

Helium is said to be preferable to nitrogen because it does not lead to dangerous radioactive isotopes like carbon 14 when bombarded by neutrons secondary to cosmic rays impinging on the capsule or its contents (Bond, 1963). This, however, seems a minor consideration since there is more nitrogen in one adult man than in a cabin atmosphere, and there are so many other ways, even in a helium-oxygen atmosphere, by which radiation can cause damage to man. Nitrogen also offers a better substitute than helium for the formation of ions in the space cabin atmosphere. Such ions have been considered beneficial, but the evidence is that there will be more than enough at the expected radiation levels with either inert gas (Clamann, 1965).

It has been calculated that under certain conditions the extra weight required to store the necessary amount of inert gas is appreciably less for helium than for nitrogen. Apart from such engineering considerations, N_2 seems somewhat preferable to helium. Since N_2 has more narcotic effect than He at high pressures, it may well have a small effect at low pressures; and since the body is adapted to the presence of N_2, this small effect might be important. Admittedly, no evidence of such an effect has yet been demonstrated in man.

A preference for helium has been mentioned on the grounds that it delays the absorption of trapped gas in the lung longer than nitrogen, but either gas provides so much delay relative to 100 per cent oxygen that the slower absorption of helium is probably not significant. Helium may also be less likely to cause bends. On the other hand, nitrogen has been recommended because it provides more protection against ionizing radiation. (This is based on the experiments of Ebert _et al_. (1958) who found that relatively high pressures of the inert gases protected bean roots against damage from ionizing radiation, nitrogen being more effective in this respect than helium. A similar protection has been observed in _Drosophila_ (Chang _et al_., 1959).) This protection actually seems to represent an elimination of the potentiating effect of oxygen, and it is supposed that the inert gases act by somehow displacing oxygen from combination on some site where it can effectively enhance the damage from radiation. Still, the protection afforded by either nitrogen or helium at pressures of less than 1 atm appears to be negligible and thus provides no basis for preference.

In conclusion, it is suggested that nitrogen is somewhat better than helium as an inert gas to be added to the necessary oxygen in the cabin atmosphere. A pressure of 2 or 3 psi is suggested as a reasonable concentration.

REFERENCES

Allen S., A comparison of the effects of nitrogen lack and hyperoxia on the vascular development of the chick embryo. Aerospace Med. 34, 897-99, 1963

(not cited in text) Bedwell, T. C., Jr., and H. Strughold, eds., Bioastronautics and the Exploration of Space: Proceedings of the Third International Symposium, San Antonio, Nov. 16-18, 1964, Brooks Air Force Base, 1965

Bond, G. F., Inert gas components for space capsule atmospheres. Fed. Proc. 22, 1042-45, 1963

Chang, T., F. D. Wilson, and W. S. Stone, Genetic radiation damage reversal by nitrogen, methane and argon. Proc. Nat. Acad. Sci. 45, 1397, 1959

Clamann, H. G., Considerations for research on cabin atmospheres. Bioastronautics and the Exploration of Space, T. C. Bedwell, Jr., and H. Strughold, eds., Brooks AFB, Texas, 285-99, 1965

(not cited in text) Cook, S. F., and F. E. South, Jr., Helium and comparative in vitro metabolism of mouse tissue slices. Am. J. Physiol. 173, 542, 1953

Cooke, J. P., and S. E. Beard, Verbal communication intelligibility in oxygen-helium, and other breathing mixtures, at low atmospheric pressures. Aerospace Med. 36, 1167-72, 1965

DuBois, A.B., T. Turaids, R. E. Mammen, and F. T. Nobrega, Pulmonary atelectasis in subjects breathing oxygen at sea level or at simulated altitude. J. Appl. Physiol. 21, 828, 1966

Ebert, M.,S. Hornsey, and A. Howard, Effect of radio sensitivity of inert gases. Nature 181, 613, 1958

Ernsting, J., Some effects of oxygen-breathing on man. Proc. Roy. Soc. Med. 53, 96-100, 1960

Ernsting, J., The influence of alveolar nitrogen concentration and environmental pressure upon the rate of gas absorption from non-ventilated lung. IAM Rept. No. 318, RAF Institute of Aviation Medicine, Farnborough, Eng., 1965

Fenn, W. O. Inert Gas Narcosis. Ann. New York Acad. of Sci. 117; 760-767, 1965

Hall, A.L., Observations on the burning of a candle at zero gravity. U.S. Naval School of Aviation Medicine Rept. No. 5 for BuMed Project MR005, 13-1002 Subtask 11, Pensacola, Fla. 1964

Hall, A. L., and H. S. Fang, Determination of the fire hazard in a 5 psia oxygen atmosphere. U.S. Naval School of Aviation Medicine Rept. No. 4 for BuMed Project MR005, 13-1002 Subtask 11, Pensacola, Fla., 1963

Huggett, C., G. von Elbe, and W. Haggerty, The combustibility of materials in oxygen-helium and oxygen-nitrogen atmospheres. Brooks AFB, Texas, 1964

Huggett, C., G. von Elbe, W. Haggerty and J. Grossman. The effects of 100% oxygen at reduced pressure on the ignitability and combustibility of materials. School of Aerospace Medicine Tech. Rept. 65-78, Brooks AFB, Texas, 1965 SAM-TR-65-78

MacHattie, L., and H. Rahn, Survival of mice in absence of inert gas. Proc. Soc. Expt. Biol. Med. 104, 772, 1960

Marshall, J., Nitrogen narcosis in frogs and mice. Am. J. Physiol. 166, 699-711, 1951

Parker, F. A., D. R. Ekberg, and D. J. Withey, Atmosphere selection and environmental control for manned space stations. General Electric Co. Valley Forge Space Technology Section, Philadelphia, 1964

Rahn, H., and L. Farhi, Gaseous environment and atelectasis. Fed. Proc. 22, 1035-41, 1963

Rodgers, S., The oxygen consumption of rat tissues in the presence of nitrogen, helium or hydrogen. Ph.D. dissertation, University of Rochester, 1966

Roth, E. M., Space cabin atmospheres, Part 2: Fire and blast hazards. NASA Special Publication SP-48, Washington, 1964

Roth, E. M., Space cabin atmospheres, Part 3: Physiological factors of inert gases. Lovelace Foundation Report on Contract NASr-115, National Aeronautics and Space Administration, Washington, 1965

Savin, B. M., Problems of space biology. Vol. 4, ed. by N. M. Sisakyan; NASA Technical Translation, NASA TT-F-368, p. 185, 1965

Schreiner, H. R., The physiological effects of argon, helium and the rar gases. Defense Documentation Center, AD 615 814 1965 Union Carbide Corp., Linde Division, Tonawanda, N.Y. (source?) (catalog no.)

Schreiner, H. R., R. C. Gregoire, and J. A. Lawrie, New biological effect of the gases of the helium group. Science 136, 653, 1962

South, F. E., Jr., and S. F. Cook, Argon, xenon, hydrogen and the oxygen consumption and glycolysis of mouse tissue slices. J. Gen. Physiol. 37, 335, 1954

Space Science Board Man-in-Space Committee, Report of the Working Group on Gaseous Environment for Manned Spacecraft, National Academy of Sciences, Washington, 1965

Volskii, M. I., The assimilation of nitrogen by animal organisms as exemplified by chicken embryos and honey-bee pupae. Doklady Akad. Nauk, ser. Biol., 128, 895, 1960

Yeager, C. E., The X-15 program. Bioastronautics and the Exploration of Space, T. C. Bedwell, Jr. and H. Strughold, eds., Brooks AFB, Texas, 535-51, 1965

GRADUATE STUDY AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

IN

ENGINEERING AND LIVING SYSTEMS

January, 1967

CONTENTS

I. INTRODUCTION

Students and faculty in many departments at M.I.T. are conducting research in the areas of interface between the engineering and life sciences. Arising from these research interests, programs of graduate study in Engineering and Living Systems have developed for students wishing to pursue a career in this rapidly evolving field. The spectrum of academic and research programs is extremely broad, ranging from basic physiologic studies to the development of new medical and biologic techniques, and the related engineering analysis and design. Each of these programs, although strongly interdisciplinary in nature, is firmly rooted in the engineering or biological discipline within which it developed.

II. RESEARCH ACTIVITIES

Presented in the following is a summary of some of the major ELS research efforts at M.I.T. These listings are set forth according to the administrative structure under which the research is being carried out, and thus include departmentally-based studies as well as those being conducted in interdepartmental facilities. From this brief description, which is necessarily incomplete, it should be evident that faculty interests have considerable breadth and flexibility. It will also be apparent to the reader that virtually all of these studies are carried out cooperatively, with active collaboration by faculty of the medical schools in the Boston area and the affiliated teaching hospitals.

A. Departmental Research:

Aeronautics and Astronautics. The complexity of advanced vehicles for transportation on or near the earth's surface, as well as in outer space or beneath the sea, places enormous demands on the man-machine interactions associated with piloting these vehicles.

In the Man-Vehicle Control Laboratory, the techniques of control theory are applied to analytical and experimental investigations of the biological control systems which enable humans to maintain themselves or a vehicle in a desired orientation in space. Flight simulators and a hybrid computer are used to study the dynamics of man-vehicle configurations and biological control systems. The research is directed by Professors Y. T. Li, Laurence R. Young, and Jacob L. Meiry, working with medical colleagues at the Massachusetts Eye and Ear Infirmary.

The research may be divided into three areas: engineering descriptions of the basic biological subsystems, development of general models for the human operator as an element in the control system of multiple-loop, time-varying vehicle orientation systems, and finally application of these models to selected vehicle control problems.

i) Biological Subsystems.

Our research in this area concentrates on the analysis of human sensors as control elements which transmit information to the human operator. Earlier research on the eye movement tracking system viewed as a sampled data system has led to further studies of details of the visual control system and the sampling of visual information. More emphasis lately has been placed on models of the vestibular system. Control models for the semicircular canals and otoliths were based on the subject output measurements (subjective sensation or eye movement). Both normal and labyrinthine defective subjects have been tested in our rotation and translation motion simulators.

The physical properties of the vestibular system and its fluids are being investigated to determine an analytical model of the system. The theoretical response of the semicircular canals to caloric stimulation, angular rotation and linear acceleration is evaluated and compared to existing experimental data.

ii) Human Operator Models.

In the development of models of the hyman operator for use in system design, our work has concentrated on descriptions of the human as an adaptive controller, multi-loop characteristics, optimal control applications, and the effects of vehicle motions on the ability of pilots to retain control for a wide variety of vehicle dynamics. The non-stationary and nonlinear behavior of men involved in complex tracking tasks is of particular interest to us. A stochastic model of learning behavior in manual control tasks has been developed recently.

iii) Vehicle and Display Applications.

A number of vehicle control applications problems are studied in the Laboratory, all of which bring out some particularly interesting aspect of the operator's control, and are intended to tie in with the more basic research performed on the biological subsystems and human operator models. Our 2-axis flight simulator and hybrid computer have been used to study helicopter hovering, manual control of a flexible booster vehicle, aircraft blind landings, a narrow vehicle for high traffic permeability, human and automatic bicycle stabilization, and phase plane displays incorporating optimal switching lines for higher than second order systems. Some recent effort has concentrated on development of a vehicle "three-dimensional display" on a CRT by linking to head movement.

Chemical Engineering. A series of studies on the properties of biological fluids and their interaction with natural and synthetic surfaces are being carried out under the direction of Professors E. W. Merrill,

E. R. Gilliland, T. K. Sherwood, K. A. Smith, and L. B. Evans. These investigations are being conducted in collaboration with staff members of the Massachusetts General Hospital, Children's Hospital Medical Center, Beth Israel Hospital, and The Retina Foundation.

i) Rheology of Human Blood.

A study of non-Newtonian rheology of human blood with reference to the interaction of cellular elements and plasma proteins, and the physiological relevance of these rheological characteristics to mammalian microcirculation.

ii) Interfacial Phenomena Related to Plasma Proteins, Lipids, and Biological Polysaccharides.

Studies of interfacial tension between saline solutions containing proteins, lipids, and/or polysaccharides, and air, immiscible liquids, and non-wetting solids. Emphasis on alveolar function and its abnormalities, as in hyaline membrane disease, and problems related to blood denaturation, as in direct oxygenation, divers' "bends," and evolution of cholesterol plaques.

iii) Membrane Transport/Polymer Structure and Properties.

Study of permeability of membranes to oxygen and carbon dioxide, and to blood solutes as urea, with special references to blood dialysis for chronic uremia (the artificial kidney) and to gas exchange during heart surgery (heart-lung machines).

iv) Antithrombogenic Membranes and Surfaces.

The chemical modification of surfaces, particularly membrane surfaces, so that human blood in contact with these surfaces is not denatured nor incited to clot by activation of either platelets or fibrinogen.

v) Viscoelastic Properties of Hyaluronates.

Basic study of the hyaluronates in steady and oscillatory Couette shear with reference to physiological function of hyaluronates in synovial fluid, vitreous humor and body tissues.

vi) Fluid Mechanics/Mass Transport.

Application of fluid mechanics to the design of extracorporeal circuits for blood oxygenation and blood dialysis.

Electrical Engineering. The biological studies led by the Electrical Engineering faculty have centered around two major areas: neurophysiology and the communications sciences, and research on biological effects of high energy radiation. The first of these investigative areas falls within the framework of the interdepartmental Research Laboratory of Electronics, and is summarized in the paragraphs describing that facility.

i) High Energy Radiation Studies.

This work is carried out in the High Voltage Research Laboratory of the Department of Electrical Engineering under the direction of Professor J. G. Trump and Mr. K. A. Wright. Investigations are focused on the engineering of intense sources of megavolt electrons and X-rays, on clarifying the physical properties of these new forms of energy, and on studying their effects on a variety of living and non-living systems. One important aspect of this investigative effort involves the treatment, in cooperation with physicians of the Lahey Clinic Foundation, of patients with malignant disease using new advanced methods of localizing the ionizing energy. The preservation of bone, nerve, and arterial tissue by radiation is also studied with the coooperation of several university hospitals. The Laboratory has unique high energy radiation and research facilities, located in a separate building adjacent to the M.I.T. campus.

Mechanical Engineering. Within the Department of Mechanical Engineering there is a broad area of research on various topics relating to engineering and living systems. These studies involve faculty and students in the Divisions of Design, Fluid Mechanics, and Materials. Most of the investigations are carried out in the Engineering Projects Laboratory--a major departmental facility providing space and instrumentation for a wide range of research requirements.

i) Sensory Aids for the Blind.

For the past five years, Professors D. M. Baumann, W. R. Ferrell, R. W. Mann and T. B. Sheridan have been supervising graduate theses in a coherent program of research and development directed towards improving the access of the blind (and deaf-blind) to the printed page and to enhancing the mobility of blind travelers. The communications aspect of the program has included research on perception by the blind of variously coded and displayed information, as well as on the design of experimental apparatus with which to conduct the research. Studies thus far have included machine coding of typed information into forms, such as Braille, which are perceivable by the blind, automated presentation and typing of Braille, and translation by computer of English texts into Braille. Mobility research for the blind has included a number of studies on characterizing and quantifying the temporal relationships of the blind traveler to his environment and its obstacles as he negotiates it with various existing experimental and hypothetical guidance devices. In addition to continued development of hand-held guidance aids, much of the current effort is focused on various aspects of a proposed mobility aid simulation and evaluation system. Using the data-marshalling power of a central digital computer, an instrumented object space is planned which will include monitoring devices and telemetry for the traveler-probes. With this system, various guidance schemes and probe characteristics could be easily tested to provide a sound basis for the design of actual guidance aids, as well as to compare and evaluate existing mobility devices.

ii) Biomechanics.

Direct observation of the internal mechanics of skeletal joints is obscured by the sustained, though time varying, forces exerted across the joints by muscle groups which, beyond exerting those forces necessary for overt limb motion and force exertion, must also provide additional connective and stance stabilizing forces across the joint. Improved knowledge of these "specific forces" across the joint would contribute to a better understanding of the biomechanics of gait and of the pathophysiology of the changes occurring in articular cartilage in degenerative arthritis.

In an effort to collect spatial and temporal data on the specific force or pressure distribution across the hip joint, a study is being conducted on the feasibility of an otherwise physiological but instrumented femoral head implant prosthesis. The work is being conducted in Mechanical Engineering (Professor Mann) in conjunction with the Department of Orthopedic Surgery, Massachusetts General Hospital.

iii) Limb Prostheses.

A cooperative program between the Mechanical and Electrical Engineering Departments at M.I.T. (Professors Mann and A. Bose), and orthopedic surgeons at Massachusetts General Hospital, led to the successful demonstration of a prototype upper extremity prosthesis with proportional, force-compensated, angular control of the elbow derived from electromyographic signals from the amputee's stump. Current efforts are directed toward introducing appropriate sensory detection, processing and display to permit more natural control of the limb. Future work may include similar studies of terminal devices (i.e. hand) and for the lower extremity.

iv) Ultrasonic Neural Surgery.

In conjunction with neurosurgeons and neurophysicists at Massachusetts General Hospital, Mechanical Engineering students, with Professor Mann, have studied aspects of a technique for creating "trackless" lesions deep in the brain or spinal cord, without direct surgical intervention. Ultrasound is generated externally to the body; at internal foci reversible or irreversible lesions are created. The procedure may be of value in the relief of spastic diseases such as Parkinson's and also can eliminate the pain a patient associates with an amputated or "phantom" limb. Prior work has included experimental studies of improved and varied sound-focusing schemes and optical devices to assist surgery. Current work is directed towards an understanding of the process by which cellular matter is destroyed upon absorption of ultrasonic energy, including a study of the acoustic properties of living grey and white brain tissue.

v) Human Control Characteristics.

Professors Sheridan and Ferrell and their students are engaged in a variety of investigations in the Man-Machine Systems Laboratory to further quantify the behavior of man in controlling vehicles and dynamic processes. Current and past work includes:

1. Study of adaptive behavior of the human operator to sudden and secular changes in vehicle dynamics; use of variable-parameter describing equations.

2. Quantitative description of manipulation; study of direct human control of remote manipulators with long telemetry delays; supervisory control of manipulators having primitive touch or visual sensors and computation capability to execute simple subroutines automatically; development of touch sensor transducers.

3. Experiments and mathematical modelling of control systems in which the input may be previewed by the human controller; use of optimal control theory and two-time scale algorithms.

4. Study of simple and semi-ballistic muscle response; correlation with electromyograms and physiological indices.

5. Development of techniques for simulation of automobile driving and piloting of air, space and undersea vehicles.

6. Methodological investigation of man-machine risk-taking and decision-making using on-line digital-analog hybrid computation.

vi) Biomedical Fluid Mechanics.

A major activity of the Fluid Mechanics Laboratory is in the general area of biomedical fluid mechanics. The group working in this area, under the direction of Professor A. H. Shapiro, currently comprises Dr. Colin Clark, Mr. Mark Schoenberg, and three graduate students. Recent and current topics of investigation are as follows:

1. Arterial Hemodynamics. Studies of the way in which pressure and flow vary with time and position throughout the arterial tree. Nonlinearities in pulse wave propagation resulting from the mechanical properties of an elastic tube and nonlinear terms in the equations of motion. Wave reflections resulting from mis-match of impedances associated with gradual and rapid longitudinal changes in cross-sectional area (including junctions) and the mechanical properties of the arterial wall. Wall friction in pulsatile flow for conditions of laminar flow, turbulent flow, and mixed laminar and turbulent flow.

2. Intra-aortic Balloon Pumping. Studies of a technique for assisting individuals in heart failure, not involving major surgery, to reduce ventricular work. A balloon at the end of a catheter is inserted into the aorta via a major artery. It is inflated and deflated in such relation to the cardiac cycle as to assume part of the work load of the left ventricle. Current investigations are directed toward determining the relationships between the balloon motions, the pressure and flows in the surrounding blood, and the cycle of operation, so that the important parameters and their effects are well enough understood to optimize a complete design before experiments with animals are undertaken.

3. Peristaltic Pumping. Studies of the mechanism by which material is transported by peristaltic waves in the intestines, in the ureter, and in mechanical pumps used for blood oxygenation and other purposes. A theoretical and experimental investigation of the mechanism of pumping at low Reynolds numbers leading to means of predicting accurately the characteristic curves of pressure versus flow. Current studies of the mechanism of ureteral reflux and the manner in which bacterial infection is carried from the bladder to the kidney countercurrent to the direction of net urine flow indicate fluid mechanical explanations of both reflux and retrograde diffusion of infection.

vii) Studies at the Peter Bent Brigham Hospital.

Two studies currently underway in the Department of Surgery at the Peter Bent Brigham Hospital are being conducted in collaboration with the Department of Mechanical Engineering. This work is under the direction of Dr. P. A. Drinker, working with students from M.I.T. and the Harvard Medical School.

1. The design of equipment for respiratory support of the critically ill or postoperative patient. In most of the deaths due to non-malignant disease in hospital Intensive Care Units, the terminal sequence usually involves a significant respiratory component. Design studies are being directed at the physiologic needs of these patients to develop equipment and techniques for

administering and controlling respiratory gas mixtures. These problems include mechanical ventilators as well as devices for precise mixing and humidification of gases. A self-regulating gas proportioner, developed as an undergraduate design project, is undergoing clinical trials.

2. Flow-induced transformation or injury to the blood. Over the last few years there has been a rapid increase in the use of artificial cardiovascular devices for implantable prostheses, as well as in extracorporeal gas exchange and dialysis applications. To date, most studies have been design-oriented, and although the hematologic disorders arising from these devices have long been recognized, only recently has attention been focused on the limiting properties of the fluid itself. Current studies are directed at the hydrodynamic behavior of the formed elements of blood, and the types and intensities of mechanical stresses causing damage or destruction of these cells.

viii) Mechanisms of Brain Injury.

Professor C. A. Berg has initiated research on the mechanisms of brain damage produced by impact on the skull. There appear to be three aspects of research in this area: (1) the rheology of the brain, (2) the mechanics of impact on the brain skull system, (3) the local mechanism of damage to the brain tissue. The first question which needs to be settled is description of the rheological properties of the brain, and it is on this question that attention will initially be focused. Microseismological experiments to determine rheological properties in vivo are being formulated. Later, the mechanics of impact and the local damage criteria will be taken up.

Nuclear Engineering. A number of activities centered around the M.I.T. reactor form part of the Engineering and Living Systems research activities under the direction of Professor G. L. Brownell. For example, the reactor has been directly used in efforts to treat brain tumors by neutron capture therapy. Two students received their Ph. D. degrees for theses in Nuclear Engineering as a result of studies on neutron spectra at the medical facility and other students have participated in various ways in this activity. In addition, the reactor has been used for activation analysis of biological samples and for the production of special isotopes to be used for biological purposes.

A number of graduate students have participated in activities at the Massachusetts General Hospital Physics Research Laboratory dealing with uses of radioisotopes in medicine. These studies have covered a wide range of topics from radioisotope techniques for measurement of brain blood flow to studies on a medical cyclotron planned for the Hospital. It is likely that these cooperative efforts will increase in the future.

Nutrition and Food Science. A graduate program of study and research in Biochemical Engineering, which is jointly sponsored by the Departments of Biology, Chemical Engineering, and Nutrition and Food Science, is administered by the latter Department under the supervision of Professor R. I. Mateles.

i) Microbial culture.

One area which has been of long-term interest is continuous culture of micro-organisms. Recent theses on continuous culture have dealt with a theoretical and experimental analysis of dynamic behavior, the kinetics of simultaneous utilization of several energy sources by pure culture and natural populations, the measurement of unsteady state growth rates of bacteria, and computer simulation of microbial systems.

ii) Fermentation.

Another area receiving increasing attention is the production of protein by growth of micro-organisms on suitable hydrocarbon or carbohydrate substrates. Work in this area deals with the effect of growth conditions on protein yield and amino acid composition, the use of thermophilic organisms to minimize cooling requirements, measurement of heat production during fermentation, determination of the mechanism by which hydrocarbon substrates are assimilated by micro-organisms, and correlations between gas transfer and power input in agitated vessels at high power inputs.

iii) Enzyme Technology.

While growth and fermentation problems occupy a central position, problems of enzyme purification and product recovery are also considered. Work in these areas at present deals with membrane processes for purification of macromolecules and centrifugal collection of small particles.

B. Interdepartmental Laboratories and Research Centers:

Center for Sensory Aids Evaluation and Development. While academic and research laboratories have demonstrated competence in the definition, research, and feasibility study of devices and systems to ameliorate the deprivation of blindness, it is clear that much psychophysical evaluation, engineering development and redesign, and systems integration must be successfully accomplished if such ideas as are developed are to be put to wide use for and by the blind.

The function of the Center for Sensory Aids Evaluation and Development is to prosecute the delineation of genuinely useful approaches and to develop them until widespread utility is demonstrated. To discharge its responsibilities the Center is staffed with full-time engineering and psychological personnel (directed by Mr. J. K. Dupress). Graduate students and M.I.T. faculty work with Center staff at the interface between research on ideas and processes and their evaluation and development.

Current work includes evaluating and extending computer programming systems and hardware by means of which retrieved type-compositors-tape is machine-translated to and presented in Braille. This work is designed so that audio outputs, when demonstrably effective, can be used.

Experiments on several existing mobility devices are proceeding to identify their merits and deficiencies, to develop a methodology of mobility-device evaluation and to build up the specialty instrumentation capability essential to such a program.

Clinical Research Center. The Clinical Research Center of the Massachusetts Institute of Technology offers the opportunity for members of all departments to conduct clinical investigations on normal subjects or patients with disease processes. The facility is administered by the Department of Nutrition and Food Science, and is supported by the Public Health Service. At present, ten subjects can be accommodated in a small hospital, complete with 24-hour coverage by physicians and nurses, an excellent diet kitchen, a laboratory capable of performing a wide variety of clinical examinations, a number of specialized procedure rooms, and supporting research laboratories. Subjects are admitted on research protocols developed by any member of the faculty, in collaboration with a qualified physician.

Since the Center was opened in October, 1964, a wide variety of problems have been investigated. Dr. Nevin S. Scrimshaw has studied protein and amino acid requirements of men with Drs. V. R. Young, T. J. Moore and J. B. Das. Interest is focused on the effect of muscular exercise and stress of psychological and infectious origins on protein and amino acid requirements. Professor H. L. Teuber and associates have studied the effects of brain injury in children and adults on subsequent neural function. Chronic radium and mesothorium poisoning has been studied by Dr. Robley D. Evans and associates at the Radioactivity Center. Professor W. A. Rosenblith and staff of the Research Laboratory of Electronics are investigating the effect of behavior and sensory stimuli on the spectral quality of the electroencephalogram.

Drs. S. J. Gray and S. A. Adibi have studied intestinal absorption of amino acids and amino acid transport across the jejunim in normal men. The effect of environmental lead intoxication on mental function of children has been studied by Dr. H. L. Hardy and associates. Dr. J. B. Stanbury, Director, and Dr. L. J. De Groot, Associate Director, of the Clinical Research Center, study endocrine physiology and inherited defects in hormone formation and action.

The goal of the Center is to offer members of the M.I.T. community facilities in which to develop clinical research projects related to the basic studies being pursued in the various departments. The Center also serves as a training facility for graduate students and postdoctoral fellows interested in metabolic diseases or other aspects of experimental medicine.

Research Laboratory of Electronics. The Research Laboratory of Electronics provides a research environment in which faculty and students from eleven academic departments participate. One major aspect of the activities of the laboratory involves studies of communication in living systems. These activities are pursued in groups centered around six major areas of interest: communications biophysics, cognitive information processing, neurophysiology, linguistics, speech communications, and artificial intelligence.

i) Communications Biophysics.

The principal concern of the Communications Biophysics Group is a better understanding of the mechanisms and logical operations that underlie sensory communication. In this task the group, under the direction of Professor W. A. Rosenblith and W. M. Siebert, combines electrophysiological and behavioral (including main psychophysical) experimentation with data processing by computers and analytical methods that are related to communication theory.

A major effort of this group is directed toward studies of coding and recoding of stimulus information in the neuroelectric activity of single units and populations of units at various levels of the auditory system. These studies involve descriptions of the statistical characteristics of firing patterns of units in the auditory nerve and the cochlear nucleus. In addition there are continuing studies of efferent pathways, of the relation of firing patterns to detailed anatomical studies, of the mechanisms of cochlear transduction, and of inhibitory mechanisms in the auditory nerve.

Psychophysical studies of hearing and of the skin sense in the past few years have been focused around the equalization and cancellation model of "bilateral unmasking."

Several experimental programs study the ways in which potentials evoked by sensory stimuli are affected by an organism's state. In man, the variables involved range from the influence of various stages of sleep to performance on information processing tasks that are undertaken simultaneously with the recordings. In rats, aversive conditioning paradigms seem so far most manageable in producing replicable results. These studies have led to an increasing concern with the behavior of the motor system, and quantitative and analytical studies of the behavior of this system and its componentry are being planned. Electrophysiological studies of conditioning in the rat have been concerned with changes in sensory-evoked potentials correlated with conditioned changes in behavior.

This group works in close cooperation with the Eaton-Peabody Laboratory for Auditory Physiology at the Massachusetts Eye and Ear Infirmary and with neurologists at the Massachusetts General Hospital.

ii) Cognitive Information Processing.

The primary research interest of this group is in the real-time acquisition and processing of visual information for display to the visual and the nonvisual senses, and in the psychology of human utilization of such information, for both communication and control. The research, under the direction of Professors S. J. Mason, M. Eden, W. F. Schreiber, F. F. Lee, and D. E. Troxel, is motivated by an interest in human capabilities for information processing and in human information requirements. Applications include sensory-aid systems for the blind and the blind-deaf, picture transmission systems, and special information-display systems for enhancement of human performance under conditions of stress.

Major projects now in progress include studies on reading machines, mobility aids, digital and optical picture processing, pattern recognition, and biological image processing.

A reading machine system has been developed that will serve as a facility for further research on character recognition, special-purpose picture processing, tactile pattern perception, and auditory displays, including artificial speech. In its present form the system is capable of book-print character recognition and generation, at real-time rates, of an auditory "spelled speech" output. A later version is aimed at artificial "connected speech" as an auditory output and also tactile displays of visual material not susceptible to character recognition. Man-machine studies with this system will help us develop realistic criteria for useful reading-aid systems for the blind and blind-deaf.

Work on mobility aids is directed at the development of a system capable of simulating, in real time and space, the operation of a large class of mobility-aids devices. The purpose of the research is to determine human information requirements and human capabilities, as a basis for the design of useful systems.

The picture-processing research is concerned with the digital and coherent-light optical processing and encoding of image information for efficient or economical transmission, subject to criteria of subjective picture quality. The problem of bandwidth compression for image transmission, without appreciable loss of subjective visual quality, and the problem of picture processing for tactile display to a blind subject, involve some of the same considerations of human pattern perception and also some of the same techniques of processing, such as edge extraction.

General pattern-recognition work involves studies of human visual, auditory, and tactile perception and also studies of automatic pattern identification. Current projects include studies of depth perception and optical illusions, reading and writing of transformed text, apparent motion, automatic extraction of information from printed sheet music, automatic printed-character recognition, and growth algorithms for the generation of complex structures, such as leaf-vein patterns.

Biological image processing deals with the acquisition and analysis of visual patterns that are important in medicine and biology. The picture processing facilities described above are being used to explore the feasibility of using fully automatic techniques or machine aids to human classification of such objects as white cells, chromosome counting, particle counting, micro-autoradiographs, three-dimensional visualization of micro-anatomic structures.

iii) Neurophysiology.

The principal research goal of the Neurophysiology Group, working under the direction of Professor J. Y. Lettvin, Professor P. D. Wall, and Dr. W. S. McCulloch, is to develop testable descriptions of sensory processes and to enlarge our understanding of the underlying physical mechanisms.

Several of the sensory processes have been studied intensively for a number of years. These include research on the physical and coding mechanisms of the olfactory system and analysis of the stimuli and firing patterns of single fibers in the frog optic nerve.

The development of the Wall-Melzack theory of pain has led to a number of predictions concerning pain control in man which are now being studied. The activity of cells in the dorsal horn of the cat spinal cord with the animal in several different states has been studied and this work will be extended to the rat. Other related research on dorsal horn activity is being pursued and similar investigations of the ventral horn are planned to begin in a short while.

Physical studies of natural and synthetic membranes, based on a set of chemical predictions made during the last year and a half, are being pursued with a view to discovering the mechanisms of nerve membrane activity.

As a supporting activity for the research mentioned above, a variety of instrumentation projects have been undertaken in order to provide low-cost, but accurate, data processing devices for looking at neural events in several different ways.

Professor B. H. Pomeranz and his students in the Department of Biology are conducting studies directed at neural feedback mechanisms involved in the control of kidney, liver, and cardio-vascular function. Their principal research centers around the following electrophysiological investigations:

1. Studies of afferent fibers from the kidney, liver and heart to the spinal cord and brain stem, to determine the physiological stimuli which produce the input of the feedback loop.

2. Studies in the spinal cord and brain stem of the interneurons responsible for integrating all the feedback loops with information from higher centers (cortex, hypothalmus, etc.).

3. Measurements of the sympathetic nervous output of the autonomic nervous system, responsible for control kidney, liver and cardiovascular function. These studies also include recording from the organs themselves in order to correlate neural output with end organ effects (e.g. blood flow to the kidney and liver, blood pressure, kidney concentrating ability, liver glucose output, etc.).

4. Effects of stimulation of renal and cardiac efferent nerves in conscious dogs over periods of several years, to attempt to produce hypertension of heart attacks and hence test the hypothesis that these diseases (which cause 65% of all deaths) are a result of increased nervous activity during stress. Chronic animal studies are being carried out in collaboration with the Department of Physiology, Harvard Medical School.

iv) Linguistics.

The Linguistics group, working under Professors N. A. Chomsky and M. Halle, has long maintained an interest in problems that are common both to linguistics and to the psychology of language, the acoustics and physiology of speech and the study of language disturbances. Studies in these areas are conducted jointly with members of the Department of Psychology or with other groups within the Research Laboratory of Electronics.

Current studies are being conducted on the physical correlates of speech, on the child's acquisition of language, on bilingualism and its relations to the psychology of language, and on mathematical models of reading and writing.

v) Speech Communication.

The general objectives of speech communication research, led by Professors K. N. Stevens, D. H. Klatt, A. V. Oppenheim, and Dr. Bernard Gold, are to further our understanding of the process of human speech generation. In particular, experimental studies of speech lead to a delineation of the capabilities of man to generate sounds that are used in language, and also to perceive and interpret these sounds. The goal of the research is to determine the inventory of the distinctive features that are used in the languages of the world and to understand the mechamisms whereby these segments and features are encoded into articulatory activity.

Research is being conducted in the physiological mechanisms that underlie the production of speech. These are examined through cineradiographic studies of the supraglottal system, through measurements of air flows and pressures in the respiratory system and through acoustic analysis of the sounds of speech.

Inseparable from the study of how segments are encoded into sound is the problem of decoding the sounds of speech by a listener. These are being actively studied by means of simulation experiments, sophisticated signal processing techniques and psychological experimentation.

vi) Artificial Intelligence.

The purpose of this work, under the direction of Professor M. L. Minsky and Dr. S. A. Papert, is to find ways to make machines solve problems that are considered to require intelligence. These problems are usually attacked by programming computers to deal directly with the necessary abstractions, rather than by simulating hypothetical physiological and psychological mechanisms.

Processes for recognizing visual objects by computer programs are being studied. These processes involve analysis of the visual field into objects and background. Objects are to be recognized by generating hypotheses and confirming them or modifying them by the results of selective attention to parts of the field and of the proposed objects. These processes will entail use of stereopsis and color, as well as the construction of abstract symbolic three-dimensional representations of the scene within computer memory.

A system that combines a computer-controlled arm and hand with a real-time computer-controlled visual system is being constructed in order to study the problems involved in visual-motor co-ordination in complex manipulation tasks. This project is being sponsored by the Advanced Research Projects Agency with the goal of developing practical manipulation systems. It seems likely that some results of this work will open up avenues of more purely scientific interest, especially in clarifying the mechanisms of human postural coordination.

III. COURSES OFFERED IN ENGINEERING AND LIVING SYSTEMS

Presented in the following is a partial list of courses given on topics associated with engineering and living systems. Not included here are the general courses in areas such as biology, biochemistry, or physiology which are offered in various M.I.T. departments. For more complete information the reader is referred to the General Catalogue. In addition to the subjects presented at M.I.T., courses at neighboring institutions are readily available to the graduate student, by cross-registration arrangements among the various schools.

Department Name	Course	Title
Mechanical Engineering	2.18	Man-Machine Systems
" "	2.181J	See Course 16.43J
Electrical Engineering	6.36J	Speech Communication
" "	6.37T	Sensory Communication
" "	6.372T	Introduction to Neuroelectric Potentials
" "	6.544J	Heuristic Programming and Artificial Intelligence
" "	6.59	Bioelectric Signals
" "	6.592	Analytical Models for Human Processing of Sensory Inputs
" "	6.594	Cognitive Information Processes
" "	6.595	Communication Sciences Seminar
" "	6.694J	Laboratory in the Physiology, Acoustics, and Perception of Speech
Chemical Engineering	10.56	Chemical Engineering in Medicine

(continued)

(continued)

Department Name	Course	Title
Aeronautics and Astronautics	16.43J	Life Support and Human Performance in Manned Systems
Nutrition and Food Science	20.43	Industrial Microbiology
" " " "	20.47	Biochemical Engineering
Nuclear Engineering	22.20	Biological Effects of Nuclear Radiation
" "	22.81	Selected Topics in Radiation and Radioisotope Applications

IV. GENERAL INFORMATION FOR STUDENTS

Graduate education at the Institute is extremely flexible. Whether a student is seeking a Master's degree, an Engineer's degree or a doctorate, he is permitted and encouraged to design an educational program, in consultation with his faculty counselor, which will build on his educational foundation toward his specific goals. In the case of doctoral study and in special cases, for Master's degree programs, a student may request the appointment of a special interdepartmental faculty committee to supervise his program of study and his thesis. We feel that this mode of study is particularly well suited for students wishing to gain an education in ELS. It provides the opportunity for an optimum arrangement of subjects of instruction and for the joint supervision of research work by appropriate members from both Engineering and the Life Sciences faculties.

Admission to the Institute as a regular student may be gained only through one of the academic departments, and students usually apply to that department which most closely identifies their field of major interest and demonstrated competence. In some cases, a student considering graduate study may find that his interests fit equally well in two or even three M.I.T. departments.

To serve as an advisory body to students in Engineering and Living Systems, the Dean of the School of Engineering has established a Steering Committee drawn primarily from the engineering faculty, with representatives from other Institute departments and academic centers. In addition to its advisory functions, this Committee provides an effective mechanism for interdepartmental and interorganizational communication through meetings, invited lectures and seminars.

Although most opportunities for financial aid for graduate students in ELS are now--and will continue to be--handled through departmentally administered assistantships and traineeships, a major activity of the Committee is the development of additional sources of fellowship support. Specifically, these fellowships are designed to permit study between departments or even institutions in areas which are not covered by other research funds.

It should be evident from the foregoing that the program at M.I.T. in ELS is one designed primarily for graduate study. This is not to say that the undergraduate has been neglected or is excluded from participating. Rather, the undergraduate years can provide through elective courses, special projects and the senior thesis, many opportunities for an introduction to problems which may then become the focus for later graduate study.

Applications for admission to the Graduate School, together with copies of the Institute's General Catalogue, which contains descriptions of all Institute requirements and subjects of instruction, may be obtained either from the Director of Admissions, Room 3-108, M.I.T., or from the head of the department to which the student intends to apply.

Prospective students desiring further information on the M.I.T. program on ELS, and those seeking special courses of graduate study which are not oriented towards a degree, are invited to write directly to: Dr. Philip A. Drinker, Executive Officer, Committee on Engineering and Living Systems, Room 3-457A, M.I.T., 77 Massachusetts Avenue, Cambridge, Massachusetts 02139.

V. THE COMMITTEE ON ENGINEERING AND LIVING SYSTEMS

Murray Eden, Ph. D., Chairman
Professor of Electrical Engineering
Lecturer in Preventive Medicine, Harvard Medical School

Philip A. Drinker, Ph. D., Executive Officer
Lecturer in Mechanical Engineering
Associate Staff (Surgery), Peter Bent Brigham Hospital

Paul E. Brown, Sc. D.
Executive Officer, Center for Advanced Engineering Study

Gordon L. Brownell, Ph. D.
Associate Professor of Nuclear Engineering
Head, Physics Research Laboratory, Massachusetts General Hospital

Leslie J. De Groot, M. D.
Associate Professor of Experimental Medicine (Nutrition and Food Science)
Associate Director of the M.I.T. Clinical Research Center

Harriet L. Hardy, M. D.
Assistant Medical Director
Head, Occupational Medical Service

Robert W. Mann, Sc. D.
Professor of Mechanical Engineering
Chairman of the Steering Committee, Center for Sensory Aids Evaluation and Development

Edward W. Merrill, Sc. D.
Professor of Chemical Engineering
Consultant in Chemical Engineering, Massachusetts General Hospital

Erik L. Mollo-Christensen, Sc. D.
Professor of Meteorology

Bruce H. Pomeranz, M. D., Ph. D.
Assistant Professor of Physiology (Biology)

Walter A. Rosenblith, Ing. Rad.
Professor of Communications Biophysics (Electrical Engineering)
Research Associate in Otology, Massachusetts Eye and Ear Infirmary, and Harvard Medical School

Albert O. Seeler, M. D.
Professor and Head of the Medical Department

John G. Trump, Sc. D.
Professor of Electrical Engineering
Committee on Research Policy, Lahey Clinic Foundation Inc.

Emily L. Wick, Ph. D.
Associate Professor of Food Chemistry (Nutrition and Food Science)
Associate Dean of Student Affairs
Chairman, Premedical Advisory Committee

Laurence R. Young, Sc. D.
Assistant Professor of Aeronautics and Astronautics

MM 12 May 1967

To: R/Associate Administrator for Advanced Research and Technology
S/Associate Administrator for Space Science and Applications

From: MM/Executive Secretary, Life Sciences Directors Group

Subj: Life Sciences Flight Experiments Presentation

Reference: Memo of 3 May 1967 from Code MM to Codes R and S establishing subject conference

The Life Sciences Flight Experiments Presentation has been changed from 18 May 1967 to 29 May 1967, 9:00-12:00, Room 625T, FOB 10B.

Consistent with the change in time, the agenda will be adjusted as follows:

9:00-9:30	Dr. S.P. Vinograd
9:30-10:15	Dr. O. Reynolds
10:15-11:00	Dr. W.L. Jones
11:00-12:00	Open Discussion

Original signed by
H.S. Brownstein

H. S. Brownstein

cc: M-1/General Bowman
MM/Dr. Bollerud
MM/Dr. Vinograd
RB/Dr. Jones
SB/Dr. Reynolds

MM/Director, Medical Science and Technology
RB/Director, Biotechnology and Human Research
SB/Director, Bioscience Programs

12 May 1967

MM/Executive Secretary, Life Sciences Directors Group

Life Sciences Flight Experiments Presentation

The subject meeting will be held in Room 625T, FOB 10B, Monday, 29 May 1967, 9:00-12:00.

Please notify my office (x20418) by 22 May 1967 of your visual aid requirements so necessary personnel and projection equipment support can be reserved.

Projection limitations in Conference Room 625T will permit a standard dual projection capability.

Original signed by
H.S. Brownstein

H. S. Brownstein

1967 San Diego Biomedical Engineering Symposium

In reply, please address:

Michael Hlavin
5829 Haber Street
San Diego, Calif. 92122
April 14, 1967

Dr. Sherman P. Vinograd
Medical Science & Technical Director
Office of Manned Space Flight, NASA
Washington, D.C.

Dear Dr. Vinograd:

Just a reminder that the four-page summary of the paper that you will present at the San Diego Biomedical Engineering Symposium should be in the mail by May 1. The summary should be in photo-ready form on the special model paper that was enclosed in my letter of March 13, 1967.

Please contact me if you need further information or more model paper. Phone 277-8900 ext. 2189.

Sincerely,

J. M. Hlavin

J. M. Hlavin

JMH:fkw

Enc.

C-M-S-P

BIOGRAPHY OF SHERMAN P. VINOGRAD, M.D.

Position	Director, Medical Science & Technology, Space Medicine, OMSF
Education	University of Wisconsin (Zoology) -B.S. 1942 University of Wisconsin Medical School-M.D. 1946 Touro Infirmary, New Orleans, La. (Internship) 1946-47 St. Mary's Hospital & University Hospitals, Madison, Wis., Residency, Internal Medicine 1950-53
Experience	U.S.N. School of Aviation Medicine - Navy Flight Surgeon 1962

Dr. Vinograd was appointed to NASA in November 1961 as Chief, Advanced Biomedical Technological Development Division. In this position he had responsibility for developing and monitoring biotechnical research in support of the over-all aerospace medical program for Apollo.

In January 1963, he was made Chief, Flight Crew Medical Operations Branch where, as flight surgeon, he was responsible for review and recommendations on procedures concerning astronaut selection, care, preparation, and insertion; the development of mission rules; in-flight medical monitoring; and medical data collection. In June 1963, he was made Assistant Director, Crew Systems Development; and in November 1963, he became Chief of the Professional Services Branch, Directorate of Space Medicine. In both this and his present capacity, he is concerned with medical and biological factors involved in man's exploration of space. He is also responsible for the biomedical experiments to be included on manned space flights. Dr. Vinograd assumed his present post in July 1964.

Prior to his affiliation with NASA, Dr. Vinograd was in the private practice of medicine, specializing in internal medicine. In 1953, he became Director of Intern Education at St. Mary's Hospital in Madison, Wisconsin. From 1955 to 1961, he was an Assistant Professor of Clinical Medicine at the University of Wisconsin Medical School.

Patents	
Memberships	A.M.A., American Academy of Allergy; Hospital staffs; University Hospital teaching staffs; State and local medical societies.
Publications	He is the author of several professional lectures and papers in the field of Space Medicine.
Recognition	
Military Affiliation	U. S. Navy, 1942 to 1946; MCR, USNR, July 1947 to July 1949
Personal Data	Born on January 24, 1921, in Milwaukee, Wisconsin Married to the former Martha Reed Resides at 6529 Sothoron Road, McLean, Virginia
Date Prepared	July 1964

NASA ROUTING SLIP

	CODE	NAME *(if necessary)*		
				ACTION
				APPROVAL
1.	MM	Vinograd		CONCURRENCE
				FILE
2.				INFORMATION
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3.				NOTE AND FORWARD
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7.				

REMARKS:

FROM:	CODE: MLA	NAME: Green	DATE: 6/13/67

NASA Form 26 (Rev. Jan. 1963)

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

IN REPLY REFER TO: MLA

JUN 12 1967

TO: MSC/Assistant Program Manager, Apollo Applications Program Office, Robert F. Thompson

MSFC/Program Manager, Saturn Apollo Applications Program Office, Leland F. Belew

KSC/Acting Program Manager, Apollo Applications Program, Robert C. Hock

FROM: ML/Director, Saturn Apollo Applications

SUBJECT: MPTF

As a result of the material presented at the 67-4 MPTF meeting at MSFC on June 1 and 2 and the discussions which followed, I believe we are now in a position to pull together a presentation for Dr. Mueller and the Center Directors on our studies of the low earth orbit missions now scheduled for CY 1970 (Ref ML-6). The purpose of this letter is to summarize the guidelines for preparing this presentation and to confirm the plans discussed in the meeting of the Steering Committee on June 2.

With regard to timing, I would like to plan a dry run for review by Messrs. Belew, Hock, and Thompson and myself at the MPTF meeting 67-5, to be held in Washington during the second week in July. We will arrange the schedule for presentation to Dr. Mueller and the Center Directors at a later time.

In the presentation itself, I would like to focus attention on the basic issues and to minimize the potential distraction introduced by non critical secondary matters. To do this, we should describe baseline plans for two mission concepts which are consistent with the present planning schedule, ML-6, showing quantitatively the degree to which these baseline missions can achieve the program objectives. Incremental changes to the baseline to more fully achieve the stated objectives should be shown separately. It is also important that we have factual backup for the conclusions we present.

The attached outline and action assignments and the statement of goals, guidelines, and assumptions will, I believe provide the framework for a good wrap up of this set of missions. Mr. Green will be in touch with your representatives to work out further details over the next month.

Charles W. Mathews

Goals, Guidelines, and Assumptions
for MPTF Presentation of the Second Year AAP Earth Orbital Missions
Attachment 1

1. Goals

1.1 To achieve, insofar as possible, continuous manned operation of an orbital workshop for a period approaching one year, using a series of manned and unmanned vehicles. Where there is conflict between continuity and maximum potential duration, continuity should take priority.

1.2 To demonstrate economical operation by reuse of the first Orbital Workshop cluster, maintaining program flexibility to establish a new workshop whenever circumstances or program decisions dictate.

1.3 To conduct further solar observations using the ATM while operations with the original cluster continue.

1.4 To conduct earth observations in support of meteorology and earth resources (APP-A, APP-B) preferably at inclinations achieving or approaching 50°.

2. Guidelines and Assumptions

2.1 The presentation should cover the feasibility of increasing CSM duration (to approach 90 days) in revisiting the original cluster.

2.2 To maintain program flexibility, CSM's should be capable of operating either with the original cluster or with a new cluster. Performance penalties, if any, should be brought out, together with configuration changes or modifications to avoid them.

2.3 An integrated systems engineering analysis of the CSM to support these missions should be provided. This should use the CSM as defined for the AAP 3 mission as a baseline and show, subsystem by subsystem, the improvements needed. It should also show the continuity (or lack of it) of this development with the spacecraft needed to support the missions later in the program (i.e. extended lunar operations, synchronous earth orbit, early space station operations).

2.4 A similar analysis of the second workshop (OWS/AL/MDA) should be provided, using the first as a baseline.

2.5 The baseline mission sequence should show alternating pairs (manned and unmanned) and single manned flights, spaced to allow reasonable overlap. If additional unmanned supply or experiment carriers are needed to attain the objectives they should be shown as increments to the baseline.

2.6 In presenting the reuse of the original cluster, we should leave open the question of when to initiate a new cluster; hardware to support a new cluster should be available to start in the first quarter of CY 70.

2.7 The new cluster should be shown at about 250 n,m, with inclination as high as possible, assuming launch vehicle performance based on the use of four solid strapped-on rockets on the SIB.

2.8 We should not include artificial G experiments in the baseline profile.

2.9 We should review both spacecraft and launch vehicle check out procedures to assess the feasibility of shortening the pad turn around time.

2.10 We should show how useful fall-back missions can be flown using the hardware developed for the baseline missions.

2.11 We should identify areas needing further work to resolve critical questions and our plans for such work.

2.12 We should prepare cost and schedule data for spacecraft and launch vehicle development and procurement as a basis for definitive evaluation of our ability to carry out the necessary activities.

2.13 Ten sets of paper copies of material presented and the reports to back it up should be prepared for distribution at the dry run.

Attachment 2

Outline of the Presentation and Action Assignments

ACTION	
MLA	1. Program Goals for the second year of AAP operations in Low Earth Orbit
	1.1 Extension of Manned Space Flight Capability - Operations - Long Duration
	1.2 Experiment Activities
MLA	2. Assumptions and Constraints
MSFC with MSC support	3. Baseline Mission Profiles and Performance Summary
	3.1 Launch Vehicle Performance
	3.2 Mission sequences and variations
	3.3 Gross weight summaries
	3.4 Altitude vs. inclination vs. duration trade off summary.
MSC	4. CSM Configuration and Subsystem Performance.
	4.1 Baseline CSM for AAP-3
	4.2 Summary of requirements for future missions
	4.3 Impact of Workshop features on CSM Performance
	4.4 Subsystem performance analysis
	4.5 Failure modes and effects
MSFC with MSC support	5. Orbital Workshop Configuration and Subsystem Performance
	5.1 Original Workshop (OWS/AL/MDA)
	5.2 Improvements in Second Workshop
	5.3 Subsystem Performance
	5.4 Reusability analysis including shut down for storage operations
	5.5 Failure modes and effects

MSFC	6.	Experiments and Payload Carriers
		6.1 ATM a. Objectives b. Reuse of ATM #1 c. Backup use of flight prototype
MSC		6.2 APPs A and B a. Objectives b. Experiments c. Carrier
MSC		6.3 Medical Experiments a. Reuse of Workshop #1 b. Experiments and Monitoring for long duration build up
MSFC/MSC		6.4 Others
MSC	7.	Crew Factors
		7.1 Time line Analysis 7.2 EVA 7.3 Training
KSC	8.	Launch Operations
MSC	9.	Mission Operations
		9.1 Planning and Software 9.2 Mission Control 9.3 Recovery
MLA	10.	Contingency Modes
Each Center in its area of responsibility	11.	Costs and Schedules

DR. VINOGRAD

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DEPARTMENT OF AEROSPACE MEDICINE & BIOASTRONAUTICS
A. H. Schwichtenberg, M.D.
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D. E. Busby, M.D.

May 22, 1967

Mr. H. S. Brownstein
Code MM
NASA Headquarters
Washington, D. C.

Dear Mr. Brownstein:

Enclosed you will find a critique of the "Physiology in the Space Environment. Volume II. Respiration" by the NAS-NRC Space Science Board.

Sincerely yours,

E M Roth

E. M. Roth, M. D.

EMR:dt
Enc.

P. S. Nitpicking in the text of each chapter will follow.

Physiology in the Space Environment

Vol. II. Respiration

Introduction

The reviews presented in this document appear to be up-to-date discussions of respiratory physiology as it relates to the space program. The major criticism is a lack of discrimination between those study areas which appear to be obligatory for development of safe and efficient space programs and those which are of secondary scientific importance. Several of the papers appear to contain misinformation with errors of both omission and commission. The recommendations of each group will be reviewed and an attempt made to dissect programmatic requirements from basic scientific curiosities and to indicate the relative role of ground-based vs. in-flight experimentation in attacking the problem.

A basic criticism extending to several of the chapters is the use of the term deconditioning. The cardiovascular and muscular adaptation to zero g are not always parallel. The adaptations themselves must be dissected from the significance of these adaptations to secondary stress imposed by subsequent EVA, planetary operations, or return to earth. It appears that skeletal muscular changes can be easily countered by appropriate exercise regimens. The cardiovascular effects, however, require further analysis and appear to be more resistant to change. Since the changes appear as an adaptation to zero g, one must consider consequences of any in-flight training program to operational capability during flight as well as to post-flight operations.

Comments on Summary + Recommendations

1. Structural Changes in Lung and Thorax (chapter 3)

General

There is no reason to believe that with appropriate exercise of thoracic muscles during flight, there will be any alteration in mechanics of breathing. The term "general deconditioning of the body" is not appropriate. Muscular "deconditioning" is specific to muscle groups inadequately used during zero g flight and there is no reason to feel that the muscles of respiration need be inadequately used.

Recommendations

1. Histological changes in the lung arising from elevated P_{O_2} can be and are being studied in ground-based chambers. Marked species specificity invalidates many of the conclusions drawn from animal work (WADD TR 66-120 and 1967 Conference). This recommendation falls into the basic science class and has no immediate programmatic significance.

2. Damage to the lung at high g loads has been found in animals exposed to g levels with "g" x time profiles much greater than required for normal operation in humans. However, contingency modes or emergencies may impose such loads on astronauts and so the basic mechanics of damage should be studied. Since high g loads of reentry may follow zero g operations, and since adaptation to g will probably change the vascular reactivity and volume changes in the thorax, such work should include overloads imposed on animals reentering from orbit. This recommendation is of basic science variety but does have some significance to the treatment of human emergencies in all programs. (Air trapping and atelectasis will be covered below).

3. There is not even indirect or theoretical evidence that the lung is a significant target when exposed to expected levels and rates of external space radiation. Since the marrow, GI tract, and skin are so much more important, I would consider this recommendation to fall into the basic science class and to be given the lowest priority.

2. Respiratory Mechanics (Chapter ~~3~~ 4)

General

I agree with the summary but feel that there will be little change in cough since the kinetic energy of the gas stream will be unchanged.

There are probably secondary factors which may alter the efficiency of the cough.

Recommendations

1. These measurements will no doubt be altered by factors discussed in chapter (3). The small changes expected and minimal operational significance places this in a basic science category which requires in-flight study.

2. Cough mechanism is of great importance and should receive more study under reduced pressure. Since there is little or no theoretical effect of zero g on the cough mechanism other than greater ease of moving particles up the respiratory tree, ground-based study should be adequate. Since experience in chambers and in flight have shown no obvious change in coughing ability, this recommendation should fall into the basic science category.

3. In view of emergency g loads factors discussed in chapter (3), this recommendation appears valid, requires only ground-based study and would fit in a basic science category. Validation of data from cadavers must be confirmed in primates before human limits can be set from cadaver study alone.

4. This recommendation has programmatic significance in that DuBois has shown that human susceptibility to atelectasis can be predicted by air-way conductance studies (DuBois 1966 reference in chapter 4). I feel that air-way conductance at specific lung volume should be used as an astronaut selection test in order to weed out those candidates who will be susceptible to atelectasis. More ground-based studies correlating individual air-way conductance patterns with susceptibility to subsequent high g environments followed by 100% O_2 at 5 psia are required. If inert gases are used in the cabin gas mixture, such studies will probably not be necessary, since only 5% of inert gas can counter the atelectatic tendency in susceptible individuals (DuBois 1966).

5. The predisposition to infection produced by atelectasis in animals should be studied as part of the basic science program. This issue is continually raised but not answered by concrete work. Human data is usually from post-anesthesia experience and not especially pertinent. Ground-based studies should be adequate.

3. Preliminary Gaseous Diffusion (Chapter 5)

General

I agree with the summary.

Recommendations

1. As part of the basic science program, such studies appear justified. Both ground-based and in-flight studies are required. Oxygen at 5 psia in past ground-based studies has not produced significant diffusion changes in humans. Species specificity is so significant that animal studies will probably provide very little more useful data for the manned program than has already been obtained (WADD TR 66-120 and 1967 Conference). Other than giving a general view of functional capacity of the lung, I doubt that the diffusion capacity can predict more exactly than simpler functional data that "reentry is dangerous". For in-flight human experimentation, diffusion studies should be included as background information in case cryptic symptoms arise.

4. Pulmonary Circulation and the Distribution of Blood and Gas in the Lungs (Chapter 6)

General

This is an excellent, logical review of this subject.

Recommendations

Most of the recommendations fall into the basic science category with very little effect on specific flight programs. They will help in evaluating alteration of response to subsequent environmental stresses imposed by the pulmonary and systemic vascular adaptation to weightlessness. Rational planning for treatment of emergencies requires that such data are available.

1. The first six recommendations require animal and human experimentation in an orbiting laboratory. They represent the most critical basic science data to be obtained in the flight programs and must be backed up with appropriate ground-based controls. They should be coupled with responses of the peripheral circuit to similar environmental stresses.

2. Recommendation No. 6 appears to be somewhat naive in that more precise data are needed in central venous and left atrial pressure that can be obtained by external observation of neck veins. The current study of Lawrence Young for Dr. Vinograd would be more pertinent than this recommendation.

3. Recommendation No. 7 has already been covered in Chapter 5.

5. Regulation of Breathing (Chapter 7)

General

I agree with the summary.

Recommendations

1. I do not see where these in-flight data would be of help during launch and reentry. Response of ventilation to g load is well known from ground-based studies and in-flight data should be no different.

During weightlessness such data would help to evaluate the exercise problems encountered during EVA. These studies should be part of the in-flight human experimentation with ground-based controls.

2. Much of the ground-based work has already been performed at the USAF SAM. The combined effect of increased CO_2 and hyperoxia on ventilation during exercise should be performed on the ground and in flight as part of the human experiment program and receive top priority.

6. Exchange of Fluids in Lungs (Chapter 8)

General

I agree with the scientific points made in this chapter but find the applications most impractical. I cannot fantasy fluid in lung or pleural spaces ever being required during nominal or contingency operations.

Recommendations

1 and 2. These are basic science studies requiring in-flight and ground-based data. No specific programs depend on the findings, but the data may be of value in optimizing the treatment of medical and surgical emergencies in future space flights.

3. This is a far-out basic science type of study which should be given low priority.

4. Much more should be known about surfactant in the lung during exposure to different gas mixtures. The treatment of pulmonary edema and other lung emergencies depends on knowledge of this factor. Ground-based animal and possibly human experimentation will be required.

7. Respiratory Tract Clearance Mechanisms (Chapter 9)

General

I agree with the summary.

Recommendations

1. There is a potential problem of sinus clearance in long duration space flight. Ground-based work on the problem has already been done. Thought might be given to improvement of sinus drainage by mechanical means in zero g environments. Animal studies of mucous clearance in zero g paralleling ground-based controls may give some insight into future problems especially when respiratory infections are superimposed on the normal mocosa. Such studies would have to be placed in the basic science group, in-flight, with moderate priority.

2. Ciliary preparations have been hard to interpret even in ground-based studies. It is difficult to foresee any effect of zero g on ciliary movement. As a basic science item, it should probably be given low priority.

8. Diffusion of Gases in Peripheral Tissue (Chapter 10)

General

This good review of diffusion problems indicates the difficulty of measurement on the ground and the paucity of critical data. Much more data are needed on the ground before data in-flight would be interpretable. Evidence of tissue hypoxia in flight has not been seen. Alteration of intercapillary distance in the periphery would be expected during the systemic vascular response to weightlessness, but dynamic measurement is too difficult.

Recommendations

1 and 2. These are basic science problems of ground-based variety with no programmatic significance. They should be given moderate to low priority.

3. This problem is of greater significance in interpreting peripheral vascular response to weightlessness and in medical handling of emergencies. In-flight studies in animals are required but will be difficult to accomplish. Moderate to high priority should be given to the problem. The studies of Oberg of Göteborg, Sweden, would be a good model (Oberg, B., Effects of Cardiovascular Reflexes on Net Capillary Transfer, Acta Physiological Scandinavica, V. 62, Supplement 229, 1964).

9. Temperature Regulation (Chapter 11)

General

This author betrays throughout the chapter a general naiveté regarding the subject. Helium, for instance, will increase not decrease respiratory heat loss. Also the decrease in plasma volume during adaptation to weightlessness should have a definite effect on thermal tolerance during such emergencies as ECS thermal failure on the lunar surface.

Recommendations

1. There is a theoretical grativational effect on evaporative heat transfer which should be included in respiratory loss calculations. The relative effect on total water transfer will be altered by many secondary factors such as forced flow in the tract. Empirical study will be required. In-flight data could be obtained in human laboratory programs but only moderate priority given to such studies in view of the small potential factor expected from theoretical considerations.

2. This could be a ground-based study to supplement the data already available.

3. This is an important point, especially in the EVA situation. Combined ground-based and in-flight studies, in the presence of exercise, may help to dissect the thermal and H_2O problems experienced in EVA. The effect of zero g on vascular response to heat is also a problem requiring active study. These should be given top priority in program planning.

4. The minor changes expected would shift this to a low priority effort with ground-based and possibly in-flight data.

5. In view of the constant P_{O_2} on earth it is not clear why periodic alteration of oxygen is required. The decrease of temperature at night may have significance to circadian rhythm in field animals, but not nearly as much to humans. Since clothing alters the microtemperature during day-night changes, this recommendation should be on moderate priority and relegated to a study of temperature-clothing preferences in flight during different operational conditions.

10. Oxygen Pressure at Near-Normal Partial Pressures (Chapter 12)

General

The author appears to be out of touch with many of the physiological considerations in the space program. For example, sensitivity to radiation is not significantly altered by 5 psia O_2 or by the levels of hypoxia one would allow during space operations. The choice of 5 psia O_2 vs. 3.5 psia was not "predicated largely on heat exchange of the astronauts and of instruments". Prime factors were reduction of decompression sickness in early phases of the mission as well as reduction in atelectatic tendency during the flight. The 5 psia choice also facilitates emergency suit operations and increases the survival time after cabin puncture. The acceptability of partial pressures of oxygen lower than normal have been well studied in aviation medicine where chronic exposure to 8,000 to 10,000 ft equivalents without prior acclimatization is the accepted threshold level.

Recommendations

1 and 3. These recommendations are fine except for the fact that the total mission reliability must be considered and not just physiological responses.

The relationship between blood tocopherol levels 5 psia O_2 and red blood cell destruction seen in the astronauts of the Gemini program should get top priority work in ground-based animal and human study and followup in the Apollo. Recent studies of Mengel at Ohio State University point out a good experimental model. The different adaptive changes in the tissues of animals (WADD AMRL TR 66-120 and 1967 Dayton Conference) suggest that species differences preclude adequate evaluation of human response by simple animal exposures. One method of normalizing the response of animals to that of humans would be to make the animals tocopherol deficient to the point where they lose a red cell mass equivalent to the human loss seen in elevated O_2 environments. Even this approach does not guarantee that other organs will behave in parallel fashion.

In any case, use of elevated P_{O_2} in space missions requires at least equal time of exposure in simulators of at least 2 and preferably 4 or more humans prior to space use.

2. This recommendation has been discussed above in the summary where it is suggested that adequate data on chronic exposure to low P_{O_2} are probably already available. What is required is an optimum curve for acclimatization rate up to 19,000 ft equivalent altitudes above which chronic adaptation is not possible. The data of the Everest Hillary Expedition point out the adaptation problems. The use of drugs to speed adaptation during emergency periods of low P_{O_2} should be studied. Preliminary findings of Albrecht and Albrecht suggest the Swiss drug Solcoseryl may increase the adaptive response under such conditions.

There are many gaps in our knowledge of response to acute hypoxia which should be filled to optimize therapeutic methods. Acute hypoxic emergencies have already occurred at NASA Houston and elsewhere in the space program. The following areas require further study:

1. Effect of various work loads on time of useful consciousness at various hypoxic levels of ambient oxygen.
2. Optimum emergency decompression modes for cabin purging or oxygen conservation to maintain an astronaut usefully conscious during controlled decompressions in space.
3. Most effective drugs and drug regimes for the resuscitation of an hypoxic astronaut.
4. Further studies of the pathophysiologic mechanisms of reversible and irreversible brain cell damage from hypoxia.
5. Further empirical study and clinical assessment of the effectiveness of cerebral dehydrating agents and/or hypothermia for treating so-called post-hypoxic cerebral edema.

In view of the importance of hypoxia in space emergencies, these studies should be given high priority. Ground-based simulation will be adequate. Details may be found in the recent study of Busby, D. E., Clinical Space Medicine - A Prospective Look at Medical Problems from Hazards of Space Operations, 1967.

4. This is, of course, a necessity just for control purposes.

5. The minimal effect of 5 psia O_2 on radiosensitivity of mice may be dose rate-sensitive with x-rays (Benjamin, F. G. and Peyser, L., Effect of Oxygen on Radiation Resistance of Mice, Aerospace Med., 35: 1147-1149, 1964. Kelton, A. A. and Kirby, J. K., Total Oxygen Pressure and Radiation Mortality in Mice, DAC-P-2030, Douglas Missile and Space Systems Division, Santa Monica, Calif., 1964). Little work has been done on proton-O_2 relationships. From other studies, the O_2 sensitivity would be even less than that for x-rays (Roth, E. M., Space-Cabin Atmospheres. Part I. Oxygen Toxicity, NASA SP-47, 1964). Studies are now underway at Berkeley on this question. Proton effects under reduced $^{P}O_2$ have not been adequately studied. From x-ray data, frank tissue hypoxia is required for significant effects. Moderate priority should be placed on such ground-based studies. Chronic low level exposure to proton radiation is another moderate to low priority requirement. Much work has already been done with x-rays and gammas and can be extrapolated to protons which have an equivalent RBE.

11. Considerations of Carbon Dioxide Concentration (Chapter 13)

General

The acceptable CO_2 levels of spacecraft cabins have nothing to do with "thermal exchange." The power penalty for CO_2 absorption required to maintain lower levels of CO_2 begins to climb beyond reasonable levels at lower cabin pCO_2. Much work has already been done on low level exposure. Effects at 7.6 torr or less have not had adequate controls out of the chamber or simulator environment. Data of Schaefer and recent studies at USAF SAM indicate current levels are reasonable for long duration flights (Busby, D. E., Clinical Space Medicine - A Prospective Look at Medical Problems from Hazards of Space Operations, 1967).

Recommendations

1. Time-concentration curves for emergency exposure are available with conversion to low pressure environment. Addition of 5 psia O_2 to these CO_2 levels must still be accomplished. This can be done on the ground. Little difference is expected from CO_2 in air exposure and low priority can probably be given to this effort.

2. These should be measured for baseline values during wakefulness and sleep in orbiting laboratories.

3. In view of the general remarks, this could be a low priority effort. Past space flights indicate no progressive difficulties from CO_2 even in the 14 day flight.

There are many other CO_2 studies not mentioned which should be considered. These are:

1. Man's response to low level chronic CO_2 exposure in various possible space atmospheres.
2. Effects of CO_2 on man while asleep; evaluate the possibility of his suffering the clinical manifestations which can accompany CO_2 withdrawal when he awakens.
3. Further studies on the combined effects of heat and CO_2, and cold and CO_2 on man; could CO_2 increase an astronaut's susceptibility to heat and cold.
4. Effects of CO_2 on work capacity and/or psychomotor task performance. This is most important for evaluation of EVA problems.
5. Effect of CO_2 on orthostatic intolerance. The vasodilatory response may be an important factor.
6. Search for practical measures to enhance the total body buffering capacity on exposure to CO_2.
7. Further studies on CO_2 withdrawl - the operational defects brought on by sudden removal of subject from high to low CO_2 environments.

8. Drugs for treating symptoms of CO_2 toxicity.

9. Response of CO_2-acclimatized man to an acute exposure at higher CO_2.

10. Diuretic response to CO_2 with exposed individuals performing at variable workloads and gravitational envirnnments.

11. Effect of chronic CO_2 exposure on gastric acid secretion in man.

12. Further studies of effect of chronic CO_2 exposure on adrenal cortical activity and calcium metabolism.

The first nine studies should be given high priority as ground-based work. The next two should be given moderate priority. The last study will require orbital capability for full simulation of calcium interactions.

12. Inert Gas (Chapter 14)

General

This review is most deficient in discussion of the engineering implications of inert gases. It should be remembered that there will be relatively little fire safety gained from the addition of 1.5 to 2 psia of inert gas to 3.5 psia of O_2. The ignition energy for solids will hardly change (see Huggett, AF-SAM-TR 66-85). The rate of burning of fabrics as compared to a commercial jet cabin will be 3.5 times greater in 5 psia O_2; 2.3 times greater in 5 psia 70% O_2-30% He or n_2, and 2.0 times in a 7 psia 50-50 mixture. Use of an inert gas at 1 g and in suborbital phases of flight is probably mandatory. In orbit, the burn rates in the different gas mixtures will probably be equivalent to or less than those in air at sea level and 1 g. I feel the author has overstated the advantages to be gained by use of small percent of inert gas in the orbital cabin fire problem.

Another area of disagreement is the use of inert gas in space suits. In a space suit, the risk of fire is so low and disadvantages of separate suit and mask circuits are so great that 100% O_2 in both circuits appears, in my view, to be the way to go.

Recommendations

1. I agree with this recommendation for a two-gas atmosphere. Past studies in evaluation of nitrogen vs. helium in decompression sickness have one major defect. The studies have been focused on the decompression hazard in EVA and crew transfer during the first few hours in a mission. During the unsteady state when nitrogen is being lost from the body and helium taken on, there is a slightly greater decompression risk with helium. No data are yet available on the steady state condition after 10-12 hrs. of flight. Theory suggests that helium may now present a slight advantage. Work should be done to validate this concept.

Present animal work comparing the inert gases nitrogen, helium, and neon has been naive and inadequate. Rodents cannot be used in such comparisons. The rate of inert gas exchange in these small animals is 1-2 orders of magnitude greater than that in humans. Any gas difference would be masked under such conditions. It is recommended that goats or chimpanzees be used in high priority, ground-based experiments to evaluate the relative decompression hazards of the 3 gases with exposures both to space suit pressures and to vacuum. It is disturbing to see sweeping conclusions and extrapolations cast about in the light of such inadequate data.

2. Agree, program oriented, high priority.

3. Agree, program oriented, high priority.

4. Agree. A recent finding presented at the Third Annual Conference on Atmospheric Contamination in Confined Spaces, Wright-Patterson AFB, Ohio, suggests that chronic cellular adaptations to 5 psia 70% O_2-30% nitrogen are of the same type but more severe than to 5 psia 100% O_2. There is no obvious reason for these findings in view of the normal P_{O_2} levels. This basic science work should be repeated at a moderate to low priority level.

5. Agree. See comments under recommendation No. 1. Little is known about the bends susceptibility of the astronaut group. Future

prediction of optimum denitrogenation scheduling, bends incidence, and severity depends on data not now available on average denitrogenation rate and bends incidence under exercise provocation of men with age and physical fitness of the astronautcs. Little or no data are available. Future computer programming of optimum scheduling demands such data. I would suggest this as high priority work.

Computer programs such as those of Stubbs (Stubbs, R. A. and Kidd, D. J., A Pneumatic Analogue Decompression Computer. RCAF-IAM-65-RD-1, RCAF, Institute of Aviation Medicine, Canada, April 1965) are now being used to schedule decompressions in the Canadian Navy. Stubbs feels they could be altered to allow programming of NASA decompressions from mixed gas environments. This is the only method one can use for the unsteady state,inert gas conditions arising from use of different atmospheres within each mission. This work should be given top priority.

There are several clinical areas which require further study:

1. Deeper study of pathophysiology of ebullism in primates. Past work has focused on survival time and psychomotor defects following decompression to a vacuum. Much more work is required on the defects and treatment of animals who are exposed beyond the point of transient psychological defects. Ebullism will be a constant problem in EVA and planetary operations. We are neglecting this area.
2. Efficacy of "low pressure - high O_2 profiles" in hyperbaric recompression for treatment of decompression sickness.
3. Empirical and clinical studies of various drugs, such as cerebral dehydrating agents, anticoagulants, and lipemia-clearing agents, for treating decompression sickness.

The studies of Roth (Roth, E. M., Space-Cabin Atmospheres. Part III. Physiological Factors of Inert Gases, NASA SP-117, 1966), and Busby (Busby, D. E., Clinical Space Medicine - A Prospective

Look at Medical Problems from Hazards of Space Operations, 1967) cover these points. The first suggestion should be given top priority and the other two, moderate priority in ground-based simulation.

13. Trace Contaminants (Chapter 15)

General

I agree with this discussion.

Recommendation

1. Agree with this statement. More emphasis should be placed on fire products and fire-product-extinguisher combinations. These can be done in ground-based studies and should receive high priority. I do not see that the cardiovascular adaptation to zero g will interact strongly with the known contaminants. I would reserve the zero g studies for moderate to low priority until an index of a stronger coupling is available for any contaminant or combination.

2. I would change this from hypersensitivity to idiosyncrasy. I know of no allergic reactions to the materials found in the cabins. None have been reported in submarines (Schaefer, K. E., personal communication).

3. Agree. This should be a high priority item as part of OART effort.

4 and 5. Agree. Especially synergism with hyperoxic environments and drugs in high priority, ground-based studies (see comments on drugs in Chapter 18). Such studies should be considered of basic science type and can be performed in ground-based laboratories.

6. The alteration of toxicity by concentration of particles requires study. This basic science effort should be given a moderate priority.

14. Particulate Matter (Aerosols) (Chapter 16)

General

Agree with discussion.

Recommendations

1, 2, 4, 5. Agree. Basic science type of research with moderate to low priority requiring zero gravity simulation.. Little effect on current programs.

3. If similar filters are not available, programmatic research of high priority - ground-based.

6. Very low priority, basic research.

15. Infection (Chapter 17)

General

The discussion of this chapter overlooks many of the practical realities of day-to-day operation. Selection of crews for cross-match compatability may be a long range goal. Isolation of crews before takeoff for infection control appears quite impractical.

Recommendation

1. If a blood transfusion capability is present in a mission, much care should be taken to get compatible crews. The value of other immunological compatability appears remote.

2. Impractical at first glance; timing and scheduling should be considered as should socio-psychological aspects.

3-6. Appear to be long range basic science efforts of moderate priority.

7. This should have higher priority and requires both ground-based and flight study.

16. Respiratory Drugs and Manned Spaceflights (Chapter 18)

General

Alteration of drug response in space cabin environments has received little or no experimental study. Recent data indicate, for example, that the antibiotic, tetracyline, will kill mice at 5 psia 100% O_2 at therapeutic doses which give no lethality at sea level conditions. All drugs to be considered for space use should be tested for such synergisms with the atmosphere. The review of Busby should be consulted (Busby, D. E., Clinical Space Medicine - A Prospective Look at Medical Problems from Hazards of Space Operations, 1967).

Recommendations

1 and 2. For long range missions, these should be given high priority. Relatively little group thought has been given to the problem of drug selection for the space environment. This is especially important for future missions where emergency treatment of astronauts for medical and surgical emergencies is required. Alteration of the gaseous environment should be a more significant factor than adaptive changes to weightlessness in altering drug effects.

Summary of Bioinstrumentation

1. It seems that several methods of dry spirometry are already available for easy conversion to space use.

2. These appear to be of second-order importance to current programs. Calibration with chest wall movement appears the simplest approach.

3. Many such devices have been used in ground-based studies. Flyable hardware may be available from Sandia Corporation or USAF SWC Lab, Kirtland AFB, New Mexico, where upper air sampling in aircraft and rockets is a prime mission. The Inhalation of Fallout group at the Lovelace Foundation or the University of Rochester AEC group may be of help. Such work should be considered basic science with only moderate priority.

4. Recent studies by the U. S. Navy suggest that chromatographs tied to omegatron mass spectrographs or a double resonance microwave spectrographs would be best for screening such contaminants. Production of flyable hardware for continuous monitoring may be a

long range goal, but should have low priority in current programs. For retrospective analysis, materials obtained from cold traps should be adequate. The current Parkin-Elmer sensor should be adequate for simultaneous O_2-CO_2 and water vapour. The large spectrographic samplers used for screening would probably be too unreliable as primary atmospheric sensors.

5. Peripheral vascular control in the periphery should be a high priority element in the basic science program. Impedance plethysmography along with the techniques of Mellander, Oberg, and Folkow in Goteborg, Sweden, appears to be the best approach to the problem.

6. This technique has been difficult enough in ground-based studies to warrant low priority for measurement in space. Value of such data for practical programmatic use are distinctly limited.

7. Suggestions for this program have been outlined (Roth, E. M., Space-Cabin Atmospheres. Part II. Fire and Blast Hazards, NASA SP-48, 1964) but require engineering followup. This program should be based on ground and zero g simulator studies. Highest priority should be given to the effort.

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