BIOMEDICAL ENGINEERING AND SPACE MEDICINE

S.P. VINOGRAD, M.D.

As the manned space flight program continues to expand in scope and complexity, its requirements for newer & more sophisticated techniques also continue to grow. The increasingly ambitious tasks undertaken and successfully accomplished in Mercury then Gemini to Apollo has been due to a continuing technological advancement, which was largely stimulated by the requirements of each of these space flight programs. The projected flight programs of the future, the Apollo Applications program and beyond, will pose even larger challenges to the technology of today. This is as true of Space Medicine as it is of any of the diverse scientific disciplines on which Manned Space flight depends. Indeed, its rate of growth may be even greater than many as increasing emphasis is placed upon medical issues as our space program advances. If it is true that necessity is the mother of invention, then the future should hold great advancements in store for us in Space Medicine because the requirements are there, and we know many of them now, as I shall attempt to relate. These requirements are the challenge of the future in Space Medicine. This challenge can only be met by the the joint activity of disciplines of the physical sciences as well as the biological sciences, a fundamental concept is well embodied in the relatively young and most essential field of Biomedical Engineering.

During the Mercury program our medical effort was largely confined to the monitorship of the safety of the astronauts. While pre space flight medical evaluation and in-flight medical monitoring were carried out with thoroughness & competency, as Mercury was our first space flight test program, of necessity employing engineering and operational evaluation, allowing little room for medical investigational activities. At the same time, we learned a great deal from it. It served to separate fact from apprehension about the effects of space flight on man, enabling us to venture into the Gemini program with significantly greater confidence. Yet, many questions remained to be answered. The great variable then & still is was the duration of flight with respect to human effect. With the advent of Gemini, our medical effort was considerably expanded. Added to an augmented medical personnel effort was, for the first time, an organized program of inflight medical experiments designed to yield more fundamental information on human responses and their trends to the environmental characteristics of space flight. This program of inflight medical experiments is a continuing and growing one whose principal investigators are members of the scientific community from without as well as within NASA. Its two basic categories of objectives are to learn man's responses and supportive requirements in space, and to carry out medical research in which the unique elements of the space environment, such as weightlessness, might be advantageously utilized.

A discussion of this program ~~as~~ carried out in Gemini & as planned in Apollo and Apollo Applications may serve to elucidate the requirements of Space Medicine from the point of view of Biomedical Engineering. From the eight Gemini medical experiments & operational procedures we were able to obtain data on the cardio-vascular & musculoskeletal, endocrine & metabolic systems, on blood & blood volume, fluid & electrolyte balance, & on ~~sleep~~ depth of sleep. ~~That the specific results of these studies have been reported~~

Experiment M001, the Cardiovascular Conditioning Experiment, was the evaluation of a counter-measure against cardio-vascular deconditioning as observed by tilt table & other procedures. The method involved the wearing of a pneumatic cuff about each thigh. The cuffs were alternately inflated and deflated in regular cycles, 2 minutes on & 4 minutes off throughout the entire flight. The technique was applied to one flight crew member in Gemini V & Gemini VII, ~~though~~ his partner serving as the control in each case. The method was demonstrated

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To be effective in bed rest & water immersion studies exerting its effect, according to concensus, by reducing the rate of blood volume redistribution and by exercising the walls of the veins of the lower extremities. In flight the automatic programmer was found to be excessively noisy & the apparatus excessively confining for use in ~~flight~~ ~~later~~ future vehicles allowing freedom of movement. ~~Although~~ The experiment was flown successfully only in Gemini VII but the data failed to show evidence that the ~~[illegible]~~ technique was at all effective. ~~[illegible]~~ ~~[illegible]~~. All factors considered, ~~[illegible]~~ other more promising methods will be evaluated ~~[illegible]~~ for their effectiveness as cardiovascular countermeasures in place of this one in the foreseeable future.

Pre- and post-flight tilt table responses were evaluated in all Gemini missions except Gemini VIII. The tilt table ~~[illegible]~~ test ~~which enables~~ consists of the evaluation of cardiovascular response to a fixed stimulus, that of the passive ~~positioning~~ placement of the body in the upright position. As compared with Mercury, in Gemini the period of passive tilt was expanded from five to 15 min., the Flack test (a calibrated Valsalva maneuver during tilt) was eliminated, and the tilt board was fitted with a saddle-like seat. With the use of the saddle the subject does not use his legs for support & ~~[illegible]~~ thus small assistance given venous return is eliminated, rendering the test more sensitive. The Gemini tilt responses have been presented in detail in detail in several reports. In summary, the Gemini V (8 day flight), flight crew responses were more pronounced and of greater duration than the Gemini IV (4 day flight) crew. A surprisingly well defined trend of tilt table response degradation as flight duration increased was disrupted with ~~[illegible]~~ the Gemini VII ~~14 day flight~~ findings. At the end of this 14 day flight one crew member showed less ~~[illegible]~~ change than any of his predecessors, the duration of which was comparable to the 4 day flight crew findings. The other showed ~~[illegible]~~ an exaggerated (pre-expressed) ~~immediate~~ post-flight response, but with a quick return to pre-flight levels comparable to that of his partner. This seeming paradox is, perhaps, best explained by the blood volume data.

¶ → In Apollo, ~~[illegible]~~ the tilt table technique will be replaced pre- & post-flight by one which accomplishes the same purpose by employing ~~a new test which employs~~ negative pressure applied to the lower half of the body. Physiologists working with this technique feel that the data obtained is both more accurate & more reproducible. This method offers the additional important advantage that it can be utilized in space since it is not gravity dependent as is the tilt table. Indeed, present plans call for the use of LBNP ~~[illegible] This test will be~~ (lower body neg. press.) in space during the Apollo Applications Program.

Pre- & post-flight plasma volume, red cell mass, & blood volume evaluations ~~were~~ carried out in Gemini IV, V, & VII. Plasma volume was directly measured using I^{125} labeled RHISA. Red cell mass measurements were carried out using Cr^{51} tagging. ~~[illegible]~~ Total circulating blood volume was calculated as the sum of the two. Red cell mass losses were of the order of 12% in both crew members of Gemini IV, & 20% in both crew members of Gemini ~~[illegible]~~ V. In Gemini VII, one astronaut showed a red cell mass loss of 19% while the other showed only a 7% drop. Plasma losses were slight and varied only slightly among the flight crews of Gemini IV and V. The Gemini VII crew, however, showed an actual increase in plasma volume. In each case, furthermore, this increase compensated almost exactly for the decrease in red cell mass so that the circulating blood volume was for the first time essentially unchanged. This was ~~[illegible]~~ very probably the reason for the relatively short duration of the tilt table response changes in the Gemini VII flight crew & for the less pronounced change in the one crew member. This marked difference between —— etc COPY TO END of ¶ p 7.

Associated measurements of red cell life span, ~~[illegible]~~ red cell indices, red cell fragility, & spleen - liver ratios all point to an increased destruction as being the primary ~~cause~~ mechanism of this ~~[illegible]~~ reduction. The cause appears to be traceable chiefly to the high O_2 environment, altho relative inactivity & perhaps WTL are not ruled out as potential contributing factor.

Another highly interesting & perhaps significant factor brought out by these data was the presence of dehydration in the Gemini VII crew as in all of our flight crews, but in this instance with concomitant evidence of hemodilution rather than hemoconcentration.

The continued pursuit of this important investigational effort is planned for Apollo and AAP. During the longer AAP missions the continuance of these studies on an in-flight basis will very probably be indicated. The means by which this can be done safely, accurately and easily have yet to be worked out.

Experiment M003, Inflight Exercise, was another cardiovascular provocative test utilizing a fixed amount of exercise as the in-flight stimulus. The method employed was a simple one which had been used in Mercury, the bungee cord exerciser. It required a pull of 70# and its stretch was limited to one foot by a restraining cable. The work accomplished per stretch was, therefore, 70 foot pounds. Exercise periods were pre-programmed at one pull per second for 30 seconds. Heart rate, blood pressure,

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and respiratory responses were recorded and response changes were sought as a function of duration of flight. In Gemini, the exercise prescribed was insufficient to reveal significant changes, but some studies. Although this can be remedied, inaccuracies due to continued exertion after the limit of the restraint cable is reached, and the problem of insufficient exercise due to inadequate activity of the larger thigh muscles cannot. We are, therefore, seeking accurate whole body exercise techniques although one AF development planned for flight aboard an early AAP appears promising.

Experiment M004, the Phono-electrocardiogram experiment consisted of the simultaneous recording of the phonocardiogram and electrocardiogram to record the timing of systole. Measurement of electro-mechanical delay, ventricular ejection time, period of systole, & period of diastole by this method have shown no changes ascribed to space flight to date. The equipment functioned well & the data were as accurate & reliable as those obtained from ground based studies. However, more sensitive techniques for determining the important elements of cardio-vascular function, with minimal encumbrance, continue to be required.

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~~Techniques which are informative, [illegible], reproducible, and non-invasive~~

For example there are no ~~methods~~ currently available non-invasive methods for determining with sufficient accuracy cardiac output or central venous pressure, flow or volume. Although there are a few newer methods which may hold some promise for these and several other problem areas, it would seem that ~~with the rapid development of the field of physics~~ somewhere in the rapidly ~~growing~~ advancing field of physics lies a principle or technique which might find successful application. ~~It is recognized [illegible] might also could be successfully applied to [illegible] those that there are different problems~~ The need exists in clinical as well as space medicine.

~~M005~~ Experiment M005 was the analysis of body fluids for biochemical, ~~endocrine~~ electrolyte, and endocrine elements. In addition to the evaluation of pre- & post flight blood and urine samples, aliquots of urine were collected in flight and preserved for post-flight analysis. The problem here was to develop a satisfactory means of determining urinary output in flight, a seemingly ~~After studied~~ simple problem which, because of the factor of weightlessness, ~~is~~ was most resistant to satisfactory solution. The method finally employed was a concentration-dilution method in which ~~[illegible]~~ a fixed amount of tritiated water was injected into the collection bag at the completion of micturition. This was mixed with the urine by manual manipulation of the bag and a [illegible] sample was squeezed from the ~~mixing~~ collection bag through a valve into a plastic sample bag which held approximately 75 cc. The remainder of the urine was expelled from the spacecraft. The concentration of tritium in the sample was determined post-flight and the urinary output was calculated. This technique was quite accurate on the ground but in weightless flight, alteration of ~~mixing~~ characteristics ~~are altered and accuracy can be~~ compromised accuracy, in some flights very ~~markedly compromised~~ markedly. Fortunately, in Gemini VII errors were small enough to be ~~essentially~~ correctable within reason by assuming a constant output of creatinine. Flight findings will, nevertheless, require confirmation. ~~Current developmental efforts~~ Present equipment development employs a centrifuge to separate the liquid from the inevitable gas phase, and a mechanical liquid flow meter. ~~Improvements~~ Virtual ~~automatic~~ automaticity is an important factor in this device since the time necessary to complete a [illegible] given task in space is [illegible] significantly greater than on earth.

~~M05~~

Experiment M006 was the measurement of bone density pre- and post flight by a special X Ray densitometric technique developed by the principal investigator. [illegible] Moderate decreases of bone density were seen in the non-weight bearing of the hand as well as the weight bearing bones of the ankle & heel. The technique utilizes standard X Ray equipment and a metal wedge densitometer. The X Ray films are read with a photo scanning apparatus. ~~Current developments may soon make it possible to work out~~ Before long a direct reading technique using radio-isotopes may be available for serial densitometric determinations in space.

Experiment M007 was the mineral balance study, a carefully controlled intake and output study to determine changes in the mobilization & metabolism of calcium and other minerals during space flight. The experiment was diligently carried out on Gemini VII by the principal investigator, astronauts, and dedicated ancillary personnel. The protocol required a 10 day preflight and 2 day post-flight period as well as the flight phase itself. Since the same urine samples were used for this as for the M005 experiment the same inaccuracies prevailed. These were correctable on a 24 hour output basis using creatinine output as a basis. The experiment showed a mildly negative calcium balance ~~in flight~~ and a more pronounced negative phosphorus and nitrogen balance in flight. Repetition of the study is planned for the Apollo Applications Program.

Experiment M008 was the analysis of sleep in flight by means of the electroencephalogram. Observations were made on one astronaut on Gemini VII. Whereas the experiment was intended to span a period of 4 days, electrode displacement and lead wire entanglement during sleep caused termination of observations at the end of 52 ~~hours~~. While the experiment ~~established the~~ demonstrated the four stages of sleep and established the feasibility of use of the EEG under operational conditions it also ~~[illegible]~~ emphasized the need for improved, less encumbering, quick don & doff electrodes, an additional challenge, albeit not a new one, for the biomedical engineering field.

Experiment M009 was the evaluation of otolith function by means of two measurement techniques. Pre- and post-flight determinations of ocular counter-rolling were accomplished by tilting the astronaut very precisely to the side while taking a series of still pictures of the eye. The degree of counter-rolling of the eye, a function relatable to otolith integrity was ~~[illegible]~~ very carefully measured from the pictures using natural features of the iris as landmarks. The in-flight evaluation consisted of measurements of the ability of the astronaut to approximate the horizontal axis of the spacecraft by manipulating

~~an~~ a rotatable illuminated white line in a goggle which blocked all vision except for the white line. Calibrations on the knurled screw which rotated the line were read by the other flight crew member and recorded. No significant changes in otolith function were noted in either of the two flight crews measured, the ~~astronauts~~ crew of Gemini V or Gemini VII. This investigation will be continued and semicircular canal ~~[illegible]~~ study will be initiated during the AAP program according to present plans.

~~The Apollo program of medical experiments will consist essentially of gathering complementary pre- and post-flight data. ~~Since~~ Apollo flight durations will not exceed the maximum duration Gemini flight. and since the AAP program, which offers a much greater opportunity for the gathering of medical data, is relatively close at hand~~

~~Turning to the Apollo program, flight durations will not exceed~~

The Apollo program of medical experiments will consist essentially of gathering complementary pre- and post-flight data since Apollo flight durations will not exceed the maximum duration Gemini flight. Pre- and post-flight tilt table studies will

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be replaced at some point by LBNP evaluations; pre- and post-flight immunological studies and lymphocyte karyotyping will be added; and the inflatable cuff technique will be replaced by the evaluation of ~~a lower body~~ an anti-deconditioning elastic garment ~~pulled~~ worn over the lower portion of the body. ~~prior to post flight tilt table or LBNP studies~~

~~The AAP program will emphasize~~

Certainly the greatest opportunity as well as the greatest challenge to space medicine thus far is in the AAP program. This ~~program~~ series of flights will utilize Apollo equipment and technology to accomplish longer and more complex orbital missions and extended lunar exploration. ~~with~~ Its primary purpose is scientific gain ~~as its primary purpose~~.

By means of the cluster technique, the third stage of the Saturn launch vehicle, the S IV B will ~~after suitable [illegible]~~ be utilized as a habitable space craft. It's volume measures approximately 20 ft. in diameter by 30 feet in length for a total of 10,000 cubic feet of available space. By means of a multiple docking adapter which will be transported into orbit by one Apollo launch in place of its lunar module the command module will dock with the S IV B. The multiple docking adapter will also carry the environmental control system and equipment for the S IV B. The gaseous atmosphere provided will be a 5 psi two gas system of 69% O_2 and 31% N_2. Flight durations of up to 30 and 60 days, are now planned for attainment early in the program. At its completion we hope to have incrementally attained flight durations of up to one year.

From the medical point of view, planning for the 30 and 60 day missions includes all of the investigational efforts begun in Gemini and Apollo utilizing improved methods & techniques. Additional investigations presently planned for these flights are the evaluation of metabolic requirements, respiratory function, semicircular canal function, and task performance in space as compared with the earth. Habitability evaluations will be given strong emphasis as flights become progressively longer. Technique and equipment improvements will be made, such as development of a bicycle ergometer for flight, an accurate & flyable gas chromatograph for measuring respired oxygen, carbon dioxide, and water vapor.

As flights continue to expand ~~[illegible]~~ into longer periods of time a flight medical laboratory, the development of which is now being initiated will be flown. This laboratory, ~~which is~~ an integrated medical & behavioral laboratory measurement system, ~~is being~~ will be designed in modular form to provide maximum flexibility. This ~~technique~~ attribute will ~~[illegible]~~ ~~[illegible]~~ facilitate the ~~[illegible]~~ replacement of older techniques with new and improved ones, and the rapid switching of experiments ~~from~~ as required by late ~~of~~ flight information thus obviating the very long lead time requirements of the past. ~~Some of the capabilities which will be demonstrated by this system do not yet exist. Almost all of them~~

~~It Its major components will consist of [illegible] physiology, [illegible] behavioral, [illegible]~~

Its major ~~capabilities~~ components capabilities will consist of physiology, behavioral, study microbiology, biochemistry and data management. ~~[illegible]~~.

Each of these areas carries with it a ~~[illegible]~~ series of opportunities and ~~challenges~~ requirements for advancement of the state of the art to decrease ~~[illegible]~~ volume, weight, & power requirements; obviate the need for liquid chemical reagents; ~~and~~ constantly improve sensitivity, accuracy, reproducibility, & ease & speed of performance; and augment the versatility of equipment & procedures. ~~commonality of equipment by expanding [illegible] the diversity & versatility of~~

The field of biomedical engineering, like any worthy field of endeavor, had its origin in ~~challenge~~ necessity and is sustained by challenge. ~~From this discussion~~ While the discussion has been limited to space medicine, there is ample ~~[illegible]~~ evidence that the challenge exists in all forms of medicine. To meet it requires ~~the~~ an ~~kind of~~ interdisciplinary ~~activity~~ approach, the kind of foresighted approach represented by this organization.

SPACE MEDICINE

INTRODUCTION

S. P. VINOGRAD, M. D.

(Fig 1) As Mr. Johnston indicated in his presentation, the effort of the Crew Systems Division supports the requirements of both OART and OMSF in the life support systems area. The balance of the Space Medicine review is concerned with our activities in in-flight medical experiments, the medical support of manned space flight, and the problem of back contamination. It should be noted that the responsibilities of Space Medicine for the most part are concerned with activities which are associated with operational situations, and are primarily related to the approved manned space flight programs.

(Fig 2) Under the organizational plan of the Office of Manned Space Flight, the functional activities in which Space Medicine participates are now included in the responsibilities of major program offices, such as Apollo, Apollo Applications, Advanced Missions, and Mission Operations. This concept was established approximately three years ago, at which time it was determined that Space Medicine could accomplish its responsibilities most effectively in the role of a staff office rather than a program office. The functions assigned to it under this definition are shown in the next figure. (Fig 3)

To facilitate its support and advisory functions, specific individuals of the Space Medicine staff are assigned to each of the major OMSF program offices: Mission Operations, Advanced Manned Missions, Apollo Applications, and Apollo. (Fig 4)

The aspects of the programs of these offices which deal with medical and biomedical matters are carried on primarily at the Manned Spacecraft Center by the Crew Systems Division and the Directorate of Medical Research and Operations. (Fig 1) Mr. Johnston has already presented the Crew Systems Division activities related to Space Medicine. My presentation will be concerned with the in-flight medical experiments program. I will be followed by Dr. Berry who will discuss his Medical Research and Operations activities in the manned space flight program. The final presentation, by Colonel Pickering, will cover a special responsibility of the Space Medicine Division -- Back Contamination.

ADMINISTRATOR'S LIFE SCIENCES REVIEW

MEDICAL EXPERIMENTS

S. P. VINOGRAD, M.D.

In our presentation of last year, we indicated that the medical experiments program encompasses two major channels of activity. (Fig 1) One is concerned with the definition and development of the flight medical experiments themselves. This activity consists of the encouragement of proposals for medical experiments from the scientific community, their receipt, evaluation, and sponsorship, their implementation in flight, subsequent post-flight analysis, and finally, with the application of the resultant data to manned space flight, to the medical experiments program, and to the broad field of medicine. Proposals for medical experiments are evaluated for scientific merit by the NIH study section system and, following this, by Space Medicine's Medical Advisory Council. (Fig 2) The second major channel of activity of the medical experiments program is the associated research and development effort which had its origin in several NASA in-house and NASA sponsored studies. These studies resulted in the identification of a series of desired medical and behavioral measurements which were classified into eight areas of medical evaluation. (Fig 3) We pointed out last year that the primary thrust of the R&D program was to be the development of a flight medical laboratory system to accommodate proposed and yet to be proposed flight medical experiments of the scientific community. This slide is an illustration of the Phase A portion of the development of a flight medical laboratory which was completed by Lockheed in February 1966. (Fig 4) Parallel R&D efforts were to be directed toward the development, test, and evaluation of new laboratory techniques and equipment better suited to our flight laboratory concept and programmatic requirements than those currently available. Additional emphasis was given the gathering of essential ground-based data, in particular, data derived from simulations.

Although funding for the development of individual MSFEB approved flight experiments had been available as a part of the Gemini and Apollo programs, funding of the integrated medical experiments program, itself, was first obtained in March 1966 as a part of the Advanced Manned Missions program. Since that time, we have been engaged in implementing as well as continuing to refine our plans for a coherent program. I would like to describe our progress this past year in terms of these two major channels of activity, the experiments, and the research and development effort, and to relate these to the eight areas of medical evaluation presently guiding our programmatic efforts. This slide summarizes the program within this context. (Fig 5)

Looking first at the medical experiments activity, the experiments approved for the Apollo program include the repetition of those which have been completed in Gemini. The additional experiments listed under Apollo are in the direction of a greater breadth and depth of investigation of the same areas of medical evaluation plus the addition of the evaluation of microbiological changes. Although these experiments have been approved for the Apollo program, several of them may be postponed until the AAP program owing to Apollo schedule changes presently under consideration.

In the development phase for the AAP program are six experiments, (Fig 6) three of which (M050, M051, and M052) are governing protocols. These are the metabolic, cardiovascular, and bone and muscle evaluations, respectively. Experiment M053 is a more advanced vestibular evaluation which will include the study of semicircular canal responses as well as a broader approach to otolith evaluation. Experiment M018 is the evaluation of electrocardiographic changes utilizing Frank lead system electrocardiography to obtain clinically comparable ECGs. Experiment M055 is a time and motion study which will consist of the analysis of motor task performance requirements in space as compared with the earth environment. In addition to these six, four more are shortly to be considered by the MSFEB. These include a more sophisticated EEG sleep evaluation experiment and three Air Force MOL related experiments to evaluate (1) a technique for determining specimen mass, (2) a technique for determining human body mass in space flight, and (3) to evaluate the effect on body conditioning of utilizing a whole body exercise device.

Of particular interest in these six experiments is the hematology investigation included within the M051 governing protocol. The work of Dr. Philip Johnson of Baylor University Medical School, Dr. Charles Mengel of Ohio State University Medical School, and Dr. David Turner of the University of Toronto is a continuation of the hematological effort begun in Gemini. This exploration of the effects of a high oxygen environment on the metabolism of the red cell membrane may result in an important scientific contribution of our space effort to clinical medicine.

In addition to the AAP medical experiments, we are now sponsoring two experiments in the definition phase. (Fig 7) These are the work of Dr. John Lawrence and Dr. Harry Winchell of the University of California in the utilization of isotope tagged carbon monoxide as an indicator of hemoglobin formation and breakdown; and the work of Dr. Donald Nelson of the Latter Day Saints Hospital, University of Utah, who is developing a new technique for the determination of parathyroid activity by means of urinary assay. Two additional experiments are currently being considered for sponsorship for the definition phase. These are a study of ballistocardiography in the weightless environment of space as compared with earth G, and the evaluation of gastric function by endoradiosonde.

In the past year, at our request, the NIH study sections have reviewed 15 proposed space flight medical experiments. These reviews have been carried out conscientiously and with outstanding competence by the study sections, their chairmen, and their members. NIH's Division of Research Grants, who maintains responsibility for the operation of the study section system, has been extremely cooperative, evidencing, itself, and encouraging within the study sections a desire to be of genuine assistance to NASA in this effort. This interagency relationship has been both productive and gratifying.

The Medical Advisory Council (Fig 8) has continued to meet at two-monthly intervals. They have completed their evaluations of 24 experiment proposals, have requested and accomplished one site visit, and have considered and made recommendations on numerous related professional issues and questions about the program which have required their attention. They have evaluated and made constructive recommendations on all of the proposed experiments processed by the NIH study sections as well as those which had been proposed prior to the establishment of the NIH relationship. In addition, they have made themselves available individually as consultants to MSC on specific technical problems as these have arisen.

Within the medical experiments area, coordination with the Air Force has been close as evidenced by the following three points. First, two medical meetings with Air Force medical principals were held within the past year. During these meetings, the two medical experiments programs were fully discussed and coordinated. Secondly, as a result of these meetings, a continuing coordinating mechanism was established in which two named Air Force medical representatives are present at all NASA MAC meetings, and two specific NASA medical representatives are to be in attendance at all counterpart Air Force meetings. Thirdly, Air Force MOL medical experiments proposed for inclusion on NASA manned space flights are, with Air Force approval, sent through NASA

Space Medicine as the sponsoring office to permit better coordination of the two programs.

Turning now to the research and development effort of the medical experiments program, we have, as you know, completed a Source Evaluation Board activity for Phase B of the development of an Integrated Medical and Behavioral Laboratory Measurement System. Two companies (GE and Lockheed) were selected and Phase B is now in progress. This over-all effort is designed with two major objectives in view: The first is to develop a flight laboratory to accommodate proposed medical and behavioral experiments, and the second is to incorporate into this system a maximum degree of flexibility. The manifold advantages of such a system have been pointed out in previous discussions. This effort together with parallel R&D efforts now in being, how procured, whether contract or grant, and where monitored are shown on this slide. (Fig 9)

As indicated in our report of last year, much of this contractual effort was initiated in Headquarters in partnership with cognizant MSC areas because of personnel shortages existing within that facility in the medical areas. All of these contracts and grants either are now or will be transferred to MSC by specific schedules within the next few months. All of these parallel efforts are directed toward the development of methods and techniques which will be utilizable at some point in time within the flight medical laboratory to improve its capability in terms of breadth, depth, or accuracy of investigative capability.

Our program outline is shown on this slide. (Fig 10) It includes four major categories: sponsorship of experiments, the flight laboratory (IMBLMS) effort, ground-based R&D efforts, and operational support for the experiments.

This next fiscal year in the experiments area we plan to continue and expand our present experiment support program. We are now planning a second meeting with top-notch investigators of the scientific community to encourage their participation in the program. At the same time, we are seeking new means to accomplish this objective on a more continuing basis. We are also planning to initiate preparations for the development of medical experiment packages for future AAP flights beyond the continuing development of the 10 experiments for the AAP 1-4 flights.

In the research and development area, our plans include the completion of Phase B and initiation of the design Phase C of the IMBLMS effort, continuation into the design, test, and evaluation phases of soon to be completed study efforts, and, in the area of obtaining ground-based data, the accomplishment of a full scale AAP 1-4 flight simulation.

Hx → 8 Areas

Program — 2 Parts

Review System

Exptl — Slides + Res./Dev. + Funding

WEIGHTLESSNESS AND MANNED SPACE FLIGHT, MEDICAL DATA TO DATE

INSTITUTE OF ENVIRONMENTAL SCIENCES

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The question of weightlessness as it affects man has received considerable attention since the first announcement of our intention to send man into space. First speculations covered a very broad spectrum, and many of them have since proven to be considerably wide of the mark in terms of our actual experience thus far. Others have been shown to be appropriate, although in general the anticipated rates of change have been overestimated. With respect to the physiological changes which have so far been demonstrated, two points merit emphasis. First, the exact etiological relationship of weightlessness to these findings has not yet been firmly established; and, secondly, to date, these changes have not been associated with overt symptomatology.

Because it was our first space flight test program, Project Mercury heavily emphasized the engineering and operational aspects of space flight. Although medical evaluation and monitoring was quite thorough from the operational point of view, little in the way of medical investigation or experiments could be accommodated at that time. Yet, despite this shortcoming the Mercury Program did serve to advance to a considerable extent our concepts of the effects of space flight on man. In effect, it served as a kind of course focus on the actual problems with which we might expect to be confronted, separating the real from the grossly unreal and placing the quantitative aspects of the broad question in perspective.

During Mercury, the most notable changes observed were an orthostatic hypotension for a few hours after MA-8, altered tilt-table responses after MA-9, dehydration on all flights, and, in a few instances, minor cardiac arrhythmias. The arrhythmias consisted of occasionally observed ectopic beats, and moderate tachycardia at critical points in the flight missions. There were no evidences of vestibular change, gastrointestinal disturbance, genito-urinary disturbance, nor any form of hallucinatory phenomenon. During the entire Mercury Program, our astronauts performed to their normal standards throughout their missions and experienced no overt symptoms of the few changes which were observed.

The Gemini Program was medically considerably expanded. It included an organized program of in-flight medical experiments and an augmented program of medical operational procedures. In the medical experiments program, members of the scientific community outside of NASA as well as within directly participate as principal investigators. Although the program of in-flight medical experiments was introduced in Gemini, it is a continuing program whose general objectives are to learn man's responses and supportive requirements in space and to carry out medical research in which the unique characteristics of the space environment might be advantageously utilized.

During the Gemini Program, a series of eight in-flight medical experiments were flown, several of them more than once. From these experiments and from the operational medical procedures, we were able to obtain data on cardiovascular function, the musculoskeletal system, blood and blood volume, fluid and electrolyte balance, endocrine activity, sleep, and vestibular functions.

Experiment M001, the Cardiovascular Conditioning Experiment, was the evaluation of a countermeasure against cardiovascular deconditioning as observed by the tilt table and other procedures. Its principal investigator was Dr. Lawrence F. Dietlein of the NASA Manned Spacecraft Center in Houston. It consisted of the regularly cycled intermittent inflation and deflation of pneumatic cuffs placed around the thighs. The cuffs, which 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 experiment was flown on Gemini V, the eight-day flight, and Gemini VII, the fourteen-day flight. The method was 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 Graveline used an inflation pressure of 50 mm of mercury applied alternately one minute on and one minute off throughout the period of immersion, the procedure as used in Gemini applied a pressure of 80 mm of mercury two minutes on and four minutes off throughout the flights. The technique is considered to mediate its effects 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 vascular tone. On Gemini V, due to technical problems, the oxygen supply required to inflate the cuffs was depleted after four days of flight. Consequently, the equipment was changed for Gemini VII so that it operated from the cabin oxygen supply system rather than its own source. The apparatus functioned well throughout the entire Gemini VII flight. Although ground-based studies utilizing the same procedure and equipment on water immersion subjects clearly demonstrated its effectiveness, space flight test data failed to confirm these findings, as will be seen on review of the Gemini tilt table response data.

Pre- and post-flight tilt table studies were accomplished on all Gemini missions with the exception of Gemini VIII, the aborted flight of Armstrong and Scott. The tilt table study is a provocative test designed to bring out incipient changes in cardiovascular responsiveness. A series of these tests were carried out 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 was extended from five to fifteen minutes, the tilt board was fitted with a saddle-like seat, and the use of the Flack test (a calibrated Valsalva maneuver) during tilt was eliminated. With the use of the saddle table, the subject does not use his legs for his support during the tilt. Recent studies have indicated that this measure renders the test perceptibly more sensitive by preventing the assistance given venous return by even this minimal activity of the lower extremities.

The characteristic responses to passive tilt include an elevation of heart rate and a narrowing of pulse pressure with a drop in systolic pressure and frequently a slight rise in diastolic pressure. Both the extent of these changes and their persistence on repeated testing are influenced by a great many circumstances even under earth-bound conditions. However, the amount of data we now have from the multiple tests of each individual and from the study of almost all of the Gemini astronauts seems to lend some credence to the immergence of a still somewhat tentative curve of responses correlatable to duration of flight.

The tilt table response changes following the eight-day Gemini V flight were slightly more pronounced than those seen following the four-day Gemini IV. However, the time to return to pre-flight levels was approximately fourty-eight hours in Gemini V as compared with twenty-four hours in Gemini IV. Of the two Gemini V astronauts, the pilot, who wore the experiment M001 thigh cuffs for the first four days of flight, did show a slightly less pronounced post-flight tilt table effect, although this was well within the range of individual variability. Following Gemini VII, the astronaut who did not wear the cuffs showed a less pronounced change of tilt table response than any of the Gemini IV or V astronauts. The Gemini VII astronaut who did wear the M001 cuffs showed a very marked alteration of response to his first post-flight tilt, which required this interruption of the procedure at eleven minutes in order to prevent syncope. However, both of the Gemini VII astronauts returned to their pre-flight tilt response levels at the end of only twenty-four hours. These changes correlate well with the blood volume changes.

Plasma volume, red cell mass, and blood volume measurements were carried out on the 4-, 8-, and 14-day flights (Gemini IV, V, and VII, respectively). On Gemini IV, only plasma volume and peripheral hematocrits were directly measured while red cell mass was calculated. Plasma volume measurements employed the RHISA technique with iodine 125. Direct measurement of red cell mass utilizing the chromium 51 technique was added on both Gemini V and Gemini VII. Total blood volume was calculated as the sum of plasma volume and red cell mass. Following flight, the red cell mass was decreased in all flight crew members. In one Gemini VII astronaut, this reduction measured only 7%. In the remaining five astronauts, red cell mass decreases ranged from 12 to 20 per cent. With the exception indicated, the least change was observed in the four-day Gemini IV flight crew. Those observed in the eight-day Gemini V flight crew were approximately 75% greater. The remaining 14-day Gemini VII crewman showed a decrease equivalent to the Gemini V crew.

Plasma volume decreases were observed in the four- and eight-day flight crews. Of these four astronauts, the Gemini IV pilot, who experienced extravehicular activity and who, as a consequence, was subject to a significantly greater thermal stress, showed the greatest decrease of plasma volume. The plasma volume decreases in the remaining three Gemini IV and V astronauts were not significantly different from each other. Total blood volume calculations in both Gemini IV and Gemini V flight crews, then, showed a reduction of total blood volume in all four astronauts which was greater in the eight-day than the four-day crew with the notable exception of the Gemini IV EVA astronaut.

On turning to the plasma volume data from Gemini VII, we note an entirely different picture. Here for the first time we saw an increase of plasma volume in both astronauts. Furthermore, in both individuals, this increase compensated almost exactly for the decreased red cell mass so that the total blood volume in both astronauts showed essentially no change. This marked difference between the 14-day flight and the two earlier flights can be explained either as a compensatory response which took place as the duration of flight was extended, or as a reflection of differences in some of the environmental factors associated with the Gemini VII flight. Most notably, the Gemini VII flight crew did not wear their pressure suits during most of their orbital flight, thereby reducing significantly the thermal stresses to which they were exposed. In addition, the Gemini VII flight crew exercised more vigorously and more frequently, drank larger quantities of water, and consumed greater amounts of food.

Associated with the blood volume studies were studies of the red cells themselves. Mean corpuscular volume was noted to increase as did red cell fragility. Spleen-liver ratios were also measured, and although an increase was seen, its significance is equivocable. Reticulocyte responses post-flight were also increased. These findings would tend to indicate that the red cell mass decrease appears to be due, in large part, to an increased red cell destruction. Based on ground-based studies, this is probably due primarily to the high oxygen environment with, perhaps, relative inactivity being a contributing factor.

All of our Gemini flight crews showed evidence of dehydration following flight as indicated by the very rapid regaining of post-flight weight losses with the drinking of water. In the Gemini VII flight crew, the presence of dehydration concomitantly with a normal blood volume and hemodilution, rather than hemoconcentration, is of particular interest, since it places the site of water loss in the tissues.

These tilt table, blood volume, hematology, and clinical data were obtained under the direction of Dr. Charles A. Berry, Director, Biomedical Research and Operations, NASA Manned Spacecraft Center in Houston. The blood volume and hematology studies are a team effort whose members include Dr. Craig Fischer, NASA Manned Spacecraft Center, Houston; Dr. Phillip Johnson, Baylor University College of Medicine; and Dr. Charles Mengel, Ohio State University Medical School.

Experiment M003 was the in-flight exercise experiment whose principal investigator was also Dr. Lawrence F. Dietlein, NASA Manned Spacecraft Center, Houston, Texas. This was an evoked response experiment whose purpose was to measure cardiovascular responses to the same fixed stimulus as the flight continued. It utilized the bungee cord exerciser similar to that used during Project Mercury. As programmed in Gemini, the M003 exercise was not a cardiovascular conditioning procedure, although this use of exercise will be explored as the program proceeds. The force required to stretch the cord was approximately 70 pounds, and the stretch distance was limited to about one foot. The work completed for full stretch was, therefore, approximately 70 foot pounds. Each exercise period consisted of a single stretch per second for 30 seconds. The number of such exercise periods ranged from two to four per day. During Gemini, none of the flight crew members showed a significant change in cardiovascular response to this exercise as programmed. This effort will be continued on future flights, probably utilizing a different form of exerciser and an altered exercise regimen. These are currently under investigation.

Experiment M004 was the in-flight phonoelectrocardiogram experiment of Dr. Carlos Vallbona, Texas Institute of Research and Rehabilitation, Houston, Texas. By recording the phonocardiogram simultaneously with the electrocardiogram, the intervals between electrical stimulus and fixed points of myocardial response, as indicated by valve closure, were determined. By thus timing the events of mechanical systole, an indication of the status of the myocardium and its responsiveness was gained. The phonocardiogram equipment consisted of a microphone and a signal conditioner. The microphone was placed over the precordium at the point of maximum intensity of sound. This experiment was flown on Gemini IV, V, and VII. Although the experiment did demonstrate expected alterations of electromechanical delay with alterations of heart rate, it failed to indicate any changes which could be considered unique to space flight. Thus, using this technique at least, we have so far been unable to corroborate Soviet findings of electromechanical changes due to space flight.

Experiment M005 was the analysis of body fluids for various hormonal, biochemical, and electrolyte determinations. The Principal Investigators were Dr. Harry Lipscomb, Baylor University School of Medicine; and Dr.

Elliott Harris, NASA Manned Spacecraft Center, Houston, Texas. The experimental procedure consisted of the analysis of both pre and post flight blood and urine specimens and of in-flight urine specimens. On Gemini VII, 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 tritiated water before filling the specimen bag. Urinary output calculations were based upon the concentration of tritium in the specimen. The equipment consisted of a valve, tritium container, common mixing bag, and specimen bags. The remainder of the urine after sampling was dumped overboard. This concentration-dilution method of determining urine volume did not completely fulfill our required standards of accuracy owing primarily to differences in mixing characteristics during weightlessness. However, this procedure was carried out on Gemini VII with sufficient accuracy that correction factors based on a presumed constant creatinine output could be applied.

The data revealed a decrease of urinary 17 hydroxycorticosteroids in flight, and an increase post flight, as compared with pre-flight values. This finding is consistent with heightened crew activities during preparation for retrofire and re-entry. Aldosterone output was noted to be moderately increased during flight and more markedly increased post flight, a finding which corroborates the post-flight retention of fluids and electrolytes also observed.

Experiment M006 was the measurement of bone density by means of a special x-ray technique developed by the Principal Investigator, Dr. Pauline B. Mack of Texas Woman's University, Dallas, Texas. These measurements were performed pre and post flight only and were carried out on Gemini IV, V, and VII. The technique employed standard x-ray equipment and a metal wedge densitometer to determine the density of the os calcis, talus, and metacarpals and phalanges of the hand. A photo-scanner is used to determine bone density from the x-rays. Comparison of pre- and post-flight films revealed a diminution of bone density in both weight-bearing and non-weight-bearing bones of all of the flight crew members. In no case were these changes severe, but, contrary to expectations, they were less marked in the Gemini VII crew than in the others. Again, this is probably attributable to the rather special environmental circumstances of the Gemini VII flight referred to in the discussion of blood volume changes above. In the case of the weight-bearing bones, the changes seen were approximately equivalent to those seen during similar periods of bed rest. The non-weight-bearing bones, unlike bed rest study findings, showed approximately the same degree of change as the weight-bearing bones.

Experiment M007 was the calcium balance study, perhaps more accurately described as a mineral balance study. It was a closely controlled intake and output evaluation designed to identify changes in the mobilization and metabolism of calcium and other minerals under weightless conditions. The principal investigators were Dr. G. Donald Whedon, Director, National Institute of Arthritis and Metabolic Diseases; Dr. Leo Lutwak of Cornell University Medical School; Dr. William Neuman of the University of Rochester Medical School; and Dr. Paul LaChance, NASA Manned Spacecraft Center, Houston, Texas. This experiment was flown only on Gemini VII, although it will be repeated at some point in the future. Intake and output evaluations included calcium, nitrogen, phosphorous, potassium, sodium, and chloride as measured in food, urine, feces, and sweat. As the primary amino acid constituent of bone matrix, hydroxyproline was also assayed. This was a highly complex experiment which required and received diligent effort on the part of the principal investigators, their team of ancillary personnel, and the Gemini VII flight and backup crews. The protocol included a ten-day pre-flight and two-day post-flight equilibration period as well as the fourteen-day flight, itself. The same flight urine samples were assayed for this experiment as for experiment M005 and the same technical difficulties prevailed. Urine volume errors were found to be correctable to a reasonable extent by assuming a constant output of creatinine.

The experiment demonstrated a mild negative calcium balance and a more pronounced negative phosphorous and nitrogen balance during flight. The calcium findings were consistent with those of the bone density experiment, M006. Plasma hydroxyproline measurements showed a slight post-flight increase, but all values were well within the normal range.

Experiment M008, the in-flight sleep analysis experiment, was flown only on Gemini VII. Depth of sleep was determined by electroencephalography. Observations were made on one astronaut for the first 48 hours of flight.

The principal investigator of this experiment was Dr. Peter Kellaway of Baylor University Medical School. The equipment consisted of electrodes and signal conditioners for the bilateral parieto-occipital leads which were recorded. In this experiment, four stages of sleep were clearly demonstrated by the EEG as reflected by the characteristic slowing of the electrical activity of the brain. "Paradoxical" sleep was readily identified by the principal investigator but cannot be classically demonstrated since electro-oculograms were not taken. Sleep was noted to be generally light and spotty the first night but somewhat more sound the second. This is not considered to be in any way unique to space flight, but only represents a very normal response to any venture of this general nature. Some increase in theta wave activity was also noted. The experiment demonstrated the feasibility of utilizing the EEG to determine precise sleep patterns under operational conditions.

Experiment M009 was the otolith function experiment designed by Captain Ashton Graybiel and Dr. Earl Miller of the U. S. Naval School of Aviation Medicine, Pensacola, Florida. The otolith portion of the vestibular system is a sensor of linear acceleration and, consequently, a sensor of gravity. Since this mechanism may be considered gravity dependent, the question of the possible development of changes in sensitivity of the otolith in the absence of gravity has been posed. The experiment was designed to evaluate otolith function by means of two methods which were the two parts of the experiment.

The first was the determination of egocentric visual localization of the horizontal in flight. Its equipment consisted of a light-proof gargle with a rotatable illuminated white line in front of one eye. During flight, the astronaut rotated the white line to what he considered the horizontal position, i.e., the position parallel with the pitch axis of the spacecraft. His ability to do this has been established as a function of the integrity of otolith responsiveness. The position of the white line was read by the other astronaut by means of external calibrations on the surface of the actuating ring. The second part of the experiment consisted of the measurement of ocular counter-rolling pre and post flight. This was done by tilting the astronaut to the side in a very precise fashion. With this movement, the eyes normally rotate very slightly in the opposite direction as if attempting to maintain alignment with the horizon. The degree of counter-rolling reflects the sensitivity of the otolith mechanism. For this portion of the experiment, the astronaut was placed in a frame with his head held very still by supporting cushions. The frame was tilted sideward to an exact fifty degrees while the camera fixed to the frame in front of the eyes took a series of still pictures. Using identifiable points on the pictures of the iris, the exact degree of counter-rolling was measured in minutes of arc. The experiment was flown on Gemini V and Gemini VII. In general, the data revealed no significant change in the otolith system in up to 14 days of space flight. Vestibular investigations will be continued into longer duration flights. Future plans include provisions for research into semicircular canal function as well, particularly as they are effected by Coriolus forces.

In summary, Gemini space flight medical data have shown a reduction of tilt table tolerance, decreased red cell mass, altered plasma volumes, dehydration, decreased bone density, and increased calcium and nitrogen output. It should be emphasized that all of this information can be classified as trend data, none of it having been associated with overt manifestations of ill effects in terms of clinical symptoms or signs. Within our present 14-day experience, we have been unable so far to demonstrate changes in the electromechanical activity of the heart, otolith function, vestibular disturbance of any kind, hallucinatory phenomena, gastrointestinal disturbance, genito-urinary disturbance, or performance decrement. On reviewing positive findings, it is exceedingly difficult if not impossible to identify single etiological factors for each of these changes. Of those changes which might be ascribable to weightlessness or weightlessness in combination with other factors, it would seem logical to include cardiovascular and musculoskeletal changes and changes in fluid balance. Judging from a long history of ground-based observations, relative inactivity is unquestionably an associated cause of cardiovascular and musculoskeletal alterations while there is little question that thermal stress is an adjunctive cause of changes in fluid balance. With respect to fluid balance, our findings indicate that dehydration and altered plasma volume are not necessarily equatable. To what extent the isolation of dehydration to tissue fluid loss, seen in the 14-day flight, is uniquely related to any of the factors or combinations of factors of space flight cannot be stated with certainty at the present time. On the basis of ground-based studies, the decreased red cell mass, shortened red cell life span, and increased red cell fragility are thought to be most reasonably referrable to the high oxygen atmosphere with perhaps relative physical inactivity as a secondary causative factor.

In conclusion, it appears to be generally true that the time courses of the effects which have been observed have been much less acute than was feared by many knowledgeable scientists early in the manned space flight program. However, we must continue to be aware that from our vantage point a few years from now our present maximum of 14-days experience will appear to be quite modest. Some of our negative findings may simply be late appearing ones. While we now have adequate reason to proceed to progressively longer duration flights without apprehension, at the same time we must continue diligently with our investigative efforts so that we may be able to give maximum medical support to man in his future conquest of space.

DRAFT

PRESENTATION TO

AMERICAN SOCIETY OF MEDICAL TECHNOLOGISTS

MIAMI BEACH, FLORIDA

JUNE 28, 1967

Mr. Chairman, members, and guests of the American Society of Medical Technologists, I am genuinely honored and pleased to have been invited to make this presentation to you today. Honored, because of the very important aspect of medicine which you represent. Pleased, because of the opportunity I now have to acquaint you with the rather unique activities of the field of space medicine and with its future needs. When I say that many of these needs may relate directly to many of you, I do not intend to imply that NASA is now recruiting medical techn~~ician~~ologist astronauts. When that utopian day arrives, I shall certainly manage to be on the selection panel. But rather, these needs are in the realm of new technique and equipment development to expand our medical evaluative capabilities during extended flights of the future.

To acquaint you with the field and its future requirements, I would like to review the role and activities of the medical experiments program, the Gemini medical findings, and ~~with~~ elements of our planned activity in Apollo and the very important follow-on Apollo Applications program.

The Apollo program of medical experiments will consist essentially of gathering confirmatory pre and post-flight data since Apollo flight durations will not exceed the maximum duration Gemini flight. Pre and post-flight tilt table studies will be replaced at some point by lower body negative pressure evaluations. Pre and post-flight immunological studies and lymphocyte karyotyping will be added. Finally, the inflatable cuff technique will be replaced by the evaluation of an anti-deconditioning elastic garment worn over the lower portion of the body.

Certainly, the greatest opportunity to learn of the effects of space flight on man and of the means by which we can support and extend his activities in space is in the Apollo Applications program. This series of flights will utilize Apollo equipment and technology to accomplish longer and more complex orbital missions and extended lunar exploration. The primary purpose of the program is scientific gain. By means of the cluster technique, the third stage of the Saturn launch vehicle, the SIV-B, will be utilized as a habitable spacecraft. Its volume measures approximately 20 feet in diameter by 30 feet in length for a total of 10,000 cubic feet of available space. By means of a multiple docking adaptor which will be transported into orbit in place of an Apollo lunar module, the command module will dock with the SIV-B. The environmental control system and equipment for the SIV-B will be contained in the multiple docking adaptor. The gaseous atmosphere provided will be a 5 psi two gas system of 69% oxygen and 31% nitrogen. Flight durations of up to 30 days and up to 60 days, respectively, are now planned early in the program. At the completion of the AAP program, we hope to have incrementally attained flight durations of up to one year.

From the medical point of view, plans for the 30 and 60-day missions include all of the investigational efforts begun in Gemini and Apollo utilizing improved methods and techniques. Additional investigations presently planned for these flights are the evaluation of metabolic requirements, respiratory function, semicircular canal function, and task performance in space as compared with the earth by means of a time and motion study. Habitability evaluations will be given strong emphasis as flights become progressively longer. Technique and equipment improvements will be made, such as the development of a bicycle ergometer for space flight, an accurate and flyable gas chromatograph for measuring respired oxygen, carbon dioxide, and water vapor, and very probably, a new device especially designed for space use for the ~~very accurate~~ determination of specimen and human body mass. This mass measurement technique, which actually consists of two pieces of equipment, one for small and one for large masses, employs the principle of inertial oscillation [TO ACHIEVE A VERY HIGH DEGREE OF ACCURACY].

As flights continue to expand into longer periods of time, an increased medical ~~evaluative~~ [INVESTIGATIVE] capability will be required. It is ~~to this end~~ [FOR THIS PURPOSE] that we have now initiated the [EARLY] developmental stages of a medical laboratory for space flight. To facilitate ~~the characteristic of~~ [MAXIMAL] flexibility, it will be designed in modular form. In this way, older techniques can be quickly replaced with new and improved ones as they are developed, and ~~incorporated~~ [FLIGHT] experiments can be rapidly switched as may be indicated by late flight information, thus obviating the very long lead time requirements of the past. The major component capabilities of the flight laboratory will consist of physiology, behavioral, microbiology, [redacted] biochemistry, and data management. Research and developmental efforts are needed in each of these areas to advance the state of the art in order to augment the versitility of equipment and procedures; improve sensitivity, accuracy, reproducibility, and ease and speed of performance; and to decrease volume, weight, and power requirements. In the field of biochemistry, liquid reagents, because of their behavior in weightlessness and because of their toxicity, must either be used in minute quantities, absolutely contained, or most desirably, completely avoided. If they are to be avoided, methodologies must be replaced by physical chemical techniques, and new development possibilities in this realm are presently being evaluated. The handling of specimens for biochemical determinations will most probably require capillary tube techniques, the many specific ramifications of which will require further study and development. A third research and development effort of importance in your field is the problem of sample preservation for the post-flight analysis of many samples of all human products, accumulated over a period of months to years to be studied for a variety of analyses. Literature searches carried out thus far have revealed that surprisingly little is known of long term sample preservation for particular determinations. As is true of most of these problem areas, the most apparent reason is that the need did not exist, again demonstrating the maternal relationship between necessity and invention. Finally, a fourth area of challenge is in the techniques which will enable us to determine changes in microbial ecology within the closed environment of the spacecraft over long periods of time. Here again, methods which can be accomplished within the spacecraft during flight must be developed, suitable methods to preserve specimens for post-flight analysis, or perhaps for more detailed post-flight analysis, must be generated, and all of this must be ~~capable of being~~ ABLE TO BE carried out ACCURATELY, EASILY, AND SAFELY within the constraints of ~~the~~ vehicular and operational ~~capabilities~~ CHARACTERISTICS. Each of these areas will require continuing and multiple research efforts. Each of them is a challenge to your field AND TO ~~the~~ THE INGENUITY OF YOU, ITS MEMBERS.

As is true of our space effort in general, space medicine has by virtue of its unique problems and unique findings contributed to its parent field either directly or by giving impetus to specific kinds of endeavor. As the future requirements which I have outlined are met, these new developments, themselves, and ramifications of the effort which they engender ~~will~~ SHOULD find increasing application to clinical medicine. This is true of many medical specialties but in none more prominently OR PROMISINGLY than the field of medical technology.

TESTS

CBC, PROTEINS
STD BL. CHEMISTRIES
SUGAR BUN
ELEMENTS OF CLOTTING
~~[illegible]~~
BODY DEFENSES – HEMATOL
WBC MOBILITY
IMMUNOCHEM.
ENDOCRINE ASSAYS
17 HYDROXY.
CATECHOLS
ADH
~~PARATHYROID~~
THYROID SPARA etc
ELECTROLYTES & ~~MINERALS~~
MINERAL BALANCE
HYDROXY PROLINE
BL. PO_2 & PCO_2
ISOTOPE TAGGING (C, CO)

METHODS

FILTER PAPER
~~[illegible]~~
EXPANDED SPECTROMETRY
XRAY "
Nuc. Mag. Resonance
Optical Rotary Dispersion
Atomic Absorption
~~Enzyme Kinetics~~
Lasers

Remember
Experimenters [illegible]
No Clinical Manipulation

Dr. Vinograd/Room 223/Building 4200

Sorry I couldn't get this to you sooner -- I had several interruptions. However, it was dictated beautifully and that was a big help.

Dona Priest

LIFE SCIENCES PAYLOAD

Introduction

The NASA Life Sciences represented by Space Medicine, Biotechnology and Human Research, and Bioscience Programs are pursuing a course of progressively integrated activity in all realmsof our respective endeavors. Reflecting this course in the area of in-flight investigation (experiments), payload planning is presented as it is being done, as an integrated Life Sciences effort.

The objectives of the Life Sciences space flight investigations are:

I. To extend man's capabilities in manned space flight by:

A. Space flight medical investigation

1. To determine the effects of space flight on man, and the time and courses of these effects.

2. To determine the specific etiologies and mechanisms by which these effects are mediated.

3. To determine means of predicting the onset and severity of undesirable affects.

4. To determine the most effective means of prevention or correction of undesirable affects.

B. Investigation of Flight Crew Support Techniques

1. To evaluate an advanced technology to enhance the flight crew capabilities in space.

2. To evaluate an advanced crew environmental support technology.

II. To Gain Scientific Knowledge

A. In Biology

B. In Exobiology

C. In Life Support Technology

D. In Medicine

Pursuant to these objectives, the Life Sciences effort can be divided into four areas of discipline-oriented activity. (It is to be noted that these are not organizational divisions.) They are:

I - Biomedicine/Behaviour

II - Bioscience

III - Crew Support Technology

IV - Crew Operational Techniques.

Experiment planning for the AAP flight alternatives evaluated in this exercise will be treated according to these four areas.

In the planning of Life Sciences flight investigation for the future, a pattern of increasing integration of its constituent activities is evident. The experimental packages proposed for AAP 1/2 through AAP 7 consist of individual experiments. By CY 1971 the onboard Biomedical/Behavioural experiments will be packaged as an integrated unit (IMBLMS), a flight laboratory measurement system capable of a wide variety of measurements to accommodate existing and still to be proposed medical/behavioural experiments. The medical/behavioural input into the description of Configuration B is therefore embodied in the experiment data sheet on IMBLMS. As the Life Sciences flight investigational effort continues to the CY 1972 and 1973 periods and beyond, progressive evolutionary stages of an integrated Life Sciences laboratory are planned. These plans are reflected in the experiment description formats for Configuration C.