

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM

NASA LIFE SCIENCES REVIEW

Presented to the Three Associate Administrators

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by

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Space Medicine, Manned Space Flight

MEDICAL EXPERIMENTS PROGRAM

The medical and behavioral experiments program is a group of activities directed toward the evaluation of changes in human function and capabilities which may be induced by space flight. The objectives of the program exist as two categories, each having its own projected application or purpose (Fig. 1).

The first is geared toward manned space flight. Its four objectives express the intention to determine as precisely as possible man's medical and behavioral responses, functional limitations, and supportive requirements in space flight. The information gained is applied to the planning of future manned space flight missions and programs. Effective planning and judicious manned versus unmanned tradeoffs will continue to be strongly dependent upon how well these objectives are fulfilled.

The second category of objectives is oriented toward earth based medical science. Its purpose is to advance medical research by carrying out well-conceived experiments designed to utilize the unique environmental characteristics of space for scientific information, whether or not the resulting data will be any way applicable to manned space flight. As an example, any physiological function which might be considered to be gravity dependent in some respect is potential subject matter for profitable investigation in the space environment.

The four objectives given in the first category are a general statement of the questions which the program is attempting to resolve. The specific questions being pursued have been formulated and arranged in order of priority. A representative list of top priority questions follow as Appendix A.

The program which has been designed to meet these objectives consists of two primary areas of activity: Experiment Management, the support of the experiments, themselves, during definition and development; and Ground Based Research and Development, the effort to develop integrated flight laboratory equipment, new and improved medical evaluative techniques to enhance our inflight capability, and to obtain ground based data, all of which are essential elements supporting the flight medical experiments effort.

The program can be further characterized by certain of its more important concepts. An enumeration of these might serve to convey a more complete picture of this effort (Fig. 2). First, experiment principal investigators are not limited to NASA personnel. Because the space program is both national and scientific in nature, because the mounting of experiments aboard space flights is extremely expensive, and because flight opportunities are relatively infrequent, strong emphasis is placed upon the participation of the most highly competent individuals of the scientific community as principal investigators, whether they are from within or outside of NASA. Secondly, a general philosophy of the program is to plan experiment flight schedules not only to explore known or expected

problems in depth, but also to conduct human systems monitoring across the board to the extent and level of detail consistent with good practice and practicality. As an example of the importance of this concept, had this not been done in Gemini we would still be totally unaware of the red blood cell and fluid compartment changes which were found. Thirdly, regarding the technical content of the program, the major variable is duration of flight. The most unknown environmental factor is prolonged weightlessness. This does not by any means imply that weightlessness is the only factor of interest, or even that it will necessarily turn out to be the most important. However, it is an important factor and it remains unknown because of our inability to reproduce it for much over thirty seconds in the earth environment. Fourth, with respect to the question of artificial g, the medical/behavioral experiments program seeks to establish the need for it by evaluating flight crews exposed to the unaltered zero g environment on flights of increasing durations. Shorter term flights can provide the opportunity to investigate and establish artificial g techniques most consistent with optimal crew, spacecraft, and mission function and performance. However, until the need for artificial g can be better determined, it is our feeling that this capability should be included in at least the design of future spacecraft. Lastly, the small number of flight crew members and the broad range of variability of individual responsiveness to a given set of conditions, which is so characteristic of us humans, necessitate the repetition of most experiments to establish statistical validity of flight findings.

The medical/behavioral experiment program began in 1963 with the study of the Biomedical Experiments Working Group (Fig. 3). This was an ad hoc group of NASA life scientists who devoted a series of meetings to an evaluation of the medical and behavioral aspects and requirements of an orbiting research laboratory. This was followed by two study contracts with industry, one with Republic and the other with North American, to explore this question in greater depth. In January 1964, the Space Medicine Advisory Group (SPAMAG), a group of 20 prominent consultants of the medical community, began its in-depth study of this problem. The SPAMAG report followed a series of eight two-day meetings chaired jointly by the NASA and the DOD.

In February 1965, a Technical Advisory Committee of ten NASA Center and Headquarters Life Sciences personnel was called together to assemble from these four reports a group of medical and behavioral experiments which could be considered candidates for an AAP (then AES) flight program. This was part of an exercise conducted for Dr. Seamans and resulted in the formulation of 23 medical/behavioral experiment concepts as a representative AAP medical experiments package. Shortly thereafter, this group of pseudo-experiments was reassembled into its eight component areas of body function, each with its list of required measurements and procedures (Fig. 4). This list has been reviewed and updated repeatedly with the aid of our consultant advisors, the Biomedical Subcommittee of STAC (formerly the Medical Advisory Council) and constitutes the desired measurement capability of the IMBIMS.

The first flight manifestation of the medical/behavioral experiments program took place in Gemini, preparations for which began in early 1964. The Gemini package consisted of eight experiments several of which were flown on more than one mission (Fig. 5 and 6). The experiments plan for the Apollo program was an expansion of the Gemini package, but necessary alterations of the flight program ultimately restricted these plans to the extent that only three pre- and postflight experiments are actually being implemented. The remainder are delayed until AAP.

As alluded to earlier, the medical/behavioral experiments program is functionally organized into two mutually dependent areas of activity (Fig. 7). The first consists of the planning, solicitation, and management of the experiments, themselves, during both definition and development. The activities entailed are outlined on this slide. Of these, the review for scientific merit deserves an additional word of explanation (Fig. 8). The system, which has been employed since 1966, includes an objective scientific review by the NIH Study Section system and a succeeding evaluation, also scientific but oriented toward Manned Space Flight capabilities and requirements, by a highly qualified team of medical consultants to NASA. This group was established in May 1965 as the Medical Advisory Council and is now the Biomedical Subcommittee of Dr. Mueller's Science and Technology Advisory Committee (STAC).

The present program of medical experiments is organized into the exploration and evaluation of the eight areas of body function mentioned earlier (Fig. 9). The individual experiments are components of these eight overall endeavors. There are currently fourteen experiments in development for AAP, five experiments in definition, and nine in process

of review for scientific merit. The slide (Fig. 10) indicates the body function areas and corresponding experiment numbers. The presently approved experiments cover six of these eight areas. A governing protocol describing the investigation of each functional area is included in existing documentation. The existing AAP medical/behavioral experiments, their organization, designators, and personnel are shown in Appendix B. Appendix C lists these same experiments using more descriptive titles to better indicate their content.

Of the five experiments in definition, only three have been funded and two of these are now overdue for renewal for lack of fiscal 1969 funds (Fig. 11). Although the remaining two experiments of the five were approved for definition over a year ago, we have not been able to initiate them thus far because of the curtailment of FY68 funds and lack of availability of FY69 experiment definition funds.

Of the nine experiments currently in review, six are candidates for development, three will supplement existing experiments in the hematology area, and three are in the microbiology area, the seventh of the areas of body function (Fig. 12). Dr. Cameron's bone densitometry technique proposes both a pre- and postflight and an inflight portion. The pre- and postflight portion is a candidate for development and the inflight for definition. The ballistocardiography and pulmonary function proposals are both candidates for definition.

Turning now to the R&D support of the medical/behavioral experiments program, three task areas are defined. The first of these, the Integrated Medical and Behavioral Laboratory Measurement System (IMBLMS) program, will develop a highly flexible and sophisticated laboratory system to accommodate the medical and behavioral measurements required for all existing experiments as well as those anticipated for the future. Its two basic aims are (1) the accommodation of medical and behavioral investigations in accordance with the full objectives of the program, and, (2) provision of maximum flexibility (Fig. 13). It is basically a rack and module system which can be assembled into working consoles according to the requirements of the spacecraft and the experiments program for any particular mission. Hardware modules or submodules for a specific experiment can be developed to fit the specifications of the IMBLMS and utilized on an "as needed" basis. The flexibility afforded by the modular approach will significantly reduce lead time requirements, enhance inflight maintenance, and enable the relatively inexpensive introduction of updated techniques and equipment. The IMBLMS will consist of five functional elements: (1) physiological, (2) behavioral, (3) biochemical, (4) microbiological, and, (5) data management. Together they will accommodate required measurements in all eight areas of medical/behavioral investigation. Appendix C is the list of measurement requirements currently targeted for the flight IMBLMS. For the AAP program or Space Station, the IMBLMS will be composed of two or three consoles plus four to six pieces of peripheral equipment. Such as the bicycle ergometer, rotating litter chair, body mass measurement system, and lower body negative pressure device.

The IMBLMS concept grew out of the studies discussed earlier. The need for time-lining the 23 pseudo-experiments issuing from the Dr. Seamans exercise in early 1965 resulted in our extending an existing MT contract with Lockheed to build a mock-up of a medical/behavioral laboratory in a mock-up of a LEM and time line these measurements with crew suited and unsuited (Fig. 14). This was accomplished as a four-month effort which ended in February 1966. In our first draft work statement in March 1966, we defined the present highly flexible IMBLMS concept including modularity, prefabricated rack mountings and interfaces, etc., and began preparations for Phase B of this phased project procurement. A Source Evaluation Board was established, an RFP drawn up and distributed, responses were evaluated, and in April 1967, two contractors were selected by Mr. Webb. Phase B1 work started in June 1967 followed by Phase B2 in October 1967. The present Phase B3 was begun in December 1968. The two contractors are continuing to work competitively in this thirteen-month phase, which will result in fabrication and test of a functional breadboard of IMBLMS. The first flight units can be completed by the summer of CY72 (Fig. 15). However, schedules will be altered in accordance with manned space flight requirements. It is anticipated that competition will be terminated at the initiation of hard design, Phase C2. An IMBLMS Project Office has now been established in the Medical Research and Operations Directorate at the Manned Spacecraft Center in Houston, and the contracts are now being transferred from Headquarters to MSC.

The second task area of the R&D support of the program consists of a series of independent grants and contracts aimed at advancing states-of-the-art of measurement techniques and equipment to augment the capabilities and accuracies of the IMBIMS. This is an important task area for many reasons, a major one being that many standard techniques are not adaptable to the environmental and other circumstances of manned space flight. Most of these requirements (Fig. 16) were identified several years ago. The existing efforts to meet these requirements have been reviewed by previous discussants. Many are progressing satisfactorily but there is a need for expanded efforts, especially in the areas of biochemistry and microbiology, as will be noted in a review of technical problems.

The third R&D task area consists of chamber studies, bed rest studies, and similar types of simulations as sources of essential ground based data. Although individual principal investigators do obtain ground based or control data as part of their experiments, economic feasibility dictates that evaluations of certain environmental factors such as spacecraft atmosphere by long term chamber studies, weightlessness as simulated by bed rest, etc., are best done by NASA with the participation of all principal investigators whose flight findings would be influenced by these aspects of the environment. Although bed rest studies have been and are being carried out, the Apollo accident, but more currently funding and man power limitations, have caused delays and cancellations in chamber studies. As recently as four months ago, a planned 60-day 5 psi 2-gas AAP atmosphere simulation which was to be run jointly by NASA and the Air Force at Wright-Patterson Air Force Base had to be cancelled for

lack of sufficient personnel and funding resources on the part of both the Air Force and NASA.

Some of the more important technical problems confronting the program are shown on this slide (Fig. 17). Although progress is being made in these areas, there is need for a more concerted attack on the measurement of metabolic costs of suited activity, and our old chronic problem of accurate fluid intake and output measurement during flight. We do have one promising lead on viral identification in-flight but funding limitations threaten to delay it even further than the $1\frac{1}{2}$ years it has already been waiting. There are existing productive efforts in biochemistry techniques and in the behavioral area but these need to be expanded considerably to enable us to work out satisfactorily the overall problems which we are attempting to resolve in manned space flight, the questions of artificial g, and manned vs. automated task accomplishment.

Resources are summarized on the slide (Fig. 18). The experiment development figures are requirements for Apollo medical and biology experiments as well as for AAP. The definition numbers indicate dollars available as do those for parallel development and simulation studies. The IMBLMS figures are requirements; the FY69 dollars have been expended and it does appear at this point that FY70 requirements for IMBLMS will be made available.

The personnel figures represent present full time professionals¹ at MSC, MR&O. In addition to these there are approximately 12 including the principle coordinating scientists who are able to devote only a part of their time to the medical/behavioral experiments. Minimum requirements for IMBLMS, alone, are 5 MSC personnel now, and will increase progressively to 10 for Phase C. To meet this least requirement are one full time and two part time personnel presently on hand. Headquarters, MM, personnel devoted to this program number one full time and two part time professionals, a personnel shortage of long standing.

Of the major issues of the program, the funding and personnel problems have already been discussed (Fig. 19). The excessively long and complex procurement procedures have been a significant impediment to the initiation of needed efforts within the short periods in which funding is actually available. Lastly, but most fundamentally, these and other issues could be dealt with more effectively were it not for the fact the medical/behavioral experiments program has never been a program. Although we have repeatedly referred to it as such, it has been a program only in terms of its purpose, objectives, planning, and technical content. It has never had a budget or organization of its own. Until March of 1966, the effort had no budget available to it at all, except for the funding of experiments in development by the flight program offices. Definition money became available through MT in the spring of 1966, but beginning one week later the funding history has been one of budgetary reductions and funding delays in the various budgetary sources from which the total

effort draws its support. As a result, overall progress could not be smoothly and evenly maintained. These funding uncertainties have led to a variety of problems, most of them obvious; but one perhaps less obvious has been its influence on the participation of the scientific community. As mentioned earlier, two of our experiments which were approved for definition over a year ago are still not funded. This kind of delay causes planning discontinuities and expense to principal investigators and their parent institutions. It constrains our ability to request and to receive the enthusiastic participation of the scientific community.

As a true programmatic effort, it would be possible to establish a coordinated base level of activity consistent with the priority of its function, the evaluation of man in manned space flight. Such a base level, suited to the lean years would be appropriately embellished for more rapid progress during better years, but in either case the effort could then progress smoothly and in a coordinated manner toward planned achievements and objectives.

QUESTIONS MEDICAL/BEHAVIORAL AREA
SEEKING TO RESOLVE

NEUROPHYSIOLOGY

1. What are the effects of the space flight environment on sleep?
2. What is the change in susceptibility to motion sickness as a function of:
 - a. Time aloft?
 - b. Freedom of movement within the spacecraft?
 - c. Rotation of the spacecraft?
3. What are the effects of sustained loss of gravitational cues on sensory perception (the special senses, kinesthesia, and other somatic senses) and on spatial orientation?

PULMONARY FUNCTION AND ENERGY METABOLISM

1. What are the effects of sustained weightlessness on the mechanics of breathing in which, normally, the gravitational forces interact with the respiratory muscles and elastic forces of the chest and lungs?
2. What is the energy cost (metabolic gas exchange) at rest and during activity in the spacecabin with and without the suit, in normal flight and during EVA?
3. What is the degree and duration of arterial hypoxia due to ventilation/perfusion inequality in the lungs during launch and re-entry in space flight?
4. Are there any alterations in alveolar gas transfer or the control of breathing under prolonged combined effects of weightlessness and a low pressure mixed gas or pure oxygen environment?

CARDIOVASCULAR FUNCTION

1. Is cardiac output adequately maintained in prolonged space flight?
2. To what extent does space flight affect normal arterial pressure controls?

3. How are venous compliance and central venous pressure and their adjusting mechanisms influenced by prolonged space flight?
4. How is cardiac function affected by long duration space flight?
5. What are the factors of space flight which cause changes in circulating blood volume and its distribution? At what point and under what conditions is a new equilibrium established?
6. What is the time course of changes in overall circulatory function as determined by provocative testing (tilt table, LBNP)?

NUTRITION AND MUSCULOSKELETAL FUNCTION

1. What are the actual caloric requirements and the variables in caloric utilization under varying workloads and under varying configurations of space suit constraints in long duration space flight?
2. What are the space flight factors or stress conditions which might change caloric, water, electrolyte, or mineral requirements? To what extent do they change these requirements?
3. By what predictive or mathematic factors are energy costs of activity in space different from those in the one-G environment?
4. To what extent is glucose metabolism changed by space flight conditions (as noted in prolonged bed rest)?
5. Are variations in body mass during space flight within the limits to be expected with adequate food and water intake and work schedules comparable with the earth environment?
6. What is the time course and degree of skeletal and muscular changes due to weightless flight? What are the relative influences of weightlessness, relative inactivity, and the atmospheric environment?
7. What are the best preventive or restorative techniques against bone and muscle deterioration due to space flight?
8. What are the effects of long duration weightless flight on water and electrolyte balance?

ENDOCRINOLOGY

1. In view of the known changes in body water distribution and balance with changes in body position, to what extent will weightlessness per se bring about losses of fluid? To what extent is anti-diuretic hormone involved in the mechanism of this change?
2. To what extent will changes in the metabolic cost of activity in space be reflected by changes in thyroid hormone production? Can a cause and effect relationship be established?
3. To what extent are the predicted losses of mineral in long duration space flight associated with increased bone resorption mediated by elevated parathyroid hormone secretion?
4. As both a reflection and mediating factor of stress response, what is the time course of changes in adrenal cortical activity in prolonged space flight?

HEMATOLOGY AND IMMUNOLOGY

1. What are the environmental factors responsible for the loss of red cell mass noted during Gemini?
What are the relative roles of:
 - a. The 100% oxygen environment?
 - b. Nitrogen in small amounts?
 - c. Weightlessness?
 - d. Duration of exposure?
 - e. Diminished red cell production vs. increased destruction?
 - f. Ambient total pressure?
 - g. Vibration?
 - h. Ambient temperature?
 - i. Dietary factors?
2. What space flight factors are responsible for changes in plasma volume?

3. Are coagulation proteins, platelet function, and vascular friability influenced by long duration space flight? If so, what are the responsible environmental factors?
4. Can one anticipate alterations of inflammatory response as a result of long duration space flight?
5. To what extent can space flight be anticipated to produce alterations of cell division or chromosomal composition? If such changes do occur, what environmental factors are responsible and what preventive action can be taken?

MICROBIOLOGY

1. What changes can be expected to take place in the microbial flora of flight crews during space flight?
2. What are the influences of space flight conditions on the relative dominance of pathogenic microorganisms?
3. Will there be genetic alteration in microbiological organisms as a result of the space flight environment? To what extent? Can a pattern of such changes be anticipated?

BEHAVIORAL EFFECTS

1. Will perceptual efficiency be affected by space flight conditions?
2. What changes in time and/or pattern of activity will make performance of tasks in space most efficient? Most comfortable for the astronaut?
3. What changes in the tolerance limits to stress occur over time in the extended periods of weightlessness?
4. What are optimal inflight and EVA work-rest periods based on factors of (a) fatigue, (b) energy loss, (c) discomfort, and other stress indicants?

AAP MEDICAL/BEHAVIORAL EXPERIMENTS
APPROVED AS OF DECEMBER 1968

MO70 - NUTRITION AND MUSCULOSKELETAL FUNCTION (Governing Protocol)

Principal Coordinating Scientist: Paul C. Rambaut, Ph.D., MSC

Assistant Coordinating Scientists: Richard Boster, D.V.M., MSC
Miss Rita Rapp, MSC
Malcolm Smith, D.V.M., MSC

Individual Experiments or Measurements:

MO71 - Mineral Balance

Principal Investigator: G. Donald Whedon, M.D., NIH

Co-Investigator : Leo Lutwak, M.D., Ph.D.
Cornell University

MO72 - Bone Densitometry

Principal Investigator: Pauline B. Mack, Ph.D.
Texas Women's University

MO73 - Bioassay of Body Fluids

Principal Investigator: Craig L. Fischer, M.D., MSC

Co-Investigator : Carolyn Leach, Ph.D., MSC

MO74 - Specimen Mass Measurement

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator : William Thornton, M.D., MSC

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APPENDIX B

MO90 - CARDIOVASCULAR FUNCTION (Governing Protocol)

Principal Coordinating Scientist: Robert L. Johnson, M.D.

Individual Experiments or Measurements:

MO91 - LBNP (Pre- and post-flight)Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator : Robert L. Johnson, M.D., MSC

MO92 - Inflight LBNP

Principal Investigator: R. L. Johnson, M.D., MSC

Co-Investigator : John Ord, Colonel, USAF, MC
Brooks AFB, TexasMO93 - VectorcardiogramPrincipal Investigator: Capt. N.W. Allebach, Bureau of
Medicine & Surgery, Washington, DCo-Investigator : R. F. Smith, M.D., Naval Aerospace
Medical Institute, Pensacola, Fla

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M110 - HEMATOLOGY AND IMMUNOLOGY (Governing Protocol)

Principal Coordinating Scientist: Craig Fischer, M.D., MSC

Individual Experiments or Measurements:

M111 - Cytogenetic Studies of Blood (Pre- and post-flight)

Principal Investigator: Michael Bender, Ph.D., ORNL, Tenn

Co-Investigator : Miss P. Carolyn Gooch, ORNL, Tenn

ML10 - HEMATOLOGY AND IMMUNOLOGY (Continued)

ML13 - Blood Volume and Red Cell Life Span

Principal Investigator: Phillip C. Johnson, M.D.
Baylor University, Texas

Consultants: Wallace N. Jensen, M.D., Ohio State University
David Turner, Ph.D., Hospital for Sick Children
Scott N. Swisher, M.D., Michigan State University
Vernon Knight, M.D., Baylor University
Wolf Vishniac, Ph.D., University of Rochester

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ML30 - NEUROPHYSIOLOGY (Governing Protocol)

Principal Coordinating Scientist: Milton R. DeLucchi, Ph.D., MSC

Individual Experiments or Measurements:

ML31 - Human Vestibular Function

Principal Investigator: Ashton Graybiel, M.D., Naval
Aerospace Medical Inst., Pensacola
Florida

Co-Investigator : Earl F. Miller, Ph.D., Naval
Aerospace Medical Institute,
Pensacola, Florida

ML32 - Neurological Experiment - EEG

Principal Investigators: Adey and Kelloway

Consultant: Maitland Baldwin, M.D.

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ML50 - BEHAVIORAL EFFECTS (Governing Protocol)

Principal Coordinating Scientist: Edward C. Moseley, Ph.D., MSC

Individual Experiments or Measurements:

ML51 - Time and Motion Study

Principal Investigator: Joseph F. Kubis, Ph.D., Fordham U,
New York

Co-Investigator : Edward J. McLaughlin, Ph.D.,
NASA Headquarters

Consultants: John T. Elrod, Ph.D.
Jacob Orlandsky, Ph.D.

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ML70 - PULMONARY FUNCTION AND ENERGY METABOLISM (Governing Protocol)

Principal Coordinating Scientist: Edward L. Beckman, M.D.

Individual Experiments or Measurements:

ML71 - Metabolic Activity

Principal Investigator: Mr. Edward Michel, MSC

Co-Investigator : J. A. Rummel, Ph.D., MSC

ML72 - Body Mass Measurement

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator : William Thornton, M.D., MSC

Consultants: Ulrich Luft, M.D., Lovelace Foundation
Wayland Hull, Ph.D., MSC
George C. Armstrong, Jr., M.D., MSC

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ADDITIONAL AREA OF INVESTIGATION:

ML90 - MICROBIOLOGY (Governing Protocol)

Principal Coordinating Scientist: James McQueen, D.V.M.

Assistant Coordinating Scientist: James K. Ferguson, Ph.D.

AAP MEDICAL/BEHAVIORAL EXPERIMENTS
APPROVED AS OF JANUARY 1969

- MO70 - NUTRITION AND MUSCULOSKELETAL FUNCTION (Governing Protocol)
 - MO71 - Mineral balance study to determine muscle, bone, and electrolyte changes due to space flight
 - MO72 - Measurements of bone density to determine the skeletal effects of space flight
 - MO73 - The analysis of blood and urine specimens to evaluate physiological changes occurring during and following space flight
 - MO74 - The evaluation of an inflight specimen mass measurement technique by means of its utilization in inflight mineral balance and body fluid assays studies
- MO90 - CARDIOVASCULAR FUNCTION (Governing Protocol)
 - MO91 - The evaluation of space flight induced alterations of circulatory responsiveness by means of the application of a fixed stimulus, lower body negative pressure (pre and post flight)
 - MO92 - The evaluation of space flight induced alterations of circulatory responsiveness by means of the application of a fixed stimulus, lower body negative pressure (inflight)
 - MO93 - Vectorcardiographic study of cardiac responses to space flight
- ML10 - HEMATOLOGY AND IMMUNOLOGY (Governing Protocol)
 - ML11 - Cytogenetic studies of blood (pre and postflight) to determine chromosomal changes which may be induced by space flight
 - ML13 - Blood volume and red cell life span studies to evaluate space flight induced alterations
- ML30 - NEUROPHYSIOLOGY (Governing Protocol)
 - ML31 - Human vestibular function as affected by space flight conditions
 - ML32 - The evaluation of sleep during manned space flight by means of the study of electroencephalographic patterns
- ML50 - BEHAVIORAL EFFECTS (Governing Protocol)
 - ML51 - Time and motion study of task accomplishment during space flight

ML70 - PULMONARY FUNCTION AND ENERGY METABOLISM (Governing Protocol)

ML71 - The evaluation of metabolic cost of activity during space flight

ML72 - The study of changes in body mass as influenced by space flight environmental factors utilizing a new inertial mass measurement technique

MEDICAL/BEHAVIORAL MEASUREMENT CAPABILITY
of

INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY
MEASUREMENT SYSTEM

INCLUDE

I. NEUROLOGICAL

Clinical Evaluation (to include reflexes
and sensory and motor pathways)

Agravic Perception of Personal and Extra-
Personal Space (Minimum restraint device)

Ocular Counter-Rolling

Oculogyral Illusion

Visual Task with Head Rotation

Electronystagmogram

Angular Acceleration Threshold

EEG

To be done
with litter-chair

II. CARDIOVASCULAR

Clinical Evaluation

ECG (Frank Lead System)

Phonocardiogram

Cardiac Output - (By impedance if technique
verified; by indicator-dilution
if necessary)

Arterial Blood Pressure

Venous Pressure - Peripheral

Blood Volume and Fluid Compartments -
See Hematology and Metabolism

Regional Blood Flow - Limb (or Digit)
(Distribution of Blood Volume)

Venous Compliance

(Limb Plethysmography)

Arteriolar Reactivity

INCLUDE

Arterial Pulse Contour

In-Flight Exercise

IBNP

Elastic Leotards

PROVIDE FOR INSTALLATION IF REQUIRED:

Ballistocardiogram

Carotid Body Stimulation

Thoracic Blood Flow

Venous Pressure - Central
(By Catheter if Necessary)

III. RESPIRATORY

Clinical Evaluation

Respiratory Rate

Lung Volumes Including Residual Volume
(For total lung capacity, and mixing
efficiency)

Pressure, Flow, and Volume (Simultaneously)
(→ Airway Resistance)

Compliance - Lung or Total
(Lung, if can)

INCLUDE

Distribution of Blood Flow and Gas in Lungs

Includes: Capillary Blood O_2 , CO_2 , and pH

Breath by Breath O_2 Consumption
and CO_2 Production

O_2 Consumption - With Measured
Exercise

Alveolar to Arterial Gradient
Breathing Air and 100% Oxygen

Diffusion Capacity (if suitable technique)
(look into O_2 ¹⁸ method - Dr. Richard W.
Hyde, U. of Pennsylvania, Dept. of
Physiology)

IV. METABOLISM AND NUTRITION

Clinical Evaluation

Energy Metabolism (Continuous O_2 and CO_2 Analysis
with Breath by Breath Sensitivity) with Various
Levels of Activity

Oral Temperature

Skin Temperature

Caloric Intake

Body Mass In-Flight (Thornton Technique - GFM)

[Lean Body Mass Pre- and Post-Flight] -
(Not a Part of DMBMB)

Muscle Size and Strength

Balance Studies

- Fluid, including Sweat
- Nitrogen (See Area IX)
- Mineral (See Area IX)
- Electrolyte (See Area IX)

INCLUDE

Provide for : Accurate Urine Volume Measurement

Accurate Wet Weight of Feces

Return of Total Dry Stool

Accurate Fluid Intake Measurement

Return of all Food Packages Marked
by Date Time and Individual

Sweat Measurement and Sample Return

Total Body Water (Breatholator or Deuterium)

‡ Clinical Laboratory Evaluations - See List Under Area IX

PROVIDE FOR INSTALLATION IF REQUIRED:

FMG

Bone Densitometry - Isotope Technique

Gastric Pressure and pH (Endoradiosonde)

Plasma Volume On-Board

Mineral Metabolism by Isotopic Techniques

V. ENDOCRINOLOGY

Clinical Evaluation

‡ Clinical Laboratory Evaluations - See List

INCLUDE

VI. HEMATOLOGY

Clinical Evaluation

Rumple Leeds

Blood Volume and Fluid Compartment

Plasma Volume - IRIISA

RBC Mass - DFP32 or Cr51

Total Body Water

RBC Survival - DFP32

Clinical Laboratory Evaluations - See List

VII. MICROBIOLOGY AND IMMUNOLOGY

Clinical Evaluation

Body Microflora (Bacterial, Viral, and Fungal)

Environmental Culturing (Bacterial, Viral, and Fungal)

Clinical Laboratory Evaluations - See List

VIII. BEHAVIORAL EFFECTS

Clinical Evaluation

Sensory Test Battery (See Also Neurology)

Perceptual Evaluation (If validity of Tests Established)

Higher Thought Processes

Memory - Short and Long Term

Vigilance (By measurement of operational tasks)

INCLUDE

Learned Activity (Tracking and Reaction Time)

Recording of Crew Intercommunication with
Automatic Phrase in 15 Minutes if not Sampled

Time and Motion Study

<u>IX. CLINICAL LABORATORY EVALUATIONS</u>	<u>Reference Area</u>
Creatine and Creatinine - Urinary	IV
Urinary and Fecal: N, Ca, P, Na, K, Cl, and Mg	IV
Mucoproteins - Urinary (P1)**	IV
Pyrophosphates - Urinary (P1)**	IV
Hydroxyprolines - Urinary (probably P1)**	IV
Total Amino Acids - Urinary (P1)**	IV
Urinary: Osmolality, Color, Sp Gr, pH, Glucose, Protein, Bile, Blood, and Microscopic (i.e., Routine Urinal- ysis - Inflight)	IV
Plasma Volume (probably P&P)*	IV & VI
Electrolytes - Serum	IV
Total Protein - Plasma	IV
Protein Electrophoresis - Plasma	IV
Glucose - Blood (Inflight)	IV
Ca and PO_4 - Serum (probably P1)	IV
Bilirubin - Serum	

*p&p - pre & post-flight

**p1 - Post-flight evaluation of inflight samples

INCLUDEReference Area

Cholesterol - Serum (probably P1)	IV
BUN (probably P1)	IV
Uric Acid - Blood (P1)	IV
Alkaline Phosphatase - Serum (probably P1)	IV
pH, pO ₂ , and pCO ₂ - Blood	III & IV
Bicarbonate - Blood	III & IV
CPK (Creatine Phosphokinase - Serum (P1)	IV
LDH and LDH Isoenzymes - Serum (On-board if have electrophoresis)	IV
SGOT - Serum	IV
SGPT - Serum	IV
Aldosterone - Urine (P1)	IV & V
ADH - Urinary and Serum (P1)	V
ACTH - Blood (P1)	V
Serum Free Thyroxin (T ₄ - Serum) (If in-flight, will require thin layer chromatography)	V
TRPA (Probably P1)	V
17-hydroxycorticosteroids - Urine and blood (P1)	V
17-ketosteroids - Urine (P1)	V
VMA - Urine (Probably P1)	V
Metanephrines - Urine (P1)	II & V
Catechols - Urine (P1)	II & V
Histamine - Blood and Urine (P1)	II & V

INCLUDEREFERENCE AREAPROVIDE FOR INCLUSION IF REQUIRED (Cont'd):

Parathyroid Hormone (Radio- Immune Technique - Serum) (P1)	V
Parathyroid Hormone - Urinary (Nelson Technique - (P1)	V
Calcitonin - Serum (P1)	V
Insulin Assay (P1)	V
Glucagon Assay (P1)	V
Serotonin (5 HIAA) - Blood (P1)	V
Platelet Adhesiveness	VI
Fibrinolytic Activity	VI
Blood Rheology	VI
Blood Lipids	VI

MEDICAL EXPERIMENTS PROGRAM

OBJECTIVES

- A. TO EXTEND MAN'S CAPABILITIES IN MANNED SPACE FLIGHT BY DETERMINING:
1. THE EFFECTS OF SPACE FLIGHT ON MAN, AND THE TIME COURSE OF THESE EFFECTS.
 2. THE SPECIFIC ETIOLOGIES AND MECHANISMS BY WHICH THESE EFFECTS ARE MEDIATED.
 3. MEANS OF PREDICTING THE ONSET AND SEVERITY OF UNDESIRABLE EFFECTS.
 4. THE MOST EFFECTIVE MEANS OF PREVENTION OR CORRECTION OF UNDESIRABLE EFFECTS.
- B. TO OBTAIN SCIENTIFIC INFORMATION OF VALUE TO CONVENTIONAL MEDICAL RESEARCH AND PRACTICE.

Figure 1

FIGURE 1

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
MAJOR CONCEPTS

Figure

1. ABLEST PRINCIPAL INVESTIGATORS OF SCIENTIFIC COMMUNITY
2. EXPERIMENTS DIRECTED TOWARD: (a) INVESTIGATION OF KNOWN PROBLEMS
(b) IN DEPTH SYSTEMS MONITORING FOR EARLY IDENTIFICATION OF POTENTIAL PROBLEMS
3. RE TECHNICAL CONTENT: (a) MOST IMPORTANT VARIABLE IS DURATION OF FLIGHT
(b) MOST UNKNOWN ENVIRONMENTAL FACTOR IS PROLONGED WEIGHTLESSNESS
4. RE ARTIFICIAL G: (a) FIRST EVALUATE MAN IN LONG DURATION WEIGHTLESSNESS
(b) UTILIZE SHORTER FLIGHTS TO DETERMINE OPTIMAL ARTIFICIAL G TECHNIQUES
(c) INCLUDE ARTIFICIAL G OPTION IN DESIGN OF SPACE STATION
5. EXPERIMENT REPETITION REQUIRED TO ESTABLISH STATISTICALLY VALID DATA.

FIGURE 2

NASA SPONSORED SOURCES OF AAP EXPERIMENTS (MEDICAL BEHAVIORAL)

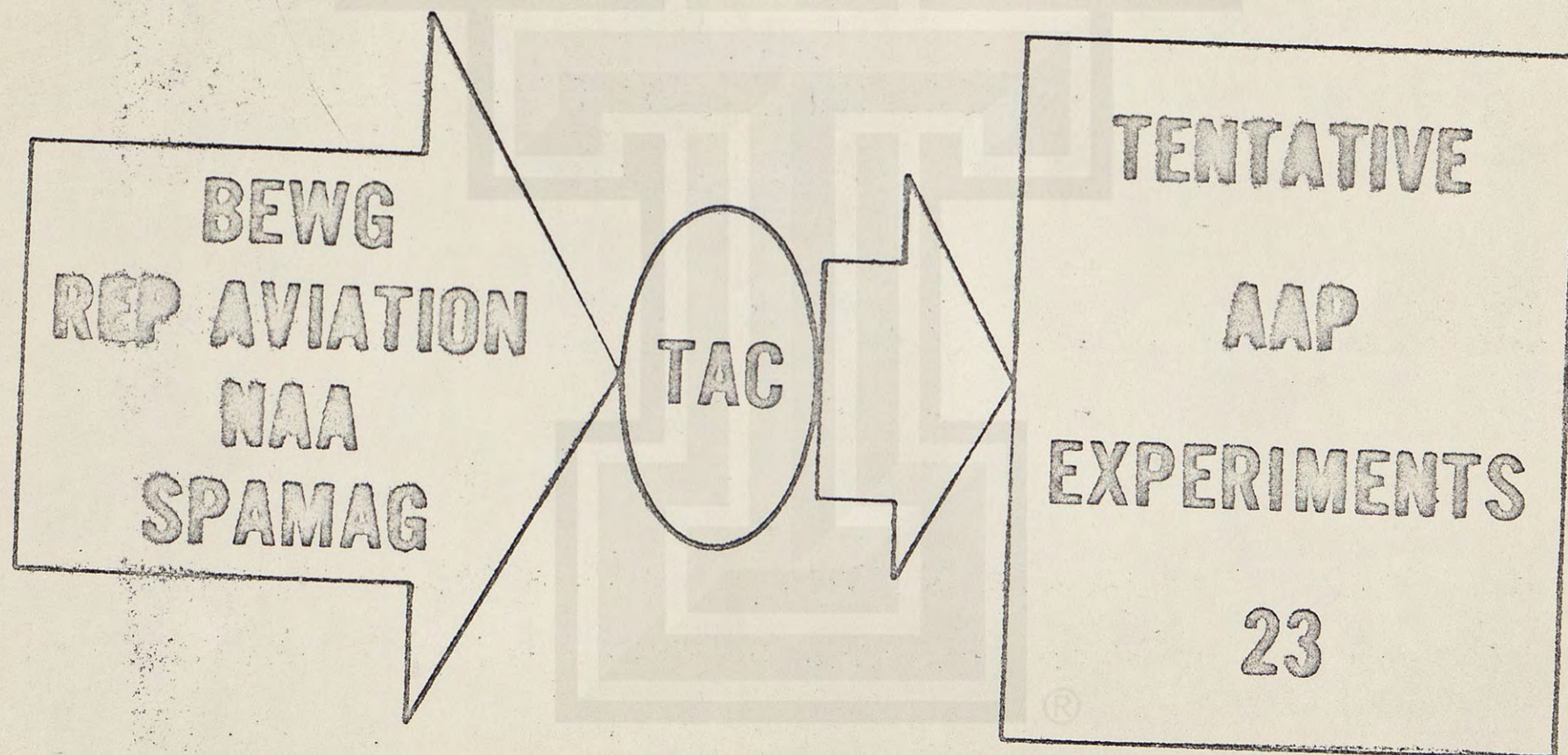


FIGURE 3

AREAS OF BODY FUNCTION TO BE INVESTIGATED

AAP MEDICAL-BEHAVIORAL EXPERIMENTS

1. NEUROLOGICAL
2. CARDIOVASCULAR
3. RESPIRATORY
4. METABOLIC & NUTRITIONAL
5. ENDOCRINE
6. HEMATOLOGICAL
7. MICROBIOLOGICAL & IMMUNOLOGICAL
8. BEHAVIORAL

Figure

FIGURE 4

EIGHT AREAS OF MEDICAL EVALUATION

EXPERIMENTS	NEURO.	RESP.	CARDIO-VASC.	METAB. & NUTRITION	ENDOCR.	HEMATOL.	MICROBIOL.	BEHAV.
GEM.	M008 M009	M003	M001 M003 M004 M005 MED. OPS.	M005 M006 M007	M005	MED. OPS.		MED. OPS.
AP.		M020	M012 M017 M023 M048	M012 M019		M011	MED. OPS.	

FIGURE 5

GEMINI MEDICAL EXPERIMENTS

- M-1 CARDIOVASCULAR CONDITIONING
- M-3 INFLIGHT EXERCISER
- M-4 INFLIGHT PHONOCARDIOGRAM
- M-5 BIOASSAYS BODY FLUIDS
- M-6 BONE DEMINERALIZATION
- M-7 CALCIUM BALANCE STUDY
- M-8 INFLIGHT SLEEP ANALYSIS
- M-9 HUMAN OTOLITH FUNCTION

Figure 6

FIGURE 6

MEDICAL EXPERIMENTS PROGRAM
FUNCTIONAL ORGANIZATION

Figure 7

I. MEDICAL/BEHAVIORAL EXPERIMENTS

- A. DETERMINATION OF REQUIREMENTS AND MAINTAINING RELATIONSHIPS, SUPPORT, AND PARTICIPATION OF THE SCIENTIFIC COMMUNITY.
- B. REVIEW OF EXPERIMENT PROPOSALS FOR SCIENTIFIC MERIT.
- C. SUPPORT OF EXPERIMENTS IN DEFINITION.
- D. SELECTION, CONVERSION, AND SUPPORT OF EXPERIMENTS FOR DEVELOPMENT PHASE.
- E. SUPPORT AND GUIDANCE DURING OPERATIONAL DATA GATHERING, AND POST MISSION DATA REDUCTION AND REPORTING PHASES.
- F. APPLICATION OF DATA TO THE MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM, MANNED SPACE FLIGHT, AND THE CIVILIAN COMMUNITY AS INDICATED.

FIGURE 7

II. R&D SUPPORT OF MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM

- A. IMBIMS (INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM).
- B. PARALLEL DEVELOPMENT EFFORTS TO ADVANCE STATES OF THE ART IN MEASUREMENT TECHNIQUES AND EQUIPMENT TO ENHANCE THE CAPABILITIES OF IMBIMS AND PROPOSED EXPERIMENTS.
- C. SIMULATIONS AND GROUND BASED DATA, I.E., THE SUPPORT OF GROUND BASED SIMULATION AND OTHER STUDIES IN ORDER TO OBTAIN A BODY OF PERTINENT DATA AS A NORMATIVE OR CONTROL BASE TO PERMIT THE EXTRACTION OF VALID CONCLUSIONS FROM FLIGHT DATA.

MEDICAL / BEHAVIOR EXPERIMENTS PROGRAM SCIENTIFIC MERIT EVALUATIONS SYSTEM

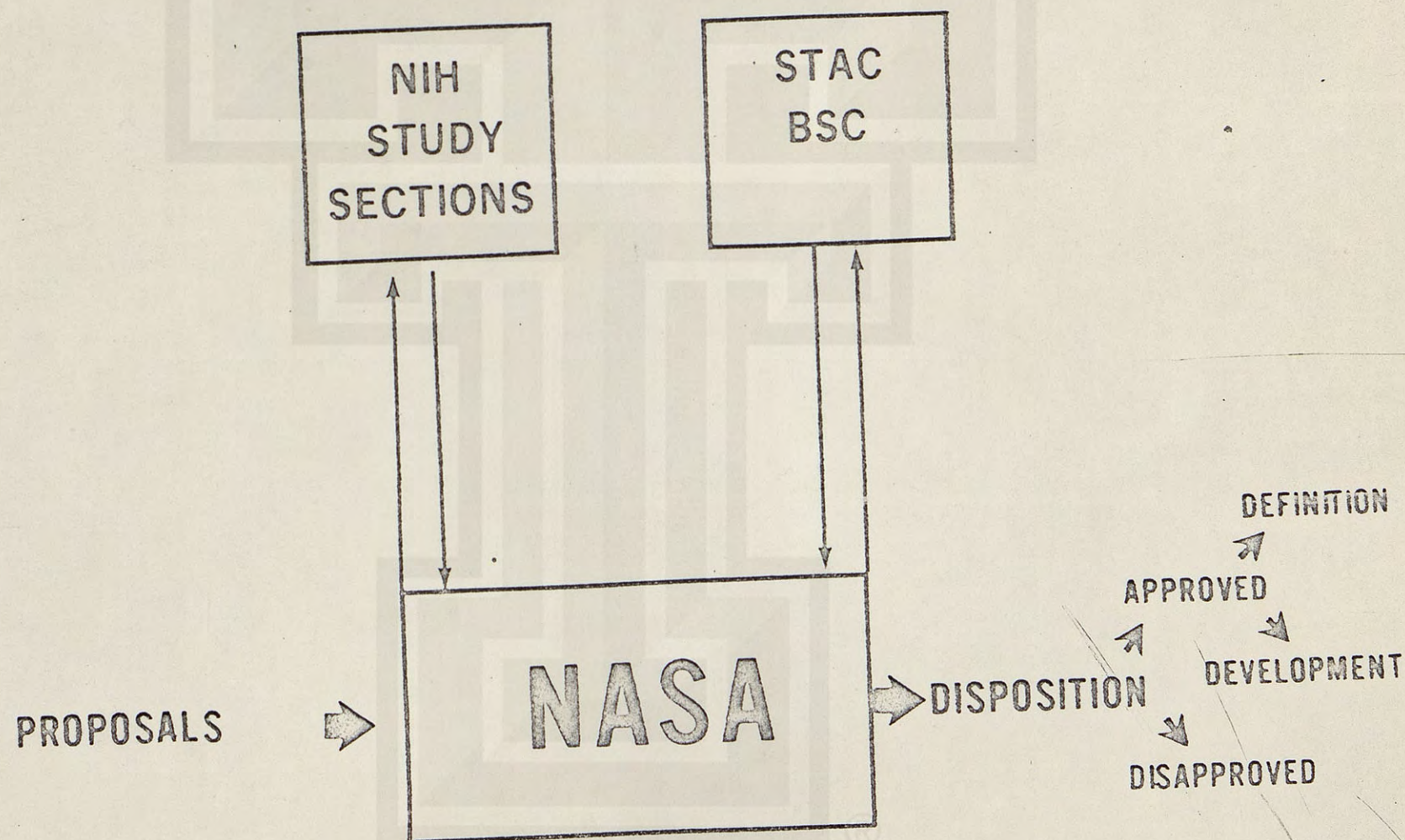


FIGURE 8

NASA HQ MM69-4377
2-14-69

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
EXISTING EXPERIMENTS
(FEBRUARY 1969)

Figure

FIGURE 9

	Nutr. & Musc. Skel. (M070)	Cardio- vascular (M090)	Hematol. & Immun. (M110)	Neuro- physiol. (M130)	Behav. Effects (M150)	Pulm. Funct. & Energy Metabolism (M170)	Micro- biology (M190)	Endocrine (M210)
Development (Approved AAP)	M071 M072 M073 M074	M091 M092 M093	M111 M113	M131 M132	M151	M171 M172		
Definition	M075 M076		M114 M115					M211
In Review	One	One	Three (Incl. review of M114 for develop- ment			One	Three	

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
EXPERIMENTS IN DEVELOPMENT
(FEBRUARY 1969)

Figure 1

FIGURE 10

- | | | | |
|------|--|------|---|
| ---- | | ---- | |
| M071 | - MINERAL BALANCE
DOCTORS WHEDON & LUTWAK (NIH & CORNELL) | M111 | - CYTOGENETIC STUDIES
DR. BENDER (ORNL) |
| M072 | - BONE DENSITOMETRY
DR. MACK (TEXAS WOMEN'S U) | M113 | - BLOOD VOLUME
DR. P. JOHNSON (BAYLOR) |
| M073 | - ANALYSIS OF BODY FLUIDS
DR. FISCHER (MSC) | ---- | |
| M074 | - SPECIMEN MASS MEASUREMENT
COL ORD (BROOKS AFB) | M131 | - VESTIBULAR FUNCTION
DR. GRAYBIEL (NAMI, USN) |
| ---- | | M132 | - EEG
DRS. ADEY & KELLOWAY (UCLA & BAYLOR) |
| M091 | - LBNP (PRE AND POSTFLIGHT)
COL ORD (BROOKS AFB) | ---- | |
| M092 | - LBNP (INFLIGHT)
DR. R. JOHNSON (MSC) | M151 | - TIME AND MOTION
DRS. KUBIS & McLAUGHLIN (FORDHAM &
NASA HQS.) |
| M093 | - VECTORCARDIOGRAM
CAPT. ALLEBACH (NAMI, USN) | ---- | |
| | | M171 | - METABOLIC ACTIVITY
MR. MICHEL (MSC) |
| | | M172 | - BODY MASS MEASUREMENT
COL ORD (BROOKS AFB) |

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
EXPERIMENTS IN DEFINITION
(FEBRUARY 1969)

Fig 11

- *M075 - GASTRIC MOTILITY
DR. M. PETERSON (WASHINGTON U)
- *M076 - CHEMICAL ANALYTICAL TECHNIQUES
DR. HUEBNER (BECKMAN INSTRUMENTS, INC.)
- M114 - RED BLOOD CELL METABOLISM
DR. MENGEL (U. OF MISSOURI)
- **M115 - ENDOGENOUS CO PRODUCTION
DRS. LAWRENCE & WINCHELL (U OF CALIFORNIA)
- **M211 - URINARY ENDOCRINE ASSAY
DR. NELSON (LATTER DAY SAINTS)

*AWAITING FUNDING FOR INITIATION

**AWAITING FUNDING FOR CONTINUATION

FIGURE 11

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
EXPERIMENT PROPOSALS IN REVIEW
FOR SCIENTIFIC MERIT
(FEBRUARY 1969)

Figure

NUTRITION AND MUSCULOSKELETAL FUNCTION

- SKELETAL STATUS***
DR. CAMERON (U. OF WISCONSIN)

CARDIOVASCULAR FUNCTION

- SPACE BALLISTOCARDIOGRAPHY*
DRS. CUNNINGHAM & SMITH (U OF CALIF.
& STANFORD)

HEMATOLOGY AND IMMUNOLOGY

- MAN'S IMMUNITY, IN VITRO ASPECTS**
DRS. RITZMANN & LEVIN (U OF TEXAS)
- RED BLOOD CELL METABOLISM (ML14)**
DR. MENGEL (U OF MISSOURI)
- SPECIAL HEMATOLOGIC EFFECTS**
DR. FISCHER (MSC)

PULMONARY FUNCTION AND ENERGY METABOLISM

- PULMONARY FUNCTION*
DR. WEST (U OF CALIF., LAJOLLA)

MICROBIOLOGY

- BACTERIOLOGY AND MICOLOGY**
DR. FERGUSON (MSC)
- VIROLOGY **
DR. McQUEEN (MSC)
- SPACECRAFT ECOLOGY**
DRS. McQUEEN & FERGUSON (MSC)

*CANDIDATE FOR DEFINITION
**CANDIDATE FOR DEVELOPMENT
***CANDIDATE FOR DEFINITION AND DEVELOPMENT (2 PARTS)

FIGURE 12

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
IMBIMS

Figure

AIMS

1. PROVIDE INFLIGHT MEASUREMENT CAPABILITY TO ACCOMMODATE ALL MEDICAL/BEHAVIORAL EXPERIMENTS
2. PROVIDE MAXIMUM FLEXIBILITY FOR:
 - a. ADAPTABILITY TO LATE CHANGES IN MISSION EXPERIMENT PLANS
 - b. EASE OF INFLIGHT MAINTENANCE
 - c. EASE AND ECONOMY OF INCORPORATION OF UPDATED TECHNIQUES AND EQUIPMENT

IMBIMS FUNCTIONAL ELEMENTS

1. PHYSIOLOGICAL MEASUREMENT
2. BEHAVIORAL MEASUREMENT
3. BIOCHEMICAL
4. MICROBIOLOGICAL
5. DATA MANAGEMENT

FIGURE 13

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
IMBLMS PROGRAM MILESTONES

Figure

FIGURE 14

PHASE A - EARLY DEFINITION

AUG. 1964 - NASA'S FOUR STUDIES COMPLETED
FEB. 1965 - TECHNICAL ADVISORY COMMITTEE (DR. SEAMAN'S STUDY)
OCT. 1965 - MOCK-UP AND TIME LINE STUDY (IMSC)
to
FEB. 1966

PHASE B - FINAL DEFINITION

MAR. 1966 - PHASE B1 WORK STATEMENT WRITTEN AND COORDINATED;
to
DEC. 1966 - PROCUREMENT PLAN APPROVED; SEB ESTABLISHED; AND
RFP RELEASED
FEB. 1967 - PROPOSALS RECEIVED AND EVALUATED; SELECTION
to
APR. 1967 - OF TWO COMPETING CONTRACTORS (GE AND IMSC)
BY MR. WEBB
JUNE 1967 - PHASE B1 CONTRACTS
to
OCT. 1967
DEC. 1967 - PHASE B2 CONTRACTS
to
FEB. 1968
DEC. 1968 - PHASE B3 CONTRACTS INITIATED
FEB. 1969 - TRANSFER OF CONTRACTS FROM HQS. TO
IMBLMS PROJECT OFFICE, MSC, MR&O

JAN. 1970 - PHASE B3 COMPLETED

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
IMBIMS PROGRAM MILESTONES (CONT'D)

Figure

PHASE C - DESIGN

JAN. 1970 - PHASE C1 (PRELIMINARY DESIGN) INITIATED

SEP. 1970 - PHASE C1 COMPLETE; SINGLE CONTRACTOR SELECTED

SEP. 1970 - PHASE C2 (FINAL DESIGN) INITIATED

PHASE D - DEVELOPMENT (FABRICATION)

AUG. 1971 - PHASE C2 COMPLETE; OVERLAPPING INITIATION OF PHASE D

AUG. 1972 - FLIGHT IMBIMS FABRICATED AND QUALIFIED

FIGURE 15

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
PARALLEL DEVELOPMENT

Figul

REQUIREMENTS (SELECTED)

METABOLIC ANALYZER, RAPID RESPONSE, ADAPTABLE TO SUITED ACTIVITY
MICROBIAL CULTURE AND IDENTIFICATION TECHNIQUES FOR INFLIGHT USE
TECHNIQUES FOR INFLIGHT BIOCHEMICAL ANALYSIS
SAMPLE PRESERVATION TECHNIQUES FOR INFLIGHT USE
IMPROVED LIMB PLETHYSMOGRAPHY TECHNIQUES
NON-INVASIVE CARDIAC OUTPUT DETERMINATION TECHNIQUES
NON-INVASIVE VENOUS PRESSURE TECHNIQUES
BEHAVIORAL MEASUREMENT TECHNIQUE REFINEMENT
BLOOD CELL COUNTING TECHNIQUES FOR INFLIGHT USE
TECHNIQUES FOR INFLIGHT MEASUREMENT OF PULMONARY DIFFUSION CAPACITY
IMPROVED URINE VOLUME MEASUREMENT DEVICE

FIGURE 16

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
PROBLEMS

Figure 17

MEASUREMENT OF METABOLISM DURING EVA

ACCURATE FLUID INTAKE AND OUTPUT MEASUREMENT IN FLIGHT

CULTURE AND IDENTIFICATION OF VIRUSES IN FLIGHT

BIOCHEMICAL ANALYTICAL TECHNIQUES SUITABLE FOR SPACE FLIGHT

PREDICTIVE INDICES AND SENSITIVE EVALUATIVE TECHNIQUES TO DETERMINE GROUP INTEGRITY AND
THE PROBLEMS OF LONG TERM GROUP ISOLATION

- BROAD PROBLEMS:
- a. DETERMINE THE NEED FOR ARTIFICIAL G
 - b. DETERMINE TASKS BEST ACCOMPLISHED BY MAN AND THOSE BEST DONE
BY AUTOMATION

FIGURE 17

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
RESOURCES

FUNDS (IN 1000'S)

I. EXPERIMENTS	FY69	FY70
DEVELOPMENT	7613	11414
DEFINITION	400	0 AVAIL.
II. R&D SUPPORT		
IMBLMS	2350	3800
PARALLEL DEVELOPMENT	0 AVAIL.	?
SIMULATIONS & G/B DATA	0 AVAIL.	?

PERSONNEL (PRESENT TOTALS - MSC)

CIVIL SERVICE	13
CONTRACTOR	0 (IMBLMS TEST CONTRACT PERSONNEL TO BE ADDED)

Fig 18

FIGURE 18

Figure

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
ISSUES

1. FUNDING DEFICIENT AND INSECURE
2. PERSONNEL INSUFFICIENT, ESPECIALLY AT MSC
3. PROCUREMENT CYCLE EXCESSIVELY LONG
4. PROGRAMMATIC ISSUE

FIGURE 19

MEDICAL/BEHAVIORAL EXPERIMENTAL PROGRAM

REVIEW FOR THE NATIONAL

ACADEMY OF SCIENCE

NASA LIFE SCIENCES REVIEW

Thursday, September 11, 1969

by

S.P. Vinograd, M.D.
Director, LMBMS Program and
Research and Technology

Space Medicine, Manned Space Flight

MEDICAL EXPERIMENTS PROGRAM

The medical and behavioral experiments program is a group of activities directed toward the evaluation of changes in human function and capabilities which may be induced by space flight. The objectives of the program exist as two categories, each having its own projected application or purpose (Fig. 1).

The first is geared toward manned space flight. Its four objectives express the intention to determine as precisely as possible man's medical and behavioral responses, functional limitations, and supportive requirements in space flight. The information gained is applied to the planning of future manned space flight missions and programs. Effective planning and judicious manned versus unmanned tradeoffs will continue to be strongly dependent upon how well these objectives are fulfilled.

The second category of objectives is oriented toward earth based medical science. Its purpose is to advance medical research by carrying out well-conceived experiments designed to utilize the unique environmental characteristics of space for scientific information, whether or not the resulting data will be any way applicable to manned space flight. As an example, any physiological function which might be considered to be gravity dependent in some respect is potential subject matter for profitable investigation in the space environment.

The four objectives given in the first category are a general statement of the questions which the program is attempting to resolve. The specific questions being pursued have been formulated and arranged in order of priority. A representative list of top priority questions follow as Appendix A.

The program which has been designed to meet these objectives consists of two primary areas of activity: Experiment Management, the support of the experiments, themselves, during definition and development; and Ground Based Research and Development, the effort to develop integrated flight laboratory equipment, new and improved medical evaluative techniques to enhance our inflight capability, and to obtain ground based data, all of which are essential elements supporting the flight medical experiments effort.

The program can be further characterized by certain of its more important concepts. An enumeration of these might serve to convey a more complete picture of this effort (Fig. 2). First, experiment principal investigators are not limited to NASA personnel. Because the space program is both national in scope and scientific in nature, because the mounting of experiments aboard space flights is extremely expensive, and because flight opportunities are relatively infrequent, strong emphasis is placed upon the participation of the most highly competent individuals of the scientific community as principal investigators, whether they are from outside or within NASA. Secondly, a general philosophy of the program is to plan experiment flight schedules not only to explore known or expected

problems in depth, but also to conduct human systems monitoring across the board to the extent and level of detail consistent with good practice and practicality. As an example of the importance of this concept, had this not been done in Gemini we would still be totally unaware of the red blood cell and fluid compartment changes which were found. Thirdly, regarding the technical content of the program, the major variable is duration of flight. The most unknown environmental factor is prolonged weightlessness. This does not by any means imply that weightlessness is the only factor of interest, or even that it will necessarily turn out to be the most important. However, it is an important factor and it remains unknown because of our inability to reproduce it for much over thirty seconds in the earth environment. Fourth, with respect to the question of artificial g, the medical/behavioral experiments program seeks to establish the need for it by evaluating flight crews exposed to the unaltered zero g environment on flights of increasing durations. Shorter term flights can provide the opportunity to investigate and establish artificial g techniques most consistent with optimal crew, spacecraft, and mission function and performance. However, until the need for artificial g can be better determined, it is our feeling that this capability should be included in at least the design of future spacecraft. Fifth, the small number of flight crew members and the broad range of variability of individual responsiveness to a given set of conditions, which is so characteristic of us humans, necessitate the repetition of most experiments to establish statistical validity of flight findings.

Lastly, the Medical/Behavioral Experiments effort must be viewed as a continuing one serving and being served by a succession of flight programs. Since for most investigations, the most important variable is duration of crew exposure to spaceflight, each of these experiments is really a continuum of observations which are made over the course of a series of flight programs from the 14 day maximum flights of Gemini through the two year maximum crew exposures to be provided by the space station. As the Medical/Behavioral Experiments Program matures new experiments, generated to fulfill needed areas of evaluation and to explore fruitful scientific research of potential benefit to earth based medicine, will be prepared for development and added to the program. Experiments will be withdrawn as they appear to have achieved optimum value to their respective hypothesis, or as they have been superseded by improved or more refined ones.

The medical/behavioral experiments program began in 1963 with the study of the Biomedical Experiments Working Group (Fig. 3). This was an ad hoc group of NASA life scientists who devoted a series of meetings to an evaluation of the medical and behavioral aspects and requirements of an orbiting research laboratory. This was followed by two study contracts with industry, one with Republic Aviation and the other with North American Aviation, to explore this question in greater depth. In January 1964, the Space Medicine Advisory Group (SPAMAG), a group of 20 prominent consultants of the medical community, began its in-depth study of this problem. The SPAMAG report followed a series of eight two-day meetings chaired jointly by the NASA and the DOD.

In February 1965, a Technical Advisory Committee of ten NASA Center and Headquarters Life Sciences personnel was called together to assemble from these four reports a group of medical and behavioral experiments which could be considered candidates for an AAP (then AES) flight program. This was part of an exercise conducted for Dr. Seamans and resulted in the formulation of 23 medical/behavioral experiment concepts as a representative AAP (AES) medical experiments package. Shortly thereafter, this group of pseudo-experiments was reassembled into its eight component areas of body function, each with its list of required measurements and procedures (Fig. 4). This list has been reviewed and updated repeatedly with the aid of our consultant advisors, the Biomedical Subcommittee of STAC (formerly the Medical Advisory Council) and constitutes the desired measurement capability of the IMBIMS.

The first flight manifestation of the medical/behavioral experiments program took place in Gemini, preparations for which began in early 1964. The Gemini package consisted of eight experiments several of which were flown on more than one mission (Fig. 5 and 6). The experiments plan for the Apollo program was an expansion of the Gemini package, but necessary alterations of the flight program ultimately restricted these plans to the extent that only three pre- and postflight experiments have actually been implemented. The remainder are delayed until AAP.

As alluded to earlier, the medical/behavioral experiments program is functionally organized into two mutually dependent areas of activity (Fig. 7). The first consists of the planning, solicitation, and management of the experiments, themselves, during both definition and development. The activities entailed are outlined on this slide. Of these, the review

for scientific merit, deserves an additional word of explanation (Fig. 8). The system, which has been employed since 1966, includes an objective scientific review by the NIH Study Section system and a succeeding evaluation, also scientific but oriented toward Manned Space Flight capabilities and requirements, by a highly qualified team of medical consultants to NASA. This group was established in May 1965 as the Medical Advisory Council and is now the Biomedical Subcommittee of Dr. Mueller's Science and Technology Advisory Committee (STAC).

The present program of medical experiments is organized into the exploration and evaluation of the eight areas of body function mentioned earlier (Fig. 9). The individual experiments are components of these eight overall endeavors. There are currently sixteen experiments in development for AAP, and four experiments in definition. The slide (Fig. 10) indicates the body function areas and corresponding experiment numbers. The presently approved experiments cover six of these eight areas. A governing protocol describing the investigation of each functional area is included in existing documentation. The AAP medical/behavioral experiments now in development, their organization, designators, and personnel are shown in Appendix B. Appendix C lists these same experiments using more descriptive titles to better indicate their content.

Experiments in definition are those which are not yet ready for flight assignment (experiment development). At such time as they are considered sufficiently mature in terms of experimental design functional hardware, and preliminary ground based data, they will be proposed to the Manned Spaceflight

Experiments Board (MSEB) for approval and assignment to a flight program for development.

Of the four experiments in definition, three have been funded and the remaining one is presently being processed for contract signature. These are shown in Fig. 11.

In addition to these, five proposals for experiment definition are anticipated in the near future (Fig. 12). Some of these will be resubmissions which are amended versions of previously submitted proposals. Others will be experiments growing out of supported R & D efforts. Still others are proposals expected from principal investigators who have given advanced notice of their intentions to submit them.

All of these still fall short of fulfilling our investigational needs. In the fall of 1967 we organized a consultant study to attempt to further define our medical requirements. It was arranged into three tasks Fig. 13 to identify as clearly as possible the questions which we are or should be seeking to resolve with respect to human responses to space flight; (2) to identify supportive research tasks; and (3) to identify specific items of information which the field of space medicine requires of the space investigations of the physical sciences. Included in the first task were judgements of the degree to which inflight animal experiments could contribute to the resolution of each of these questions. All questions and recommendations throughout the study were given a priority rating of I, II, or III, to be interpreted as a consensus judgement of over-all importance. The questions listed in Appendix A are a condensed but unabridged version of the priority I questions which resulted from that study. By comparing our on-going and expected experiments with this list of information requirements a series of additional experiment needs are apparent. This is

shown in Fig. 14

Turning now to the R & D support of the medical/behavioral experiments program, three task areas are defined. The first of these, the Integrated Medical and Behavioral Laboratory Measurement System (IMBLMS) program, will develop a highly flexible and sophisticated laboratory system to accommodate the medical and behavioral measurements required for all existing experiments as well as those anticipated for the future. The medical/behavioral experiments program is unique in that it is an effort to gain sound scientific knowledge of human responses to virtually unknown environment by means of research in a medium which requires hard, complex and predetermined engineering and operational interfaces. The IMBLMS concept was devised to meet this set of circumstance by providing maximum internal flexibility (modularity) with minimal or no impact on its basic envelope of external needs. The two basic aims of the IMBLMS are (1) the accommodation of medical and behavioral investigations in accordance with the full objectives of the program, and, (2) provision of maximum flexibility (Fig.15). It is basically a rack and module system which can be assembled into working consoles according to the requirements of the spacecraft and the experiments program for any particular mission. Hardware modules or submodules for a specific experiment can be developed to fit the specifications of the IMBLMS and utilized on an "as needed" basis. The flexibility afforded by the modular approach will significantly reduce lead time requirements, enhance inflight maintenance, and enable the relatively inexpensive introduction of updated techniques and equipment. The IMBLMS will consist of five functional elements: (1) physiological, (2) behavioral, (3) biochemical, (4) microbiological, and, (5) data management. Together they will accommodate required measurements in all eight areas of medical/behavioral investigation. Appendix D is the list

of measurement requirements currently targeted for the flight IMBIMS. For the Second Dry Launch Workshop or Space Station, the IMBIMS will be composed of two or three consoles plus four to six pieces of peripheral equipment such as the bicycle ergometer, rotating litter chair, body mass measurement system, and lower body negative pressure device.

The IMBIMS concept grew out of the studies discussed earlier. The need for time-lining the 23 pseudo-experiments issuing from the Dr. Seamans exercise in early 1965 resulted in our extending an existing MIT contract with Lockheed to build a mock-up of a medical/behavioral laboratory in a mock-up of a LEM and time line these measurements with crew suited and unsuited (Fig. 16). This was accomplished as a four-month effort which ended in February 1966. In our first draft work statement in March 1966, we defined the present highly flexible IMBIMS concept including modularity, prefabricated rack mountings and interfaces, etc., and began preparations for Phase B of this phased project procurement. A Source Evaluation Board was established, an RFP drawn up and distributed, responses were evaluated, and in April 1967, two contractors were selected by Mr. Webb. Phase B1 work started in June 1967 followed by Phase B2 in October 1967. The present Phase B3 was begun in December 1968. The two contractors are continuing to work competitively in this thirteen-month phase, which will result in fabrication and test of a functional breadboard of IMBIMS. Completion of the first flight units is currently scheduled for the summer of CY73 (Fig. 17). However, schedules will be altered in accordance with manned space flight requirements. It is anticipated that competition will be terminated at the initiation of hard design, Phase C2. An IMBIMS Project Office has now been established in the Medical Research and Operations Directorate at the Manned Spacecraft Center in Houston. The IMBIMS Program Office, NASA Headquarters, is in the Directorate

of Space Medicine. The two IMBMS contracts were transferred from Headquarters to the MCC Project Office in February, 1969.

The second task area of the R & D support of the program consists of a series of independent grants and contracts aimed at advancing states-of-the-art of measurement techniques and equipment to augment the capabilities and accuracies of the IMBMS. This is an important task area for many reasons, a major one being that many standard techniques are not adaptable to the environmental and other circumstances of manned space flight. Most of these requirements (Fig. 18) were identified several years ago. Existing efforts to meet them are progressing satisfactorily but there is a need for expanded efforts, especially in the areas of behavior, biochemistry, microbiology, energy metabolism during suited activity, and our old chronic problem of accurate fluid intake and output measurement.

The third R & D task area consists of chamber studies, bed rest studies, and similar types of simulations as sources of essential ground based data. Although individual principal investigators do obtain ground based or control data as part of their experiments, economic feasibility dictates that evaluations of certain environmental factors such as spacecraft atmosphere by long term chamber studies, weightlessness as simulated by bed rest, etc., are best done by NASA with the participation of all principal investigators whose flight findings would be influenced by these aspects of the environment.

The over-all program of Medical/Behavioral Experiments is oriented toward both space operations and scientific gain. It is viewed as an essential contributor to two of the major decision areas with which we (NASA) are now

CONFRONTED: The questions of manned vs. automated task accomplishment,
and the requirement for artificial gravity.

QUESTIONS MEDICAL/BEHAVIORAL AREA
NEEDING TO RESOLVE

NEUROPHYSIOLOGY

1. What are the effects of the space flight environment on sleep?
2. What is the change in susceptibility to motion sickness as a function of:
 - a. Time aloft?
 - b. Freedom of movement within the spacecraft?
 - c. Rotation of the spacecraft?
3. What are the effects of sustained loss of gravitational cues on sensory perception (the special senses, kinesthesia, and other somatic senses) and on spatial orientation?

PULMONARY FUNCTION AND ENERGY METABOLISM

1. What are the effects of sustained weightlessness on the mechanics of breathing in which, normally, the gravitational forces interact with the respiratory muscles and elastic forces of the chest and lungs?
2. What is the energy cost (metabolic gas exchange) at rest and during activity in the spacecabin with and without the suit, in normal flight and during EVA?
3. What is the degree and duration of arterial hypoxia due to ventilation/perfusion inequality in the lungs during launch and re-entry in space flight?
4. Are there any alterations in alveolar gas transfer or the control of breathing under prolonged combined effects of weightlessness and a low pressure mixed gas or pure oxygen environment?

CARDIOVASCULAR FUNCTION

1. Is cardiac output adequately maintained in prolonged space flight?
2. To what extent does space flight affect normal arterial pressure controls?

- 2
3. How are venous compliance and central venous pressure and their adjusting mechanisms influenced by prolonged space flight?
 4. How is cardiac function affected by long duration space flight?
 5. What are the factors of space flight which cause changes in circulating blood volume and its distribution? At what point and under what conditions is a new equilibrium established?
 6. What is the time course of changes in overall circulatory function as determined by provocative testing (tilt table, LBNP)?

NUTRITION AND MUSCULOSKELETAL FUNCTION

1. What are the actual caloric requirements and the variables in caloric utilization under varying workloads and under varying configurations of space suit constraints in long duration space flight?
2. What are the space flight factors or stress conditions which might change caloric, water, electrolyte, or mineral requirements? To what extent do they change these requirements?
3. By what predictive or mathematic factors are energy costs of activity in space different from those in the one-G environment?
4. To what extent is glucose metabolism changed by space flight conditions (as noted in prolonged bed rest)?
5. Are variations in body mass during space flight within the limits to be expected with adequate food and water intake and work schedules comparable with the earth environment?
6. What is the time course and degree of skeletal and muscular changes due to weightless flight? What are the relative influences of weightlessness, relative inactivity, and the atmospheric environment?
7. What are the best preventive or restorative techniques against bone and muscle deterioration due to space flight?
8. What are the effects of long duration weightless flight on water and electrolyte balance?

ENDOCRINOLOGY

1. In view of the known changes in body water distribution and balance with changes in body position, to what extent will weightlessness per se bring about losses of fluid? To what extent is anti-diuretic hormone involved in the mechanism of this change?
2. To what extent will changes in the metabolic cost of activity in space be reflected by changes in thyroid hormone production? Can a cause and effect relationship be established?
3. To what extent are the predicted losses of mineral in long duration space flight associated with increased bone resorption mediated by elevated parathyroid hormone secretion?
4. As both a reflection and mediating factor of stress response, what is the time course of changes in adrenal cortical activity in prolonged space flight?

HEMATOLOGY AND IMMUNOLOGY

1. What are the environmental factors responsible for the loss of red cell mass noted during Gemini?

What are the relative roles of:

 - a. The 100% oxygen environment?
 - b. Nitrogen in small amounts?
 - c. Weightlessness?
 - d. Duration of exposure?
 - e. Diminished red cell production vs. increased destruction?
 - f. Ambient total pressure?
 - g. Vibration?
 - h. Ambient temperature?
 - i. Dietary factors?
2. What space flight factors are responsible for changes in plasma volume?

3. Are coagulation proteins, platelet function, and vascular friability influenced by long duration space flight? If so, what are the responsible environmental factors?
4. Can one anticipate alterations of inflammatory response as a result of long duration space flight?
5. To what extent can space flight be anticipated to produce alterations of cell division or chromosomal composition? If such changes do occur, what environmental factors are responsible and what preventive action can be taken?

MICROBIOLOGY

1. What changes can be expected to take place in the microbial flora of flight crews during space flight?
2. What are the influences of space flight conditions on the relative dominance of pathogenic microorganisms?
3. Will there be genetic alteration in microbiological organisms as a result of the space flight environment? To what extent? Can a pattern of such changes be anticipated?

BEHAVIORAL EFFECTS

1. Will perceptual efficiency be affected by space flight conditions?
2. What changes in time and/or pattern of activity will make performance of tasks in space most efficient? Most comfortable for the astronaut?
3. What changes in the tolerance limits to stress occur over time in the extended periods of weightlessness?
4. What are optimal inflight and EVA work-rest periods based on factors of (a) fatigue, (b) energy loss, (c) discomfort, and other stress indicators?

· AAP MEDICAL/BEHAVIORAL EXPERIMENTS
APPROVED AS OF July 1969

MO70 - NUTRITION AND MUSCULOSKELETAL FUNCTION (Governing Protocol)

Principal Coordinating Scientist: Paul C. Rambaut, Ph.D., MSC

Assistant Coordinating Scientists: Richard Boster, D.V.M., MSC
Miss Rita Rapp, MSC
Malcolm Smith, D.V.M., MSC

Individual Experiments or Measurements:

MO71 - Mineral Balance

Principal Investigator: J. Donald Whedon, M.D., NIH

Co-Investigator : Leo Lutwak, M.D., Ph.D.
Cornell University

MO72 - Bone Densitometry

Principal Investigator: Pauline B. Mack, Ph.D.
Texas Women's University

MO73 - Bioassay of Body Fluids

Principal Investigator: Craig L. Fischer, M.D., MSC

Co-Investigator : Carolyn Leach, Ph.D., MSC

MO74 - Specimen Mass Measurement

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator : William Thornton, M.D., MSC

* * * * *

M090 - CARDIOVASCULAR FUNCTION (Governing Protocol)

Principal Coordinating Scientist: Robert L. Johnson, M.D.

Individual Experiments or Measurements:

M091 - IBNP (Pre- and post-flight)

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator : Robert L. Johnson, M.D., MSC

M092 - Inflight IBNP

Principal Investigator: R. L. Johnson, M.D., MSC

Co-Investigator : John Ord, Colonel, USAF, MC
Brooks AFB, Texas

M093 - Vectorcardiogram

Principal Investigator: Capt. N.W. Allebach, Bureau of
Medicine & Surgery, Washington, DC

Co-Investigator : R. F. Smith, M.D., Naval Aerospace
Medical Institute, Pensacola, Fla.

* * * * *

M110 - HEMATOLOGY AND IMMUNOLOGY (Governing Protocol)

Principal Coordinating Scientist: Craig Fischer, M.D., MSC

Individual Experiments or Measurements:

M111 - Cytogenetic Studies of Blood (Pre- and post-flight)

Principal Investigator: Michael Bender, Ph.D., ORNL, Tenn.

Co-Investigator : Miss P. Carolyn Gooch, ORNL, Tenn.

M112 - Immunology Study (Pre- and post-flight)

Principal Investigator: S. E. Ritzman, M.D., University of
Texas, Galveston

Co-Investigator : W. C. Levine, M.D., University of
Texas, Galveston

3
H110 - METABOLISM AND HEMATOLOGY (Continued)

H111 - Blood Volume and Red Cell Life Span

Principal Investigator: Phillip C. Johnson, M.D.
Baylor University, Texas

H112 - Red Blood Cell Metabolism

Principal Investigator: C. Hengel, M.D.
University of Missouri

Consultants: Wallace H. Jensen, M.D., Ohio State University
David Turner, Ph.D., Hospital for Sick Children
Scott H. Swisher, M.D., Michigan State University
Vernon Knight, M.D., Baylor University
Wolf Vishniac, Ph.D., University of Rochester

* * * * *

H130 - NEUROPHYSIOLOGY (Governing Protocol)

Principal Coordinating Scientist: Milton R. DeLucchi, Ph.D., MSC

Individual Experiments or Measurements:

H131 - Human Vestibular Function

Principal Investigator: Ashton Graybiel, M.D., Naval
Aerospace Medical Institute
Pensacola, Florida

Co-Investigator: Earl F. Miller, Ph.D., Naval
Aerospace Medical Institute,
Pensacola, Florida

H132 - Neurological Experiment - EEG

Principal Investigator: Dr. W. Ross Adey
University of California, Los
Angeles

Peter Kellaway, Ph.D.
Baylor University, Texas

Consultant: Paulina Baldwin, M.D.

* * * * *

1150 - BEHAVIORAL EFFECTS (Governing Protocol)

Principal Coordinating Scientist: Edward C. Hosoley, Ph.D., MSC

Individual Experiments or Measurements:

1151 - Time and Motion Study

Principal Investigator: Joseph P. Radis, Ph.D., Fordham University, New York

Co-Investigator: Edward J. McLaughlin, Ph.D., NASA Headquarters

Consultants: John T. Elrod, Ph.D.,
Jesse Orlensky, Ph.D.

1170 - PULMONARY FUNCTION AND ENERGY METABOLISM (Governing Protocol)

Principal Coordinating Scientist: Edward L. Bechman, M.D.

Individual Experiments or Measurements:

1171 - Metabolic Activity

Principal Investigator: Dr. Edward Michel, MSC

Co-Investigator: J. A. Ruzel, Ph.D., MSC

1172 - Body Mass Measurement

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator: William Thornton, M.D., MSC

Consultants: Ulrich C. Luft, M.D., Lovelace Foundation
Mayland Hall, Ph.D., MSC
George C. Armstrong, Jr., M.D., MSC

ADDITIONAL AREA OF INVESTIGATION:

1190 - MICROBIOLOGY (Governing Protocol)

Principal Coordination Scientist: James McQueen, D.V.M.

Assistant Coordinating Scientist: James K. Ferguson, Ph.D.

AAP MEDICAL/BEHAVIORAL EXPERIMENTS
APPROVED AS OF JANUARY 1969

M070 - NUTRITION AND MUSCULOSKELETAL FUNCTION (Governing Protocol)

- M071 - Mineral balance study to determine muscle, bone, and electrolyte changes due to space flight
- M072 - Measurements of bone density to determine the skeletal effects of space flight
- M073 - The analysis of blood and urine specimens to evaluate physiological changes occurring during and following space flight
- M074 - The evaluation of an inflight specimen mass measurement technique by means of its utilization in inflight mineral balance and body fluid assays studies

M090 - CARDIOVASCULAR FUNCTION (Governing Protocol)

- M091 - The evaluation of space flight induced alterations of circulatory responsiveness by means of the application of a fixed stimulus, lower body negative pressure (pre and post flight)
- M092 - The evaluation of space flight induced alterations of circulatory responsiveness by means of the application of a fixed stimulus, lower body negative pressure (inflight)
- M093 - Vectorcardiographic study of cardiac responses to space flight

M110 - HEMATOLOGY AND IMMUNOLOGY (Governing Protocol)

- M111 - Cytogenetic studies of blood (pre and postflight) to determine chromosomal changes which may be induced by space flight
- M112 - The determination of changes in blood immunological and coagulation factors which may be caused by spaceflight.
- M113 - Blood volume and red cell life space studies to evaluate space flight induced alterations
- M114 - Evaluation of red cell metabolic and membrane changes as mediating factors in red cell mass changes.

M130 - NEUROPHYSIOLOGY (Governing Protocol)

M131 - Human vestibular function as affected by space flight conditions

M132 - The evaluation of sleep during manned space flight by means of the study of electroencephalographic patterns

M150 - BEHAVIORAL EFFECTS (Governing Protocol)

M151 - Time and motion study of task accomplishment during space flight

M170 - PULMONARY FUNCTION AND ENERGY METABOLISM (Governing Protocol)

M171 - The evaluation of metabolic cost of activity during space flight

M172 - The study of changes in body mass as influenced by space flight environmental factors utilizing a new inertial mass measurement technique

MEDICAL/BEHAVIORAL MEASUREMENT CAPABILITY
of

INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY
MEASUREMENT SYSTEM

INCLUDE

I. NEUROLOGICAL

Clinical Evaluation (to include reflexes
and sensory and motor pathways)

Aggravate Perception of Personal and External
Personal Space (Minimum restraint device)

Ocular Counter-Rolling

Oculopyral Illusion

Visual Task with Head Rotation

Electroystagmiogram

Angular Acceleration Threshold

EEG

} to be done
with litter-chair

II. CARDIOVASCULAR

Clinical Evaluation

ECG (Frank Lead System)

Phonocardiogram

Cardiac Output - (By impedance if technique
verified; by indicator-dilution
if necessary)

Arterial Blood Pressure

Venous Pressure - Peripheral

Blood Volume and Fluid Compartments -
See Hematology and Metabolism

Regional Blood Flow - Limb (or Digit)
(Distribution of Blood Volume)

Venous Compliance

Arteriolar Reactivity

} (Limb Plethysmography)

INCLUDE

Arterial Pulse Contour

In-Flight Exercise

IBNP

Elastic Isotards

PROVIDE FOR INSTALLATION IF REQUIRED:

Ballistocardiogram

Carotid Body Stimulation

Thoracic Blood Flow

Venous Pressure - Central
(by Catheter if Necessary)

III. RESPIRATORY

Clinical Evaluation

Respiratory Rate

Lung Volumes Including Residual Volume
(For total lung capacity, and mixing
efficiency)

Pressure, Flow, and Volume (Simultaneously)
(→ Airway Resistance)

Compliance - Lung or Total
(Lung, if can)

INCLUDE

Distribution of Blood Flow and Gas in Lungs

Included: Capillary Blood O_2 , CO_2 , and pH

Breath by Breath O_2 Consumption
and CO_2 Production

O_2 Consumption - With Measured
Exercise

Alveolar to Arterial Gradient
Breathing Air and 100% Oxygen

Diffusion Capacity (if suitable technique)
(look into O_2 10 method - Dr. Richard W.
Hydo, U. of Pennsylvania, Dept. of
Physiology)

IV. METABOLISM AND NUTRITION

Clinical Evaluation

Energy Metabolism (Continuous O_2 and CO_2 Analysis
with Breath by Breath Sensitivity) with Various
Levels of Activity

Oral Temperature

Skin Temperature

Caloric Intake

Body Mass In-Flight (Thornton Technique - DIT)

[Lean Body Mass Pre- and Post-Flight] -
(Not a Part of IMB/M3)

Muscle Size and Strength

Balance Studies

- Fluid, including Sweat
- Nitrogen (See Area IX)
- Mineral (See Area IX)
- Electrolyte (See Area IX)

INCLUDE

Provide for : Accurate Urine Volume Measurement
Accurate Wet Weight of Feces
Return of Total Dry Stool
Accurate Fluid Intake Measurement
Return of all Fecal Packages Marked
by Date Time and Individual
Stool Measurement and Sample Return

Total Body Water (Breatholator or Deuterium)

4 Clinical Laboratory Evaluations - See List Under Area IX

PROVIDE FOR INSTALLATION IF REQUIRED:

ENG

Bone Densitometry - Isotope Technique

Gastric Pressure and pH (Endoradiosonde)

Plasma Volume On-Board

Mineral Metabolism by Isotopic Techniques

V. ENDOCRINOLOGY

Clinical Evaluation

4 Clinical Laboratory Evaluations - See List

INCLUDE

VI. HEMATOLOGY

Clinical Evaluation

Burpee Loads

Blood Volume and Fluid Compartment

Plasma Volume - MIFSA

RBC Mass - DEP32 or Cr51

Total Body Water

RBC Survival - DEP32

Clinical Laboratory Evaluations - See List

VII. MICROBIOLOGY AND IMMUNOLOGY

Clinical Evaluation

Body Microflora (Bacterial, Viral, and Fungal)

Environmental Culturing (Bacterial, Viral, and Fungal)

Clinical Laboratory Evaluations - See List

VIII. BEHAVIORAL EFFECTS

Clinical Evaluation

Sensory Test Battery (See Also Neurology)

Perceptual Evaluation (If validity of Tests Established)

Higher Thought Processes

Memory - Short and Long Term

Vigilance (By measurement of operational tasks)

INCLUDE

Learned Activity (Tracking and Reaction Time)
 Recording of Crew Intercommunication with
 Automatic Trans in 15 Minutes if not Sampled
 Time and Motion Study

<u>IX. CLINICAL LABORATORY EVALUATIONS</u>	<u>Reference Area</u>
Creatine and Creatinine - Urinary	IV
Urinary and Fecal: N, Ca, P, Na, K, Cl, and Mg	IV
Macoproteins - Urinary (P1)**	IV
Pyrophosphates - Urinary (P1)**	IV
Hydroxyprolines - Urinary (probably P1)**	IV
Total Amino Acids - Urinary (P1)**	IV
Urinary: Osmolality, Color, Sp Gr, pH, Glucose, Protein, Bile, Blood, and Microscopic (ie., Routine Urinal- ysis - Inflight)	IV
Plasma Volume (probably P&P)*	IV & VI
Electrolytes - Serum	IV
Total Protein - Plasma	IV
Protein Electrophoresis - Plasma	IV
Glucose - Blood (Inflight)	IV
Ca and PO ₄ - Serum (probably P1)	IV
Bilirubin - Serum	

*p&p - pre & post-flight

**p1 - Postflight evaluation of inflight samples

<u>INCLUDE</u>	<u>Reference Area</u>
Cholesterol - Serum (probably P1)	IV
BUN (probably P1)	IV
Uric Acid - Blood (P1)	IV
Alkaline Phosphatase - Serum (probably P1)	IV
pH, pO ₂ , and pCO ₂ - Blood	III & IV
Bicarbonate - Blood	III & IV
CPK (Creatine Phosphokinase - Serum (P1)	IV
LDH and LDH Isoenzymes - Serum (On-board if have electrophoresis)	IV
SGOT - Serum	IV
SGPT - Serum	IV
Adosterone - Urine (P1)	IV & V
ADH - Urinary and Serum (P1)	V
ACTH - Blood (P1)	V
Serum Free Thyroxin (T ₄ - Serum) (If in-flight, will require thin layer chromatography)	V
THPA (Probably P1)	V
17-hydroxycorticosteroids - Urine and blood (P1)	V
17-ketosteroids - Urine (P1)	V
VMA - Urine (Probably P1)	V
Metanephrines - Urine (P1)	II & V
Catechols - Urine (P1)	II & V
Histamine - Blood and Urine (P1)	II & V

INCLUDE:Reference Area

5 Hydroxy Indolacetic acid - Urinary (Probably P1)	V
Blood Cell Morphology (RBC, WBC, and Diff - Smear will suffice for platelets)	VI
Reticulocyte Count	VI
Hematocrit	VI
Hemoglobin	VI
RBC Fragility (Osmotic)	VI
RBC Mean and Survival	VI
Bleeding Time	VI
Clotting Time	VI
Prothrombin Consumption	VI
Clot Retraction	VI
Lymphocyte Karyotyping (probably P1)	VI
WBC Mobilization (Rebuck Technique)	VI
Immunoglobulin and Fibrinogen Transferrin Hemoglobin Methemoglobin	VI & VII onboard if have electrophoresis
RBC Enzyme Studies (P1) (ref. Governing Protocol M110)	VI
Complement Titration	VII
Antibody Titration	VII

PROVIDE FOR INCLUSION IF REQUIRED:

Sulfate - Urinary	IV
TCH (P1)	V
Growth Hormone (P1)	V
Thyroid Bound Globulin (T ₃) (P1)	V

INCLUDE

REFERENCE AREA

PROVIDE FOR INCLUSION IF REQUIRED (Cont'd):

Parathyroid Hormone (Radio- Immune Technique - Serum) (P1)	V
Parathyroid Hormone - Urinary (Nelson Technique - (P1)	V
Calcitonin - Serum (P1)	V
Insulin Assay (P1)	V
Glucagon Assay (P1)	V
Serotonin (5 HIAA) - Blood (P1)	V
Platelet Aggregability	VI
Fibrinolytic Activity	VI
Blood Rheology	VI
Blood Lipids	VI

MEDICAL EXPERIMENTS PROGRAM

OBJECTIVES

- A. TO EXTEND MAN'S CAPABILITIES IN MAINTAINED SPACE FLIGHT BY DETERMINING:
 - 1. THE EFFECTS OF SPACE FLIGHT ON MAN, AND THE TIME COURSE OF THESE EFFECTS.
 - 2. THE SPECIFIC ETIOLOGIES AND MECHANISMS BY WHICH THESE EFFECTS ARE MEDIATED.
 - 3. MEANS OF PREDICTING THE ONSET AND SEVERITY OF UNDESIRABLE EFFECTS.
 - 4. THE MOST EFFECTIVE MEANS OF PREVENTION OR CORRECTION OF UNDESIRABLE EFFECTS.
- B. TO OBTAIN SCIENTIFIC INFORMATION OF VALUE TO CONVENTIONAL MEDICAL RESEARCH AND PRACTICE.

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM

MAJOR CONCEPTS

1. ABLEST PRINCIPAL INVESTIGATORS OF SCIENTIFIC COMMUNITY
2. EXPERIMENTS DIRECTED TOWARD: (a) INVESTIGATION OF KNOWN PROBLEMS
(b) IN DEPTH SYSTEMS MONITORING FOR EARLY IDENTIFICATION OF POTENTIAL PROBLEMS
3. RE TECHNICAL CONTENT: (a) MOST IMPORTANT VARIABLE IS DURATION OF FLIGHT
(b) MOST UNKNOWN ENVIRONMENTAL FACTOR IS PROLONGED WEIGHTLESSNESS
4. RE ARTIFICIAL G: (a) FIRST EVALUATE MAN IN LONG DURATION WEIGHTLESSNESS
(b) UTILIZE SHORTER FLIGHTS TO DETERMINE OPTIMAL ARTIFICIAL G TECHNIQUES
(c) INCLUDE ARTIFICIAL G OPTION IN DESIGN OF SPACE STATION
5. EXPERIMENT REPETITION REQUIRED TO ESTABLISH STATISTICALLY VALID DATA.
6. MEDICAL/BEHAVIORAL EXPERIMENTS ARE, IN GENERAL, A CONTINUUM OF OBSERVATIONS.

SECRET
(ORIGINAL DESTROYED)

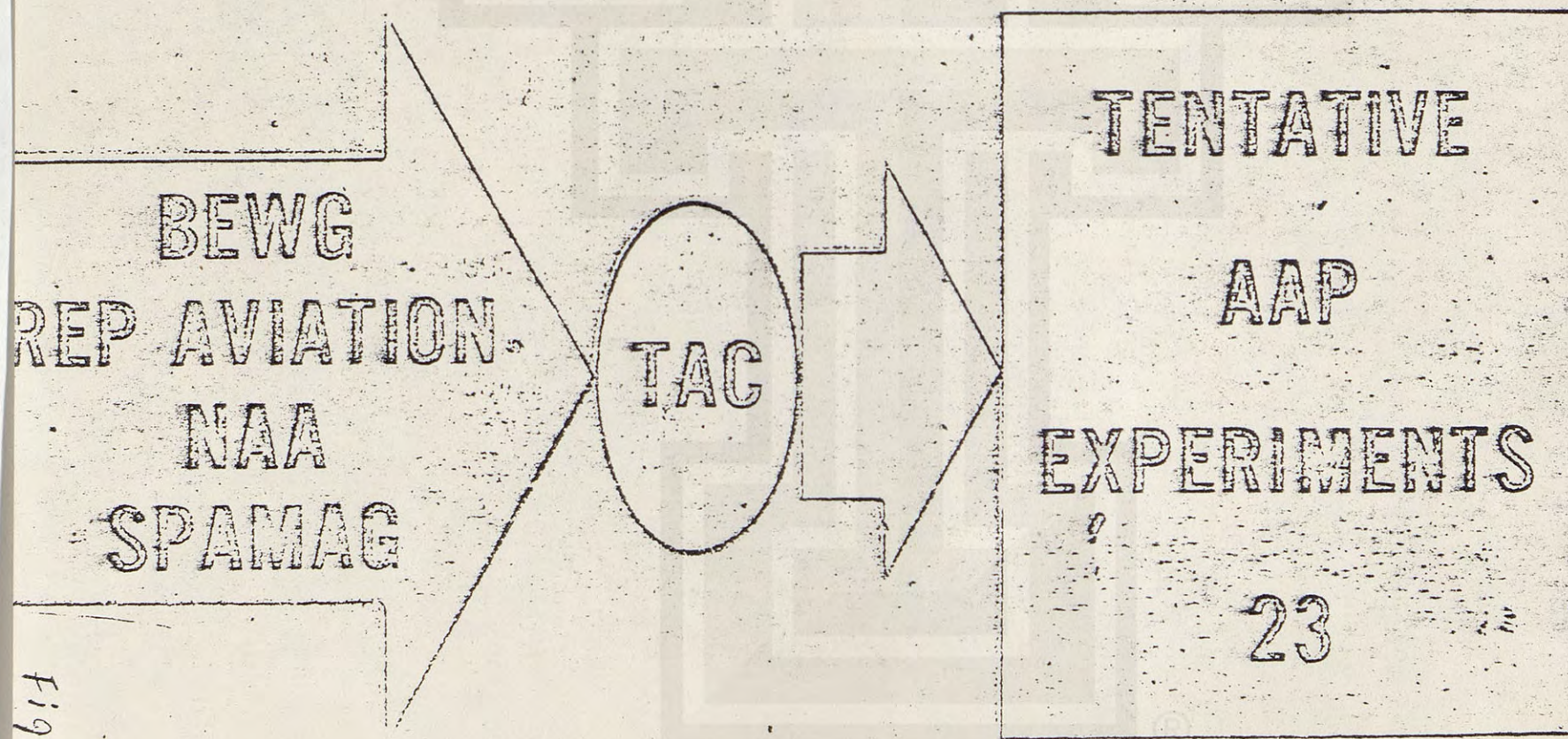


Fig. 3

AREAS OF BODY FUNCTION TO BE INVESTIGATED
AND MEDICAL BEHAVIORAL EXPERIMENTS

1. NEUROLOGICAL
2. CARDIOVASCULAR
3. RESPIRATORY
4. METABOLIC & NUTRITIONAL
5. ENDOCRINE
6. GERMATOLOGICAL
7. MICROBIOLOGICAL & IMMUNOLOGICAL
8. BEHAVIORAL

TOP VERTICAL



THE BRIGHT LITTLE SLIP

AND THE LIGHT SLEEP ALIVE

OF THE OCEAN FLOOR

EIGHT AREAS OF MEDICAL EVALUATION

	NEURO	RESP	CARDIO- VASC	METAB. & NUTRITION	ENDOCR	HEMATOL	MICROBIOL	BEHAV
EXPERIMENTS								
GEMINI	MO08 MO09	MO03	MO01 MO03 MO04 MO05 MED.OPS.	MO05 MO06 MO07	MO05	MED.OPS.		MED. OPS.
APOLLO		MO20	MO12 MO17 MO23 MO48	MO12 MO19		MO11	MED.OPS.	

FIGURE 6

MEDICAL EXPERIMENTS PROGRAM
FUNCTIONAL ORGANIZATION

I. MEDICAL/BEHAVIORAL EXPERIMENTS

- A. DETERMINATION OF REQUIREMENTS AND MAINTAINING RELATIONSHIPS, SUPPORT, AND PARTICIPATION OF THE SCIENTIFIC COMMUNITY.
- B. REVIEW OF EXPERIMENT PROPOSALS FOR SCIENTIFIC MERIT.
- C. SUPPORT OF EXPERIMENTS IN DEFINITION.
- D. SELECTION, CONVERSION, AND SUPPORT OF EXPERIMENTS FOR DEVELOPMENT PHASE.
- E. SUPPORT AND GUIDANCE DURING OPERATIONAL DATA GATHERING, AND POST MISSION DATA REDUCTION AND REPORTING PHASES.
- F. APPLICATION OF DATA TO THE MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM, MANED SPACE FLIGHT, AND THE CIVILIAN COMMUNITY AS INDICATED.

II. R&D SUPPORT OF MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM

- A. EBL'S (INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM).
- B. PARALLEL DEVELOPMENT EFFORTS TO ADVANCE STATES OF THE ART IN MEASUREMENT TECHNIQUES AND EQUIPMENT TO ENHANCE THE CAPABILITIES OF EBL'S AND PROPOSED EXPERIMENTS.
- C. SIMULATIONS AND GROUND BASED DATA, I.E., THE SUPPORT OF GROUND BASED SIMULATION AND OTHER STUDIES IN ORDER TO OBTAIN A BODY OF PERTINENT DATA AS A NORMATIVE OR CONTROL BASE TO PERMIT THE EXTRACTATION OF VALID CONCLUSIONS FROM FLIGHT DATA.

MEDICAL / BEHAVIOR EXPERIMENTS PROGRAM SCIENTIFIC MERIT EVALUATIONS SYSTEM

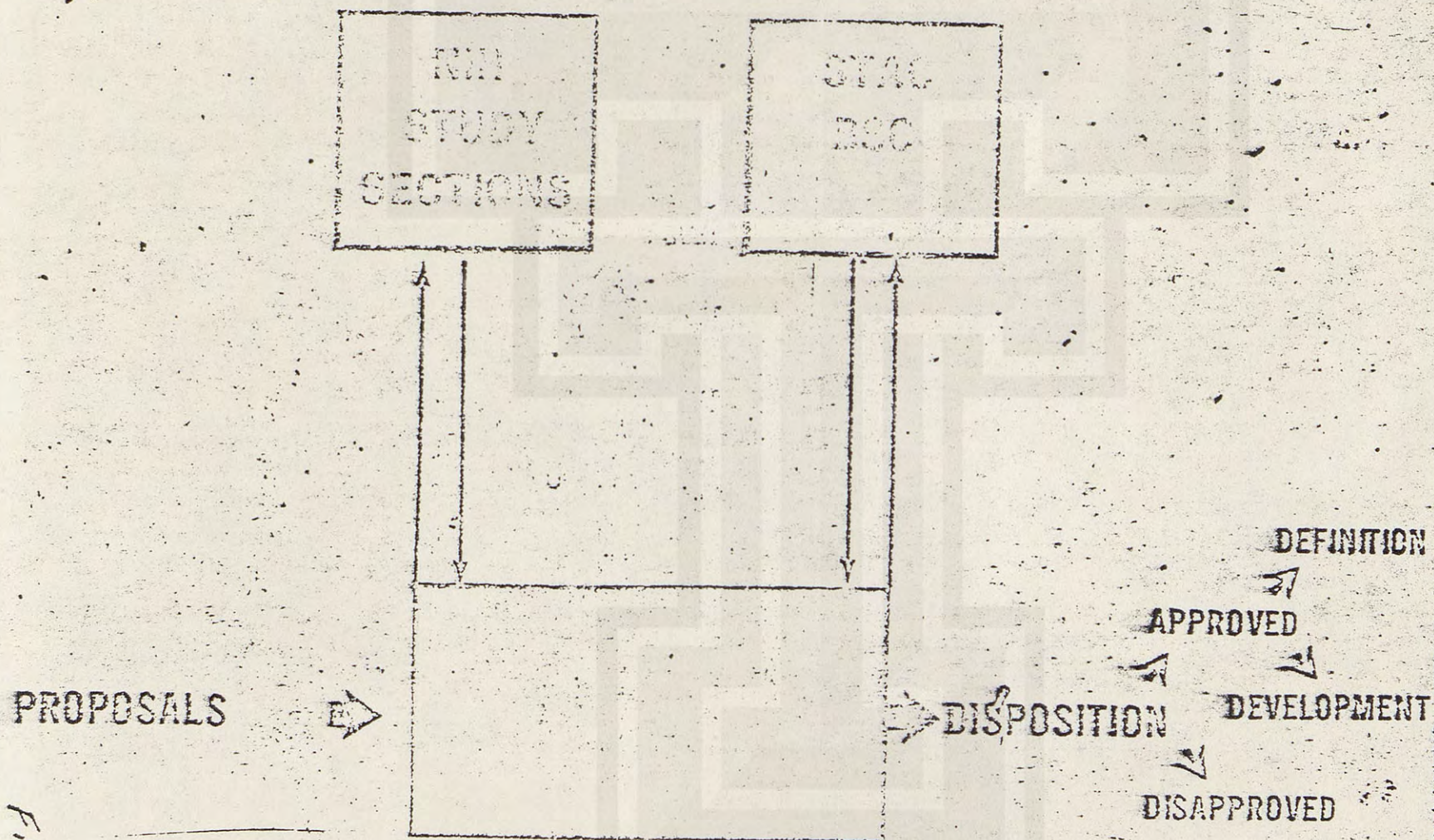


Fig. 8

NASA HQ LEM69-4377

2-14-69

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
EXISTING EXPERIMENTS
(FEBRUARY 1969)

	Nutr. & Musc. Skel. (M070)	Cardio vascular (M090)	Hematol. & Immun. (M110)	Neuro- physiol. (M130)	Behav. Effects (M150)	Pulm. Funct. & Energy Metabolism (M170)	Micro- biology (M190)	Endocrine (M210)
Development (Approved AAP)	M071	M091	M111	M131	M151	M171		
	M072	M092	M112	M132		M172		
	M073	M093	M113					
	M074		M114					
Definition	M075							
	M076	M115						M211

Fig. 9

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM

EXPERIMENTS IN DEVELOPMENT

(SEPTEMBER 1969)

M070 - NUTRITION AND MUSCULOSKELETAL FUNCTION
PCS: PAUL C. RAMBAUT, PH.D., MSC
M071 - MINERAL BALANCE
M072 - BONE DENSITOMETRY
M073 - ANALYSIS OF BODY FLUIDS
M074 - SPECIMEN MASS MEASUREMENT

M090 - CARDIOVASCULAR FUNCTION
PCS: ROBERT L. JOHNSON, M.D.
M091 - LBMP (PRE-AND POST-FLIGHT)
M092 - INFLIGHT LBMP
M093 - VECTORCARDIOGRAM

M110 - HEMATOLOGY AND IMMUNOLOGY
PCS: CRAIG FISCHER, M.D., MSC
M111 - CYTOGENETIC STUDIES OF BLOOD
(PRE-AND POST-FLIGHT)
M112 - IMMUNOLOGY STUDY (PRE-AND
POST-FLIGHT)
M113 - BLOOD VOLUME AND RED CELL
LIFE SPAN
M114 - RED BLOOD CELL METABOLISM

M130 - NEUROPHYSIOLOGY
PCS: MILTON R. DeLUCCHI, PH.D., MSC
M131 - HUMAN VESTIBULAR FUNCTION
M132 - NEUROLOGICAL EXPERIMENT-EEG

M150 - BEHAVIORAL EFFECTS
PCS: EDWARD C. MOSELEY, PH.D., MSC
M151 - TIME AND MOTION STUDY

M170 - PULMONARY FUNCTION AND ENERGY
METABOLISM
PCS: EDWARD L. BECKMAN, M.D.
M171 - METABOLIC ACTIVITY
M172 - BODY MASS MEASUREMENT

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
EXPERIMENTS IN DEFINITION
(SEPTEMBER 1969)

M075 - GASTRIC MOTILITY
DR. M. PETERSON (WASHINGTON U)

M076 - CHEMICAL ANALYTICAL TECHNIQUES
DR. HUEBNER (BECKMAN INSTRUMENTS, INC.)

M115 - ENDOGENOUS CO PRODUCTION
DRS. LAWRENCE & WINCHELL (U OF CALIFORNIA)

M211 - URINARY ENDOCRINE ASSAY
DR. NELSON (LATTER DAY SAINTS)

MEDICAL/BEHAVIORAL EXPERIMENTS
ANTICIPATED PROPOSALS FOR EXPERIMENT DEFINITION (FY 70)

BONE DENSITY (PHOTON ABSORPTION)

J. CAMERON (U. OF WISCONSIN)

GLUCOSE METABOLISM

T. PIEMME (U. OF PITTSBURGH)
G. D. WHEEDON (NIH)
L. LUTWAK (CORNELL U.)

SPECIAL HEMATOLOGICAL EFFECTS

C. FISCHER (MSC)

SPACECRAFT ECOLOGY, BACTERIOLOGY, AND
MYCOLOGY

J. K. FERGUSON (MSC)

SPACECRAFT ECOLOGY, VIROLOGY

J. McQUEEN (MSC)

PULMONARY FUNCTION

J. WEST (UCLA)

MEDICAL REQUIREMENTS STUDY
SEPTEMBER 1967

TASKS - DEFINE AND INDICATE PRIORITY

- I. (A) QUESTIONS TO BE RESOLVED BY MEDICAL/BEHAVIORAL EXPERIMENTS EFFORTS.
(B) POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS IN RESOLVING THESE QUESTIONS.
- II. R&D REQUIREMENTS
- III. INFORMATION NEEDED BY SPACE MEDICINE FROM SPACE PHYSICAL SCIENCES.

CONTRIBUTORS

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MAYO CLINIC

DR. S.P. VINOGRAD, CHAIRMAN
SPACE MEDICINE, NASA HEADQUARTERS

MEDICAL/BEHAVIORAL EXPERIMENTS
NEEDED EXPERIMENT DEFINITION EFFORTS

CARDIAC OUTPUT

REGIONAL BLOOD FLOW

VENOUS PRESSURE EVALUATIONS (CENTRAL AND PERIPHERAL)

VASCULAR REACTIVITY AND VENOUS COMPLIANCE

ARTERIAL PRESSURE CONTROLS

LEAN BODY MASS - BODY COMPLIANCE

RENAL CONTROL OF WATER, ELECTROLYTE AND ACID-BASE BALANCE

INFLAMMATORY RESPONSE

ENDOCRINE CHANGES

BEHAVIORAL STUDIES

INFORMATION PROCESSING

MEMORY

ACTIVITY

ADAPTABILITY

GROUP PROCESSES

BIORHYTHMS

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MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
INELMS

AIMS

1. PROVIDE INFLIGHT MEASUREMENT CAPABILITY TO ACCOMMODATE ALL MEDICAL/BEHAVIORAL EXPERIMENTS
2. PROVIDE MAXIMUM FLEXIBILITY FOR:
 - a. ADAPTABILITY TO LATE CHANGES IN MISSION EXPERIMENT PLANS
 - b. EASE OF INFLIGHT MAINTENANCE
 - c. EASE AND ECONOMY OF INCORPORATION OF UPDATED TECHNIQUES AND EQUIPMENT

INELMS FUNCTIONAL ELEMENTS

1. PHYSIOLOGICAL MEASUREMENT
2. BEHAVIORAL MEASUREMENT
3. BIOCHEMICAL
4. MICROBIOLOGICAL
5. DATA MANAGEMENT

Fig. 15

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
IMBIMS PROGRAM MILESTONES

PHASE A - EARLY DEFINITION

AUG. 1964 - NASA'S FOUR STUDIES COMPLETED

FEB. 1965 - TECHNICAL ADVISORY COMMITTEE (DR. SEAMAN'S STUDY)

OCT. 1965 - MOCK-UP AND TIME LINE STUDY (IMSC)

to
FEB. 1966

PHASE B - FINAL DEFINITION

MAR. 1966 - PHASE B1 WORK STATEMENT WRITTEN AND COORDINATED;
to
DEC. 1966 PROCUREMENT PLAN APPROVED; SEB ESTABLISHED; AND
RFP RELEASED

FEB. 1967 - PROPOSALS RECEIVED AND EVALUATED; SELECTION
to
OF TWO COMPETING CONTRACTORS (GE AND IMSC)
APR. 1967 BY MR. WEBB

JUNE 1967 - PHASE B1 CONTRACTS
to
OCT. 1967

DEC. 1967 - PHASE B2 CONTRACTS
to
FEB. 1968

DEC. 1968 - PHASE B3 CONTRACTS INITIATED

FEB. 1969 - TRANSFER OF CONTRACTS FROM EQS. TO
IMBIMS PROJECT OFFICE, MSC, MR&O

JAN. 1970 - PHASE B3 COMPLETED

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
IMBIMS PROGRAM MILESTONES (CON'D)

PHASE C - DESIGN

JAN. 1970 - PHASE C1 (PRELIMINARY DESIGN) INITIATED

SEP. 1970 - PHASE C1 COMPLETE; SINGLE CONTRACTOR SELECTED

SEP. 1970 - PHASE C2 (FINAL DESIGN) INITIATED

PHASE D - DEVELOPMENT (FABRICATION)

AUG. 1971 - PHASE C2 COMPLETE; OVERLAPPING INITIATION OF PHASE D

AUG. 1973 - FLIGHT IMBIMS FABRICATED AND QUALIFIED

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
PARALLEL DEVELOPMENT

REQUIREMENTS (SELECTED)

METABOLIC ANALYZER, RAPID RESPONSE, ADAPTABLE TO SUITED ACTIVITY

MICROBIAL CULTURE AND IDENTIFICATION TECHNIQUES FOR INFLIGHT USE

TECHNIQUES FOR INFLIGHT BIOCHEMICAL ANALYSIS

SAMPLE PRESERVATION TECHNIQUES FOR INFLIGHT USE

IMPROVED LIDB PLETHYSMOGRAPHY TECHNIQUES

NON-INVASIVE CARDIAC OUTPUT DETERMINATION TECHNIQUES

NON-INVASIVE VENOUS PRESSURE TECHNIQUES

BEHAVIORAL MEASUREMENT TECHNIQUE REFINEMENT

BLOOD CELL COUNTING TECHNIQUES FOR INFLIGHT USE

TECHNIQUES FOR INFLIGHT MEASUREMENT OF PULMONARY DIFFUSION CAPACITY

IMPROVED URINE VOLUME MEASUREMENT DEVICE

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM

S. P. Vinograd, M.D.
Director, IMBLMS Program and
Research and Technology

Space Medicine, Manned Space Flight



MEDICAL EXPERIMENTS PROGRAM

The medical and behavioral experiments program is a group of activities directed toward the evaluation of changes in human function and capabilities which may be induced by space flight. The objectives of the program exist as two categories, each having its own projected application or purpose (Fig. 1).

The first is geared toward manned space flight. Its four objectives express the intention to determine as precisely as possible man's medical and behavioral responses, functional limitations, and supportive requirements in space flight. The information gained is applied to the planning of future manned space flight missions and programs. Effective planning and judicious manned versus unmanned trade-offs will continue to be strongly dependent upon how well these objectives are fulfilled.

The second category of objectives is oriented toward earth based medical science. Its purpose is to advance medical research by carrying out well-conceived experiments designed to utilize the unique environmental characteristics of space for scientific information, whether or not the resulting data will be any way applicable to manned space flight. As an example, any physiological function which might be considered to be gravity dependent in some respect

is potential subject matter for profitable investigation in the space environment.

The program which has been designed to meet these objectives consists of two primary areas of activity: Experiment Management, the support of the experiments themselves during definition and development; and Supporting Research and Development, the effort to develop integrated flight laboratory equipment, new and improved medical evaluative techniques to enhance our inflight capability, and to obtain ground-based data, all of which are essential elements supporting the flight medical experiments effort.

The program can be further characterized by certain of its more important concepts. An enumeration of these might serve to convey a more complete picture of this effort (Fig. 2). First, experiment principal investigators are not limited to NASA personnel. Because the space program is both national in scope and scientific in nature, because the mounting of experiments aboard space flights is extremely expensive, and because flight opportunities are relatively infrequent, strong emphasis is placed upon the participation of highly competent individuals of the scientific community as principal investigators, whether they are from within NASA or outside. Secondly, a general philosophy of the program is to plan experiment flight schedules not only to explore known or expected problems in depth, but also to conduct

human systems monitoring across the board to the extent and level of detail consistent with good practice and practicality. As an example of the importance of this concept, had this not been done in Gemini we would still be unaware of the red blood cell and fluid compartment changes which were found. Thirdly, regarding the technical content of the program, the major variable is duration of flight. The most unknown environmental factor is prolonged weightlessness. This does not by any means imply that weightlessness is the only factor of interest, or even that it will necessarily turn out to be the most important. However, it is an important factor and it remains unknown because of our inability to reproduce it for much over thirty seconds in the earth environment. Fourth, with respect to the question of artificial g, the medical/behavioral experiments program seeks to establish the need for it by evaluating flight crews exposed to the unaltered zero g environment on flights of increasing durations. Shorter term flights can provide the opportunity to investigate and establish artificial g techniques most consistent with optimal crew, spacecraft, and mission function and performance. Until the need for artificial g can be better determined, it is our feeling that this capability should be included in at the least the design phase of future spacecraft. Fifth, the small number of flight crew members and the broad range of variability of individual responsiveness to a given set of conditions, which is so characteristic of us

humans, necessitate the repetition of most experiments to establish statistical validity of flight findings. Lastly, the Medical/Behavioral Experiments effort must be viewed as a continuing one serving and being served by a succession of flight programs. Since for most investigations the most important variable is duration of crew exposure to spaceflight, each of these experiments is really a continuum of observations which are made over the course of a series of flight programs from the 14-day maximum flight of Gemini through the two-year crew exposures which may be provided by the Space Station. As the Medical/Behavioral Experiments Program matures, new experiments generated to fulfill needed areas of evaluation and to explore fruitful scientific research of potential benefit to earth-based medicine will be prepared for development and added to the program. Experiments will be withdrawn as they appear to have achieved optimum value to their respective hypotheses, or as they have been superseded by improved or more refined ones.

The Medical/Behavioral Experiments Program began in 1963 with the study of the Biomedical Experiments Working Group (Fig. 3). This was an ad hoc group of NASA life scientists who devoted a series of meetings to an evaluation of the medical and behavioral aspects and requirements of an orbiting research laboratory. This was followed by two study contracts with industry, one with Republic Aviation and the other with North American Aviation, to explore this question in greater depth. In January 1964, the Space Medicine

Advisory Group (SPAMAG), a group of 20 prominent consultants of the medical community, began its in-depth study of this problem. The SPAMAG report followed a series of eight two-day meetings chaired jointly by the NASA and the DoD.

In February 1965, a Technical Advisory Committee of ten NASA Center and Headquarters Life Sciences personnel was called together to assemble from these four reports a group of medical and behavioral experiments which could be considered candidates for an AES (later AAP and now Skylab) flight program. This was a part of an early study of Skylab requirements which was initiated by Dr. Seamans, who was then the Associate Administrator of NASA. It resulted in the formulation of 23 medical/behavioral experiment concepts as a representative Skylab (AAP) medical experiments package. Shortly thereafter, this group of pseudo-experiments was reassembled into its eight component areas of body function, each with its list of required measurements and procedures (Fig. 4). Since then this list has been reviewed and updated repeatedly with the aid of our consultant advisors, the Biomedical Subcommittee of STAC (formerly the Medical Advisory Council), and constitutes the desired measurement capability of the Integrated Medical and Behavioral Laboratory Measurement System (IMBLMS).

The first flight manifestation of the medical/behavioral experiments program took place in Gemini, preparations for which

began in early 1964. The Gemini package consisted of eight experiments, several of which were flown on more than one mission (Fig. 5 and 6). The experiments plan for the Apollo program was an expansion of the Gemini package, but necessary alterations of the flight program ultimately restricted these plans to the extent that only three pre- and post-flight experiments have actually been implemented. The remainder are delayed until Skylab.

As alluded to earlier, the medical/behavioral experiments program is functionally organized into two mutually dependent areas of activity (Fig. 7). The first consists of the planning, solicitation, and management of the experiments themselves during both definition and development. The activities entailed are outlined in Figure 7. Of these, the review for scientific merit deserves an additional word of explanation (Fig. 8). The system, which has been employed since 1966, includes an objective scientific review by the NIH Study Section system and a succeeding evaluation, also scientific but oriented toward Manned Space Flight capabilities and requirements, by a highly qualified team of medical consultants to NASA. This group was established in May 1965 as the Medical Advisory Council and is now the Biomedical Subcommittee of NASA's Science and Technology Advisory Committee (STAC).

Experiments in definition are those which are not yet ready for flight assignment (experiment development). At such time

as they are considered sufficiently mature in terms of experimental design, functional hardware, and preliminary ground-based data, they will be proposed to the Manned Spaceflight Experiments Board (MSFEB) for approval and assignment to a flight program for development.

The present program of medical experiments is organized into the exploration and evaluation of the eight areas of body function mentioned earlier (Fig. 9). The individual experiments are components of these eight overall endeavors. There are currently sixteen experiments in development for Skylab, and four experiments in definition. Figure 10 indicates the body function areas and corresponding experiment numbers. The presently approved experiments are specific investigations within six of these eight areas. As more experiments are proposed, approved, and developed, each of these eight functional areas will be more fully evaluated and, perhaps, new areas will be added --for example, general cell/tissue responses, biorhythms, etc. A governing protocol describing the investigation of each functional area is included in existing documentation. The Skylab medical/behavioral experiments now in development, their organization, designators, and personnel are shown in Appendix B. Appendix C lists these same experiments using more descriptive titles to better indicate their content. Figure 11 lists the four medical experiments currently in definition.

All of these still fall short of fulfilling our investigation-al needs. In the fall of 1967, a consultant study was organized to attempt to further define our medical requirements. It was arranged into three tasks (Fig. 12) to identify as clearly as possible the questions which we are or should be seeking to resolve with respect to human responses to space flight; to identify supportive research tasks; and to identify specific items of information which the field of space medicine requires from the space investigations of the physical sciences. Included in the first task were judgments of the degree to which inflight animal experiments could contribute to the resolution of each of these questions. All questions and recommendations throughout the study were given a priority rating of I, II, or III, to be interpreted as a consensus judgment of overall importance. The questions listed in Appendix A are a condensed, but unabridged, version of the priority I questions which resulted from that study. By comparing our on-going and expected experiments with this list of information requirements, a series of additional experiment needs are apparent. This is shown in Figure 13.

Turning now to the R&D support of the medical/behavioral experiments program, three task areas are defined. The first of these, the Integrated Medical and Behavioral Laboratory Measurement System (IMBLMS) Program, is an effort to develop a highly flexible and sophisticated laboratory system to accommodate the

medical and behavioral measurements required for all existing experiments as well as those anticipated for the future. The medical/behavioral experiments program is unique in that it is a quest for sound scientific knowledge of human responses to a virtually unknown environment. In essence, it consists of research into virtually unknown problems in a medium which offers relatively few opportunities and relatively few subjects, and yet requires hard, complex, and predetermined engineering and operational interfaces. The IMBLMS concept was devised to meet this set of circumstances by providing maximum internal flexibility (modularity) with minimal or no impact on its basic envelope of external needs for any given spacecraft. The two basic aims of the IMBLMS are: (1) the accommodation of medical and behavioral investigations in accordance with the full objectives of the program; and (2) the provision of maximum flexibility (Fig. 14). It is basically a rack and module system which can be assembled into working consoles according to the requirements of the spacecraft and the experiments program for any particular mission. Hardware modules or submodules for a specific experiment can be developed to fit the specifications of the IMBLMS and utilized on an "as needed" basis. The flexibility afforded by the modular approach will significantly reduce hardware lead-time requirements (presently about two years), enhance inflight maintenance, and enable the relatively inexpensive introduction of updated techniques and

equipment. The IMBLMS will consist of five functional elements: (1) physiological; (2) behavioral; (3) biochemical; (4) microbiological; and (5) data management. Together they will accommodate required measurements in all eight areas of medical/behavioral investigation. Appendix D is the list of measurement requirements currently targeted for the flight IMBLMS. For Skylab II or the Space Station, the IMBLMS will be composed of two or three consoles plus five or six pieces of peripheral equipment such as the exercise ergometer, rotating litter chair, body mass measurement system, and the lower body negative pressure device.

The IMBLMS concept grew out of the studies discussed earlier. The need for time-lining the 23 pseudo-experiments issuing from the Seaman's AAP (now Skylab) study in early 1965 resulted in our extending an existing MT contract with Lockheed to build a mock-up of a medical/behavioral laboratory in a mock-up of a LEM and time line these measurements with crew suited and unsuited (Fig. 15). This was accomplished as a four-month effort which ended in February 1966. In our first draft work statement in March 1966, we defined the present highly flexible IMBLMS concept including modularity, prefabricated rack mountings and interfaces, etc., and began preparations for Phase B of this phased project procurement. A Source Evaluation Board was established, an RFP drawn up and distributed, responses were evaluated, and in April 1967 two contractors were selected by the NASA Administrator. Phase B

IMBLMS definition, is being carried out in four segments. Phase B1 work started in June 1967 followed by Phase B2 in October 1967. Phase B3 was initiated in December 1968 and completed in February 1970. This phase consisted of the construction and testing of an IMBLMS functional breadboard and its delivery and installation at the Manned Spacecraft Center, Houston, Texas. The competition will continue to the end of Phase B4, the preliminary design of a flight IMBLMS. It is currently planned that the full flight IMBLMS will be ready for flight aboard the Space Station. An earlier, less complete IMBLMS will be prepared for flight aboard Skylab II. Schedules will be altered, however, as may be required by changes in overall flight program and mission planning.

An IMBLMS Project Office was established in the Medical Research and Operations Directorate at the Manned Spacecraft Center in Houston in late 1968 and the two IMBLMS contracts were transferred from Headquarters to the MSC Project Office in February 1969. The IMBLMS Program Office, NASA Headquarters, is in the Directorate of Space Medicine, Office of Manned Space Flight.

The second task area of the R&D support of the program consists of a series of independent grants and contacts aimed at advancing states-of-the-art of measurement techniques and equipment to augment the capabilities and accuracies of the IMBLMS. This is an important task area for many reasons, a major one being that

many standard techniques are not adaptable to the environmental and other circumstances of manned space flight. Two broad examples are the need for non-invasive techniques of physiologic measurements and the need for chemical determinations which do not require liquid reagents, especially potentially toxic ones. Most of these requirements (Fig. 17) were identified several years ago. Existing efforts to meet them are progressing satisfactorily but there is a need for expanded efforts, especially in the areas of behavior, biochemistry, microbiology, energy metabolism during suited activity, and the chronic problem of accurate fluid intake and output measurement with maximum facility.

The third R&D task area consists of chamber studies, bed rest studies, and similar types of simulations as sources of essential ground-based data. Although individual principal investigators do obtain ground-based or control data as part of their experiments, economic feasibility dictates that evaluations of certain environmental factors such as spacecraft atmosphere by long term chamber studies, weightlessness as simulated by bed rest, etc., are best done by NASA with the participation of all principal investigators whose flight findings would be influenced by these aspects of the environment.

The overall program of Medical/Behavioral Experiments is oriented toward both space operations and scientific gain. It is

viewed as an essential contributor to two of the major decision areas with which we (NASA) are confronted: The question of manned versus automated task accomplishment, and the requirement for artificial gravity during long duration manned spaceflight missions.

14

QUESTIONS MEDICAL/BEHAVIORAL AREA
SMEXING TO RESOLVE

NEUROPHYSIOLOGY

1. What are the effects of the space flight environment on sleep?
2. What is the change in susceptibility to motion sickness as a function of:
 - a. Time aloft?
 - b. Freedom of movement within the spacecraft?
 - c. Rotation of the spacecraft?
3. What are the effects of sustained loss of gravitational cues on sensory perception (the special senses, kinethesis, and other somatic senses) and on spatial orientation?

PULMONARY FUNCTION AND ENERGY METABOLISM

1. What are the effects of sustained weightlessness on the mechanics of breathing in which, normally, the gravitational forces interact with the respiratory muscles and elastic forces of the chest and lungs?
2. What is the energy cost (metabolic gas exchange) at rest and during activity in the spacecabin with and without the suit, in normal flight and during EVA?
3. What is the degree and duration of arterial hypoxia due to ventilation/perfusion inequality in the lungs during launch and re-entry in space flight?
4. Are there any alterations in alveolar gas transfer or the control of breathing under prolonged combined effects of weightlessness and a low pressure mixed gas or pure oxygen environment?

CARDIOVASCULAR FUNCTION

1. Is cardiac output adequately maintained in prolonged space flight?
2. To what extent does space flight affect normal arterial pressure controls?

3. How are venous compliance and central venous pressure and their adjusting mechanisms influenced by prolonged space flight?
4. How is cardiac function affected by long duration space flight?
5. What are the factors of space flight which cause changes in circulating blood volume and its distribution? At what point and under what conditions is a new equilibrium established?
6. What is the time course of changes in overall circulatory function as determined by provocative testing (tilt table, LBMP)?

NUTRITION AND MUSCULOSKELETAL FUNCTION

1. What are the actual caloric requirements and the variables in caloric utilization under varying workloads and under varying configurations of space suit constraints in long duration space flight?
2. What are the space flight factors or stress conditions which might change caloric, water, electrolyte, or mineral requirements? To what extent do they change these requirements?
3. By what predictive or mathematic factors are energy costs of activity in space different from those in the one-G environment?
4. To what extent is glucose metabolism changed by space flight conditions (as noted in prolonged bed rest)?
5. Are variations in body mass during space flight within the limits to be expected with adequate food and water intake and work schedules comparable with the earth environment?
6. What is the time course and degree of skeletal and muscular changes due to weightless flight? What are the relative influences of weightlessness, relative inactivity, and the atmospheric environment?
7. What are the best preventive or restorative techniques against bone and muscle deterioration due to space flight?
8. What are the effects of long duration weightless flight on water and electrolyte balance?

ENDOCRINOLOGY

1. In view of the known changes in body water distribution and balance with changes in body position, to what extent will weightlessness per se bring about losses of fluid? To what extent is anti-diuretic hormone involved in the mechanism of this change?
2. To what extent will changes in the metabolic cost of activity in space be reflected by changes in thyroid hormone production? Can a cause and effect relationship be established?
3. To what extent are the predicted losses of mineral in long duration space flight associated with increased bone resorption mediated by elevated parathyroid hormone secretion?
4. As both a reflection and mediating factor of stress response, what is the time course of changes in adrenal cortical activity in prolonged space flight?

HEMATOLOGY AND IMMUNOLOGY

1. What are the environmental factors responsible for the loss of red cell mass noted during Gemini?

What are the relative roles of:

 - a. The 100% oxygen environment?
 - b. Nitrogen in small amounts?
 - c. Weightlessness?
 - d. Duration of exposure?
 - e. Diminished red cell production vs. increased destruction?
 - f. Ambient total pressure?
 - g. Vibration?
 - h. Ambient temperature?
 - i. Dietary factors?
2. What space flight factors are responsible for changes in plasma volume?

3. Are coagulation proteins, platelet function, and vascular friability influenced by long duration space flight? If so, what are the responsible environmental factors?
4. Can one anticipate alterations of inflammatory response as a result of long duration space flight?
5. To what extent can space flight be anticipated to produce alterations of cell division or chromosomal composition? If such changes do occur, what environmental factors are responsible and what preventive action can be taken?

MICROBIOLOGY

1. What changes can be expected to take place in the microbial flora of flight crews during space flight?
2. What are the influences of space flight conditions on the relative dominance of pathogenic microorganisms?
3. Will there be genetic alteration in microbiological organisms as a result of the space flight environment? To what extent? Can a pattern of such changes be anticipated?

BEHAVIORAL EFFECTS

1. Will perceptual efficiency be affected by space flight conditions?
2. What changes in time and/or pattern of activity will make performance of tasks in space most efficient? Most comfortable for the astronaut?
3. What changes in the tolerance limits to stress occur over time in the extended periods of weightlessness?
4. What are optimal inflight and EVA work-rest periods based on factors of (a) fatigue, (b) energy loss, (c) discomfort, and other stress indicants?

SKYLAB MEDICAL/BEHAVIORAL EXPERIMENTS
APPROVED AS OF July 1969

M070 - NUTRITION AND MUSCULOSKELETAL FUNCTION (Governing Protocol)

Principal Coordinating Scientist: Paul C. Rambaut, Ph.D., MSC

Assistant Coordinating Scientists: Richard Boster, D.V.M., MSC
Miss Rita Rapp, MSC
Malcolm Smith, D.V.M., MSC

Individual Experiments or Measurements:

M071 - Mineral Balance

Principal Investigator: G. Donald Whedon, M.D., NIH

Co-Investigator: Leo Lutwak, M.D., Ph.D.
Cornell University

M072 - Bone Densitometry

Principal Investigator: Pauline B. Mack, Ph.D.
Texas Women's University

M073 - Bioassay of Body Fluids

Principal Investigator: Craig L. Fischer, M.D., MSC

Co-Investigator: Carolyn Leach, Ph.D., MSC

M074 - Specimen Mass Measurement

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator: William Thornton, M. D., MSC

* * * *

M090 - CARDIOVASCULAR FUNCTION (Governing Protocol)

Principal Coordinating Scientist: G. W. Hoffler, M.D. (Acting)

Individual Experiments or Measurements:

M091 - LBNP (Pre- and post-flight)Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator: Robert L. Johnson, M.D., MSC

M092 - Inflight LBNP

Principal Investigator: R. L. Johnson, M.D., MSC

Co-Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, TexasM093 - VectorcardiogramPrincipal Investigator: Capt. N.W. Allebach, Bureau of
Medicine & Surgery, Washington, D.C.Co-Investigator: R. F. Smith, M.D., Naval Aerospace
Medical Institute, Pensacola, Fla.

* * * *

M110 - HEMATOLOGY AND IMMUNOLOGY (Governing Protocol)

Principal Coordinating Scientist: Craig Fischer, M.D., MSC

Individual Experiments or Measurements:

M111 - Cytogenetic Studies of Blood (Pre- and post-flight)

Principal Investigator: Michael Bender, Ph.D., ORNL, Tenn.

Co-Investigator: Miss P. Carolyn Gooch, ORNL, Tenn.

M112 - Immunology Study (Pre- and post-flight)Principal Investigator: S.E. Ritzman, M.D., University of
Texas, GalvestonCo-Investigator: W.C. Levine, M.D., University of
Texas, Galveston

M110 - HEMATOLOGY AND IMMUNOLOGY (cont'd)

M113 - Blood Volume and Red Cell Life Span

Principal Investigator: Phillip C. Johnson, M.D.
Baylor University, Texas

M114 - Red Blood Cell Metabolism

Principal Investigator: C. Mengel, M.D.
University of Missouri

Consultants: Wallace N. Jensen, M.D., George Washington University
David Turner, Ph.D., Hospital for Sick Children
Scott N. Swisher, M.D., Michigan State University
Vernon Knight, M.D., Baylor University
Wolf Vishniac, Ph.D., University of Rochester

* * * *

M130 - NEUROPHYSIOLOGY (Governing Protocol)

Principal Coordinating Scientist: Milton R. DeLucchi, Ph.D., MSC

Individual Experiments or Measurements:

M131 - Human Vestibular Function

Principal Investigator: Ashton Graybiel, M.D., Naval
Aerospace Medical Institute,
Pensacola, Florida

Co-Investigator: Earl F. Miller, Ph.D., Naval
Aerospace Medical Institute,
Pensacola, Florida

M132 - Neurological Experiment - EEG

Principal Investigator: Dr. W. Ross Adey
University of California, Los
Angeles

Peter Kellaway, Ph.D.
Baylor University, Texas

* * * *

M150 - BEHAVIORAL EFFECTS (Governing Protocol)

Principal Coordinating Scientist: Edward C. Moseley, Ph.D., MSC

Individual Experiments or Measurements:

M151 - Time and Motion Study

Principal Investigator: Joseph F. Kubis, Ph.D., Fordham
University, New York

Co-Investigator: Edward J. McLaughlin, Ph.D.
NASA Headquarters

Consultants: John T. Elrod, Ph.D.
Jesse Orlansky, Ph.D.

* * * *

M170 - PULMONARY FUNCTION AND ENERGY METABOLISM (Governing Protocol)

Principal Coordinating Scientist: John A. Rummel, Ph.D., MSC (Acting)

Individual Experiments or Measurements:

M171 - Metabolic Activity

Principal Investigator: Mr. Edward Michel, MSC

Co-Investigator: J. A. Rummel, Ph.D., MSC

M172 - Body Mass Measurement

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator: William Thornton, M.D., MSC

Consultants: Ulrich C. Luft, M.D., Lovelace Foundation
Wayland Hull, Ph.D., MSC
George C. Armstrong, Jr., M.D., MSC

* * * *

ADDITIONAL AREA OF INVESTIGATION:

M190 - MICROBIOLOGY (Governing Protocol)

Principal Coordination Scientist: James McQueen, D.V.M.

Assistant Coordinating Scientist: James K. Ferguson, Ph.D.

AAP MEDICAL/BEHAVIORAL EXPERIMENTS
APPROVED AS OF JANUARY 1969

- M070 - NUTRITION AND MUSCULOSKELETAL FUNCTION (Governing Protocol)
- M071 - Mineral balance study to determine muscle, bone, and electrolyte changes due to space flight
 - M072 - Measurements of bone density to determine the skeletal effects of space flight
 - M073 - The analysis of blood and urine specimens to evaluate physiological changes occurring during and following space flight
 - M074 - The evaluation of an inflight specimen mass measurement technique by means of its utilization in inflight mineral balance and body fluid assays studies
- M090 - CARDIOVASCULAR FUNCTION (Governing Protocol)
- M091 - The evaluation of space flight induced alterations of circulatory responsiveness by means of the application of a fixed stimulus, lower body negative pressure (pre and post flight)
 - M092 - The evaluation of space flight induced alterations of circulatory responsiveness by means of the application of a fixed stimulus, lower body negative pressure (inflight)
 - M093 - Vectorcardiographic study of cardiac responses to space flight
- M110 - HEMATOLOGY AND IMMUNOLOGY (Governing Protocol)
- M111 - Cytogenetic studies of blood (pre and postflight) to determine chromosomal changes which may be induced by space flight
 - M113 - Blood volume and red cell life span studies to evaluate space flight induced alterations
- M130 - NEUROPHYSIOLOGY (Governing Protocol)
- M131 - Human vestibular function as affected by space flight conditions
 - M132 - The evaluation of sleep during manned space flight by means of the study of electroencephalographic patterns
- M150 - BEHAVIORAL EFFECTS (Governing Protocol)
- M151 - Time and motion study of task accomplishment during space flight

23-

ML70 - PULMONARY FUNCTION AND ENERGY METABOLISM (Governing Protocol)

ML71 - The evaluation of metabolic cost of activity during space flight

ML72 - The study of changes in body mass as influenced by space flight environmental factors utilizing a new inertial mass measurement technique



MEDICAL/BEHAVIORAL MEASUREMENT CAPABILITY
of
INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY
MEASUREMENT SYSTEM (IMBLMS)

I. Clinical

History

Physical Examination

II. Cardiovascular

ECG

VCG

PCG

VbCG

ZCG

Cardiac Output

Heart Rate

Blood Pressure (arterial)

Blood Pressure (venous)

Plethysmography (limb)

Pulse Wave Velocity

Pulse Wave Contour

Ballistocardiogram

III. Respiratory

Respiratory Rate (RR)

Vital Capacity (VC)

Timed Vital Capacity (VC_1 , VC_3)

Inspiratory Capacity (IC)

Expiratory Reserve Volume (ERV)

Tidal Volume (TV)

Minute Tidal Volume (MTV)

Maximum Inspiratory Flow (MIF)

Maximum Expiratory Flow (MEF)

Maximum Breathing Capacity (MBC)

Alveolar pO_2 Alveolar pCO_2 Respiratory Dead Space (V_D)Alveolar Ventilation (V_A)Residual Volume (V_R)Airway Resistance (R_A)

Lung Compliance

Cardiac Output

 O_2 Consumption CO_2 Production

Diffusing Capacity

IV. Metabolism

Ear Canal Temperature

O₂ Consumption, CO₂ Production

Average Skin Temperature

Muscle Size and Strength

Body Mass and Specimen Mass

Balance Studies

V. Endocrinology(See Section X, Laboratory
Analysis)VI. Hematology(See Section X, Laboratory
Analysis)VII. Neurological

EEG

EMG

EOG

Agravic Perception

Ocular Counterrolling

Oculogyral Illusion

Angular Accel Threshold

Visual Task w/Head Rotation

Coriolis (Motion) Sickness
SusceptibilityVIII. BehavioralSensoryVision

Depth Perception

Brightness Threshold

Visual Field

Critical Flicker Fusion

Phorias

Acuity

Dark Adaptation

Photo Stress

Color Perception

Auditory

Pitch Discrimination

Auditory Absolute Threshold

Auditory Temporal Acuity

Speech Intelligibility

Cutaneous

Pressure Thresholds

Psychomotor

Fine Motor Abilities - Steadiness

Complex Motor Abilities

Gross Body Coordination

Continuous Control - Tracking

Reaction Time (Simple & Complex)

VIII. Behavioral (Cont'd)Complex

Time and Motion

Concentration (Problem Solving)

IX. MicrobiologyBacteria/Fungi

Culture/Sensitivity

Stain

Observe

Identify

Transmit

Photograph

X. Laboratory AnalysisBlood

Hemoglobin

Hematocrit

pH

pCO₂

RBC Count

WBC Count

WBC Differential

Platelet Estimation

Reticulocytes

X. Laboratory Analysis (Cont'd)Blood (cont'd)

RBC Fragility

RBC Mass

Bleeding Time

Clotting Time

RBC Survival

RBC Morphology

Clot Retraction

pO₂Plasma

Sodium

Potassium

Chloride

Calcium

Proteins

Glucose

Phosphate

Plasma Volume

SGOT

SGPT

Alkaline Phosphatase

Bilirubin

X. Laboratory Analysis
(Cont'd)Urine

Color

Volume

Specific Gravity

Glucose

Protein

Bile

pH

Blood

Microscopic

Calcium

Phosphate

Sodium

Potassium

Chloride

Acetone Bodies

Miscellaneous

Total Body Water

XI. Environment

Pressure

Atmospheric Composition

Temperature, Humidity

Spacecraft Motion

Noise

Radiation



MEDICAL EXPERIMENTS PROGRAM

OBJECTIVES

- A. TO EXTEND MAN'S CAPABILITIES IN MANNED SPACE FLIGHT BY DETERMINING:
 - 1. THE EFFECTS OF SPACE FLIGHT ON MAN AND THE TIME COURSE OF THESE EFFECTS.
 - 2. THE SPECIFIC ETIOLOGIES AND MECHANISMS BY WHICH THESE EFFECTS ARE MEDIATED.
 - 3. MEANS OF PREDICTING THE ONSET AND SEVERITY OF UNDESIRABLE EFFECTS.
 - 4. THE MOST EFFECTIVE MEANS OF PREVENTION OR CORRECTION OF UNDESIRABLE EFFECTS.
- B. TO OBTAIN SCIENTIFIC INFORMATION OF VALUE TO CONVENTIONAL MEDICAL RESEARCH AND PRACTICE.

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM

MAJOR CONCEPTS

1. ABLEST PRINCIPAL INVESTIGATORS OF SCIENTIFIC COMMUNITY
2. EXPERIMENTS DIRECTED TOWARD: (a) INVESTIGATION OF KNOWN PROBLEMS
(b) IN DEPTH SYSTEMS MONITORING FOR EARLY IDENTIFICATION OF POTENTIAL PROBLEMS
3. RE TECHNICAL CONTENT: (a) MOST IMPORTANT VARIABLE IS DURATION OF FLIGHT
(b) MOST UNKNOWN ENVIRONMENTAL FACTOR IS PROLONGED WEIGHTLESSNESS
4. RE ARTIFICIAL G: (a) FIRST EVALUATE MAN IN LONG DURATION WEIGHTLESSNESS
(b) UTILIZE SHORTER FLIGHTS TO DETERMINE OPTIMAL ARTIFICIAL G TECHNIQUES
(c) INCLUDE ARTIFICIAL G OPTION IN DESIGN OF SPACE STATION
5. EXPERIMENT REPETITION REQUIRED TO ESTABLISH STATISTICALLY VALID DATA.
6. MEDICAL/BEHAVIORAL EXPERIMENTS ARE, IN GENERAL, A CONTINUUM OF OBSERVATIONS.

NASA SPONSORED SOURCES OF AAP EXPERIMENTS (MEDICAL BEHAVIORAL)

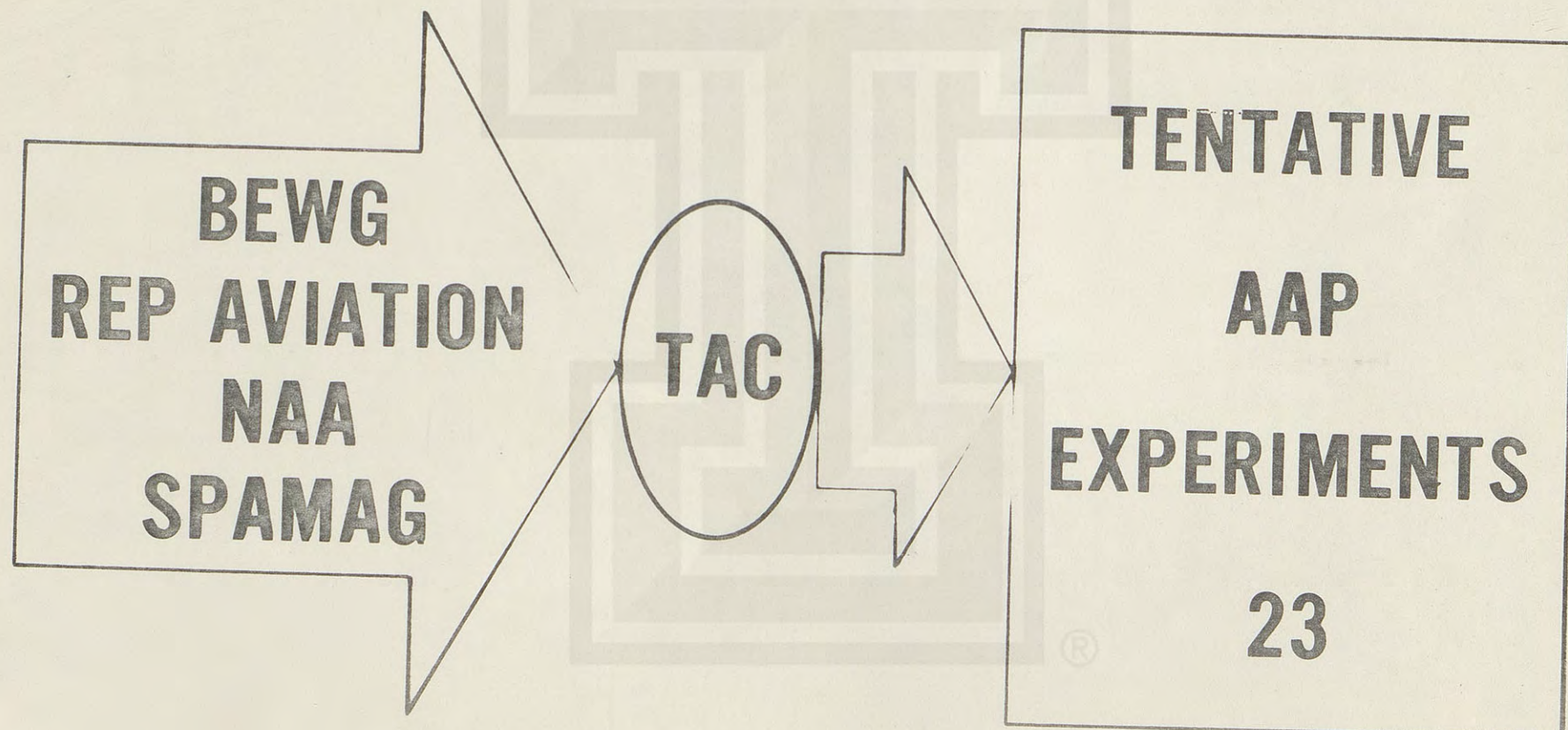


Fig. 3

AREAS OF BODY FUNCTION TO BE INVESTIGATED AAP MEDICAL-BEHAVIORAL EXPERIMENTS

- 1. NEUROLOGICAL**
- 2. CARDIOVASCULAR**
- 3. RESPIRATORY**
- 4. METABOLIC & NUTRITIONAL**
- 5. ENDOCRINE**
- 6. HEMATOLOGICAL**
- 7. MICROBIOLOGICAL & IMMUNOLOGICAL**
- 8. BEHAVIORAL**

Fig. 4

GEMINI MEDICAL EXPERIMENTS

- M-1 CARDIOVASCULAR CONDITIONING
- M-3 INFLIGHT EXERCISER
- M-4 INFLIGHT PHONOCARDIOGRAM
- M-5 BIOASSAYS BODY FLUIDS
- M-6 BONE DEMINERALIZATION
- M-7 CALCIUM BALANCE STUDY
- M-8 INFLIGHT SLEEP ANALYSIS
- M-9 HUMAN OTOLITH FUNCTION

EIGHT AREAS OF MEDICAL EVALUATION

	NEURO	RESP	CARDIO- VASC	METAB. & NUTRITION	ENDOCR	HEMATOL	MICROBIOL	BEHAV
EXPERIMENTS								
GERMINI	MD08 MD09	MD03	MD01 MD03 MD04 MD05 MED.OPS.	MD05 MD06 MD07	MD05	MED.OPS.		MED. OPS.
APOLLO		MD20	MD12 MD17 MD18 MD23 MD48	MD12 MD19		MD11	MED.OPS.	

Fig. 6

**MEDICAL EXPERIMENTS PROGRAM
FUNCTIONAL ORGANIZATION**

I. MEDICAL/BEHAVIORAL EXPERIMENTS

- A. DETERMINATION OF REQUIREMENTS AND MAINTAINING RELATIONSHIPS, SUPPORT, AND PARTICIPATION OF THE SCIENTIFIC COMMUNITY.**
- B. REVIEW OF EXPERIMENT PROPOSALS FOR SCIENTIFIC MERIT.**
- C. SUPPORT OF EXPERIMENTS IN DEFINITION.**
- D. SELECTION, CONVERSION, AND SUPPORT OF EXPERIMENTS FOR DEVELOPMENT PHASE.**
- E. SUPPORT AND GUIDANCE DURING OPERATIONAL DATA GATHERING, AND POST MISSION DATA REDUCTION AND REPORTING PHASES.**
- F. APPLICATION OF DATA TO THE MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM, MANED SPACE FLIGHT, AND THE CIVILIAN COMMUNITY AS INDICATED.**

II. R&D SUPPORT OF MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM

- A. DMLMS (INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM).**
- B. PARALLEL DEVELOPMENT EFFORTS TO ADVANCE STATES OF THE ART IN MEASUREMENT TECHNIQUES AND EQUIPMENT TO ENHANCE THE CAPABILITIES OF DMLMS AND PROPOSED EXPERIMENTS.**
- C. SIMULATIONS AND GROUND BASED DATA, I.E., THE SUPPORT OF GROUND BASED SIMULATION AND OTHER STUDIES IN ORDER TO OBTAIN A BODY OF PERTINENT DATA AS A NORMATIVE OR CONTROL BASE TO PERMIT THE EXTRAPOLATION OF VALID CONCLUSIONS FROM FLIGHT DATA.**

MEDICAL / BEHAVIOR EXPERIMENTS PROGRAM SCIENTIFIC MERIT EVALUATIONS SYSTEM

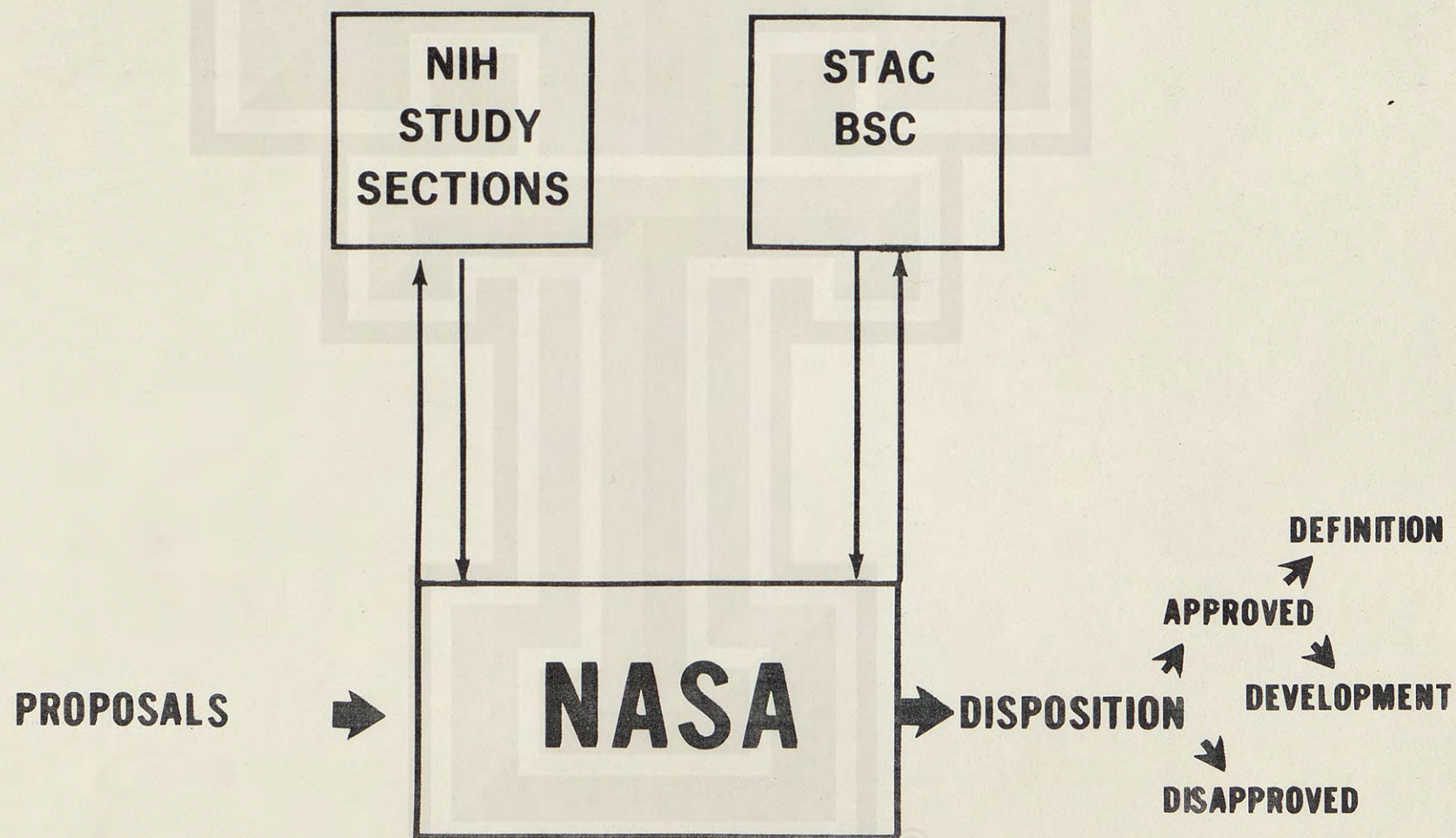


Fig. 8

NASA HQ MM69-4377
2-14-69

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
EXISTING EXPERIMENTS
(FEBRUARY 1969)

	Nutr. & Musc. Skel. (M070)	Cardio- vascular (M090)	Hematol. & Immun. (M110)	Neuro- physiol. (M130)	Behav. Effects (M150)	Pulm. Funct. & Energy Metabolism (M170)	Micro- biology (M190)	Endocrine (M210)
Development (Approved AAP)	M071	M091	M111	M131	M151	M171		
	M072	M092	M112	M132		M172		
	M073	M093	M113					
	M074		M114					
Definition	M075							
	M076		M115					M211

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MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM

EXPERIMENTS IN DEVELOPMENT

(SEPTEMBER 1969)

MD70 - NUTRITION AND MUSCULOSKELETAL FUNCTION
PCB: PAUL C. RAMBAUT, PH.D., MSC
MD71 - MINERAL BALANCE
MD72 - BONE DENSITOMETRY
MD73 - ANALYSIS OF BODY FLUIDS
MD74 - SPECIMEN MASS MEASUREMENT

MD90 - CARDIOVASCULAR FUNCTION
PCB: G. W. Hoffler, M.D. (Acting)
MD91 - LEMP (PRE-AND POST-FLIGHT)
MD92 - INFLIGHT LEMP
MD93 - VECTORCARDIOGRAM

MD10 - HEMATOLOGY AND DERMOLOGY
PCB: CRAIG FISCHER, M.D., MSC
MD11 - CYTOGENETIC STUDIES OF BLOOD (PRE-AND POST-FLIGHT)
MD12 - DERMATOLOGY STUDY (PRE-AND POST-FLIGHT)
MD13 - BLOOD VOLUME AND RED CELL LIFE SPAN
MD14 - RED BLOOD CELL METABOLISM

MD30 - NEUROPHYSIOLOGY
PCB: MILTON R. DeLUCCHI, PH.D., MSC
MD31 - HUMAN VESTIBULAR FUNCTION
MD32 - NEUROLOGICAL EXPERIMENT-ENG

MD50 - BEHAVIORAL EFFECTS
PCB: EDWARD C. MOSLEY, PH.D., MSC
MD51 - TIME AND MOTION STUDY

MD70 - PULMONARY FUNCTION AND ENERGY METABOLISM
PCB: John A. Rummel, Ph.D., MSC (Act.)
MD71 - METABOLIC ACTIVITY
MD72 - BODY MASS MEASUREMENT

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
EXPERIMENTS IN DEFINITION
(SEPTEMBER 1969)

- M075 - GASTRIC MOTILITY
DR. M. PETERSON (WASHINGTON U)
- M076 - CHEMICAL ANALYTICAL TECHNIQUES
DR. HUEBNER (BECKMAN INSTRUMENTS, INC.)
- M115 - ENDOGENOUS CO PRODUCTION
DRS. LAWRENCE & WINCHELL (U OF CALIFORNIA)
- M211 - URINARY ENDOCRINE ASSAY
DR. NELSON (LATTER DAY SAINTS)

/

150

MEDICAL REQUIREMENTS STUDY
SEPTEMBER 1967

TASKS - DEFINE AND INDICATE PRIORITY

- I. (A) QUESTIONS TO BE RESOLVED BY MEDICAL/BEHAVIORAL EXPERIMENTS EFFORTS.
- (B) POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS IN RESOLVING THESE QUESTIONS.
- II. R&D REQUIREMENTS
- III. INFORMATION NEEDED BY SPACE MEDICINE FROM SPACE PHYSICAL SCIENCES.

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SPACE MEDICINE, NASA HEADQUARTERS

MEDICAL/BEHAVIORAL EXPERIMENTS
NEEDED EXPERIMENT DEFINITION EFFORTS

CARDIAC OUTPUT

REGIONAL BLOOD FLOW

VENOUS PRESSURE EVALUATIONS (CENTRAL AND PERIPHERAL)

VASCULAR REACTIVITY AND VENOUS COMPLIANCE

ARTERIAL PRESSURE CONTROLS

LEAN BODY MASS - BODY COMPOSITION

RENAL CONTROL OF WATER, ELECTROLYTE AND ACID-BASE BALANCE

INFLAMMATORY RESPONSE

ENDOCRINE CHANGES

BEHAVIORAL STUDIES

INFORMATION PROCESSING

MEMORY

ACTIVITY

ADAPTABILITY

GROUP PROCESSES

BIORHYTHMS

**MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
DBLMS**

AIMS

1. PROVIDE INFLIGHT MEASUREMENT CAPABILITY TO ACCOMMODATE ALL MEDICAL/BEHAVIORAL EXPERIMENTS
2. PROVIDE MAXIMUM FLEXIBILITY FOR:
 - a. ADAPTABILITY TO LATE CHANGES IN MISSION EXPERIMENT PLANS
 - b. EASE OF INFLIGHT MAINTENANCE
 - c. EASE AND ECONOMY OF INCORPORATION OF UPDATED TECHNIQUES AND EQUIPMENT

DBLMS FUNCTIONAL ELEMENTS

1. PHYSIOLOGICAL MEASUREMENT
2. BEHAVIORAL MEASUREMENT
3. BIOCHEMICAL
4. MICROBIOLOGICAL
5. DATA MANAGEMENT

2

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
DBLMS PROGRAM MILESTONES

PHASE A - EARLY DEFINITION

AUG. 1964 - NASA'S FOUR STUDIES COMPLETED

FEB. 1965 - TECHNICAL ADVISORY COMMITTEE (DR. SEAMAN'S STUDY)

OCT. 1965 - MOCK-UP AND TIME LINE STUDY (LMSC)

to

FEB. 1966

PHASE B - FINAL DEFINITION

MAR. 1966 - PHASE B1 WORK STATEMENT WRITTEN AND COORDINATED;

to

PROCUREMENT PLAN APPROVED; SEB ESTABLISHED; AND

DEC. 1966 RFP RELEASED

FEB. 1967 - PROPOSALS RECEIVED AND EVALUATED; SELECTION

to

OF TWO COMPETING CONTRACTORS (GE AND LMSC)

APR. 1967 BY MR. WEBB

JUNE 1967 - PHASE B1 CONTRACTS

to

OCT. 1967

DEC. 1967 - PHASE B2 CONTRACTS

to

FEB. 1968

DEC. 1968 - PHASE B3 CONTRACTS INITIATED

FEB. 1969 - TRANSFER OF CONTRACTS FROM HQS. TO

DBLMS PROJECT OFFICE, MEC, MR&O

FEB. 1970 - PHASE B3 COMPLETED

MEDICAL/BEHAVIORAL EXPERIMENTS PROGRAM
PARALLEL DEVELOPMENT

REQUIREMENTS (SELECTED)

METABOLIC ANALYZER, RAPID RESPONSE, ADAPTABLE TO SUITED ACTIVITY
MICROBIAL CULTURE AND IDENTIFICATION TECHNIQUES FOR INFLIGHT USE
TECHNIQUES FOR INFLIGHT BIOCHEMICAL ANALYSIS
SAMPLE PRESERVATION TECHNIQUES FOR INFLIGHT USE
IMPROVED LIMB PLETHYSMOGRAPHY TECHNIQUES
NON-INVASIVE CARDIAC OUTPUT DETERMINATION TECHNIQUES
NON-INVASIVE VENOUS PRESSURE TECHNIQUES
BEHAVIORAL MEASUREMENT TECHNIQUE REFINEMENT
BLOOD CELL COUNTING TECHNIQUES FOR INFLIGHT USE
TECHNIQUES FOR INFLIGHT MEASUREMENT OF PULMONARY DIFFUSION CAPACITY
IMPROVED URINE VOLUME MEASUREMENT DEVICE

MEDICAL/BEHAVIORAL EXPERIMENTS

I. GENERAL PROGRAM DESCRIPTION

Page

1

II. IMBLMS DESCRIPTION AND INTERFACE REQUIREMENTS

5

A. Description of total IMBLMS

B. Description of Individual Peripheral Components

1. Body Mass Measurement Device

11

2. Bicycle Ergometer

12

3. Specimen Mass Measurement Device

13

4. Rotating Litter Chair

14

5. Lower Body Negative Pressure Device

15

C. Schedule/Availability

16

III. APPENDICES

A. AAP Medical/Behavioral Experiments Approved as of July 1969

B. IMBLMS Measurement Capability

C. Medical Behavioral Experiments, Experiment Definition

BICMEDICAL AND BEHAVIORAL EXPERIMENTS

I.. GENERAL PROGRAM DESCRIPTION

OBJECTIVES

The objectives of the medical/behavioral experiments program are:

- A. To extend man's capabilities in manned space flight by determining:
 - 1. The effects of space flight on man, and the time course of these effects.
 - 2. The specific etiologies and mechanisms by which these effects are mediated.
 - 3. The means of predicting the onset and severity of undesirable effects.
 - 4. The most effective means of prevention or correction of undesirable effects.
- B. To obtain scientific information of value to conventional medical research and practice.

The objectives outlined for this study will be obtained by means of individual measurements to explore each of the eight areas of body function toward which the medical/behavioral program effort has been directed. In pursuing these objectives basic principles apply which relate clearly to flight program planning.

1. The key variable in the evaluation of man in space is duration of flight. Thus, medical/behavioral measurements of flight crew members will, as a general rule, be required more frequently during the extended portion of an incremental mission than earlier in that mission, although they will in general be qualitatively the same. An exception to this general principle will be measurement of initial changes (first 48 hours).
2. It is important to obtain as great a redundancy of pertinent measurements of individual crew members as is practicable in any given flight configuration to establish statistical validity.
3. A major practical aim of this effort is to utilize these observations to be prepared with appropriate preventive or remedial techniques such as lower body negative pressure, special exercises, and other conditioning methods for maintaining man in a satisfactory condition during future long-duration missions. This will include the evaluation of the long term effects of zero-G to determine the desirability or need for artificial gravity, i.e., to conduct the observations required in order to make the so-called "g decision."

The eight areas of study include: (1) neurophysiology, (2) cardiovascular function, (3) pulmonary function and energy metabolism, (4) nutrition and musculoskeletal function, (5) endocrinology, (6) hematology and immunology, (7) microbiology, and (8) behavioral response.

3

PROGRAM

The medical/behavioral experiments program is functionally organized in the following manner:

I. Medical/Behavioral Experiments

- A. Determination of requirements and maintaining relationships, support, and participation of the scientific community.
- B. Review of experiment proposals for scientific merit.
- C. Support of experiments in definition.
- D. Selection, conversion, and support of experiments for development phase.
- E. Support and guidance during operational data gathering, and post mission data reduction and reporting phases.
- F. Application of data to the medical/behavioral experiments program, manned space flight, and the civilian community as indicated.

II. R&D Support of Medical/Behavioral Experiments Program

- A. EMBLMS (Integrated Medical and Behavioral Laboratory Measurement System)
- B. Parallel development efforts to advance states of the art in measurement techniques and equipment to enhance the capabilities of EMBLMS and proposed experiments.
- C. Simulations and ground based data, i.e., the support of ground based simulation and other studies in order to obtain a body of pertinent data as a normative or control base to permit the extraction of valid conclusions from flight data.

4.

The experimental package proposed for AAP 1 through 4 consists of individual experiments. Seven of the eight areas of investigation are presently included in this package, namely, (1) nutrition and musculoskeletal function, (2) cardiovascular function,; (3) hematology and immunology, (4) neurophysiology, (5) behavioral effects, (6) pulmonary function and energy metabolism, and (7) microbiology. Within these seven areas, 16 individual experiments are defined. In addition to these 16 MEFEB approved experiments, five more are currently in the definition phase. One of these is in the hematology area, two are in nutrition and musculoskeletal function, one in endocrinology, and one experiment is in the area of pulmonary function. Appendix A is a list of the presently approved AAP medical/behavioral experiments with areas, personnel, and designators identified. All of these and all of the medical/behavioral experiments now in definition will be completely accommodated by the IMBLS. Appendix B lists the measurement capability of the IMBLS.

Since the duration of crew exposure to the space flight environment is the major variable of this investigational area, all or most experiments will be repeated on missions of increasing durations irrespective of the particular flight programs which are able to carry them. It is anticipated, therefore, that AAP experiments scheduled for the first dry workshop will be repeated on the second, and these on the Space Station, etc. This will hold true until changes or responses, or lack of them, can be sufficiently established. At the same time new experiments will be added as they become ready for development and are evaluated and approved for manned space flight programs.

II IMBIMS - DESCRIPTION & INTERFACE REQUIREMENTS

1. The Integrated Medical and Behavioral Laboratory Measurement Systems (IMBIMS) is a highly flexible and sophisticated laboratory system to accommodate the medical and behavioral measurements required for existing experiments as well as those anticipated for the future. Its two basic aims are (a) the accommodation of medical and behavioral investigations in accordance with the full objectives of the program and, (b) provision of maximum flexibility. It is basically a rack and module system which can be assembled into working consoles according to the requirements of the spacecraft and the medical/behavioral experiments program for any particular mission. Hardware modules and submodules for specific experiments can be developed to fit specifications of the IMBIMS and utilized on an "as needed" basis for any particular mission. The flexibility afforded by the modular approach will thus significantly reduce leadtime requirements, enhance inflight maintenance, and enable the relatively inexpensive introduction of updated techniques and equipment. The IMBIMS will consist of five functional elements: (1) physiological, (2) behavioral, (3) biochemical, (4) microbiological, and (5) data management. Together they will accommodate required measurements of all eight areas of investigation to which the medical/behavioral experiments program is directed.

For the second dry workshop and Space Station, the IMBIMS will be composed of two or three consoles plus five or six pieces of peripheral equipment hard mounted to the spacecraft. Presently identified peripheral equipment includes the bicycle ergometer, rotating litter chair, lower body

negative pressure device, body mass measurement device and the specimen mass measurement device. Figure 1 is a rough sketch of the general concept of IMBMS.

The following IMBMS specifications are presently foreseen estimates, however, the values are all only rough approximations and must be treated as such. It should be carefully noted that these provisional specifications will be subject to alteration as the development effort continues.

Weight - Ascent 1200-1500 lbs. (~ 500 lbs of peripheral requirement included)

- Return 150-200 lbs. (per resupply)

Volume - Ascent 265-350 ft.³ (including ~ 62 ft.³ for peripheral equipment)

Dimensions - Consoles:

If two, of the order of 5x5.5x2 ft, each.

If three, of the order of 5x3.5x2 ft, each.

Peripheral Equipment: (See descriptions of each)

Power - Average - ~700w

- Peak - ~1800w

- Standby - ~50w

- Total - Dependent upon mission

Data - Analog - Includes TV

- Digital - Max. rate 256 KBS

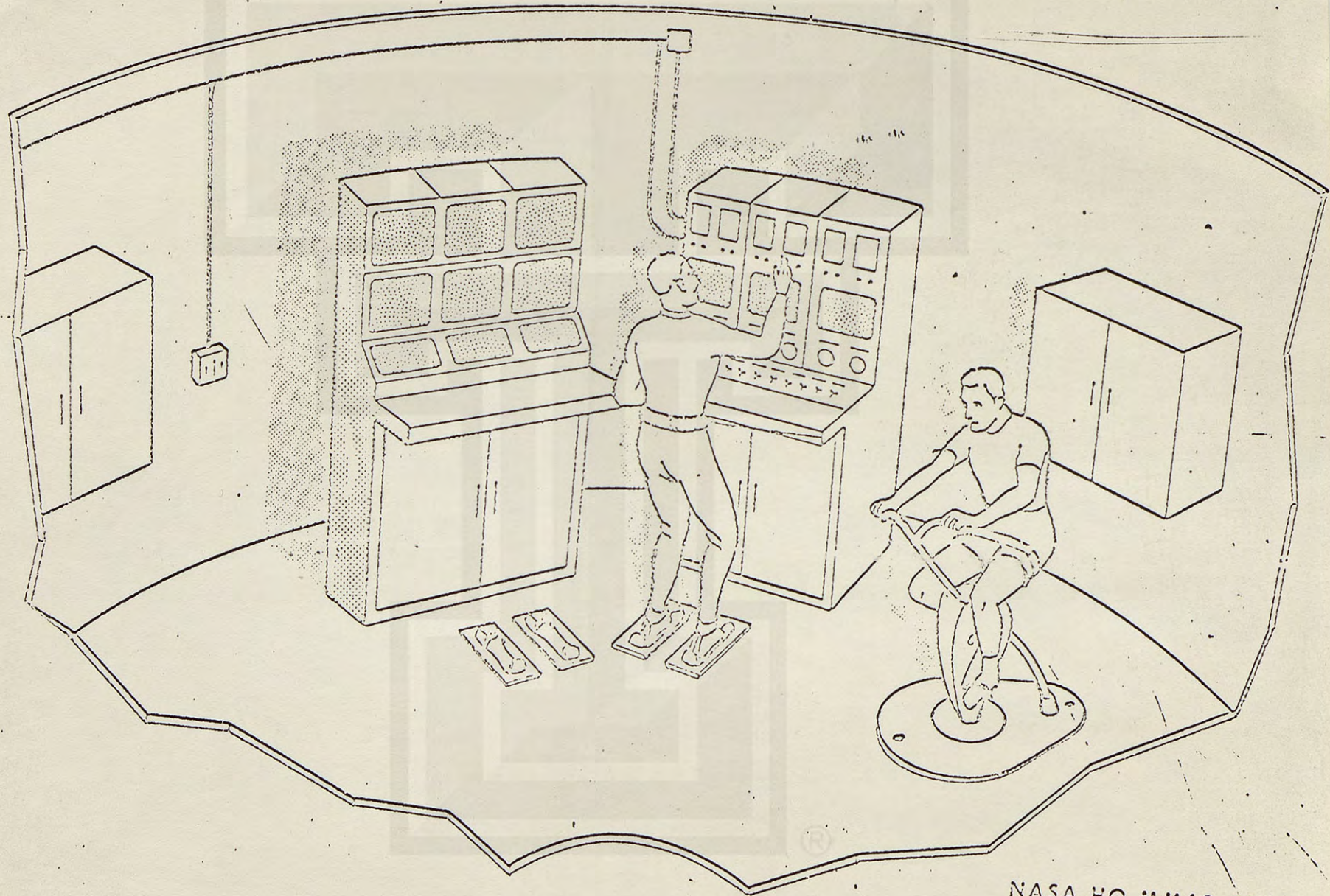
- Film - For use with AAP or space station developed camera

- Tape - For both analog (including video) and digital data

Thermal (BTU/hr) - Standby - ~170 BTU/hr

- Operate - ~2000 BTU/hr

IMBLMS INTEGRATED MEDICAL/BEHAVIORAL LABORATORY MEASUREMENT SYSTEM



NASA HQ MM69-5745
6-27-69

Mode of Operation

Cabin temperature control of $70^{\circ}\text{F} \pm 5^{\circ}\text{F}$ required. Nominal zero g required when evaluating the effects of weightlessness; artificial gravity when evaluating comparative effects of artificial g. No attitude requirements.

Role of Man

IMBIMS is the system of laboratory equipment operated by man to evaluate man. Therefore, man is an absolute requirement. Crew time requirements:

- (a) For performance, approximately 12-15 hours per man per week estimated requirement
- (b) Maintenance time: Unknown at present

Crew Skills

Specially trained M. D. mandatory. Additional specially trained physiologist desirable. IMBIMS maintenance technician essential. This can be a crew member trained in electronic maintenance for other space station equipment as well. He should be thoroughly familiar with the systems aspects of IMBIMS.

Operation

IMBIMS will be in operation an estimated 6 to 8 hours/day, 6 days a week. The medical astronaut will be the primary operator. The physiologist (if one is aboard) will be his secondary operator. At least one of them will be in attendance whenever IMBIMS is being used for flight crew evaluation. Primary responsibility for medical experiments, IMBIMS and its use will rest with the medical astronaut at all times. It is envisioned that IMBIMS will be operated much like a physician operates his office. The operator will see and run specific studies on a succession

of crew members each day according to a predetermined plan. Long term missions will require a formal flight plan prior to launch, but the medical astronaut must retain a degree of latitude to change the schedule and procedures with the concurrence of Earth based P.I.'s.

Anticipated frequency of operation of peripheral equipment in AAP is given on the data sheets in Section IIB. It should be noted that these estimates apply only to the AAP first dry launch workshop, and they are only rough estimates which are likely to change. They are included only for the very general guidance of the experiments module, Space Station, and second dry workshop contractors and planners.

Waste Management

There is a spacecraft interface requirement between IMBMS and Waste Management. The obtaining of urine and fecal samples is not a part of IMBMS; nor does IMBMS provide a specific urine volume measurement technique. These are the Space Station Contractors' responsibilities; however, they are of the highest order of importance to the attainment of the medical and behavioral experiments program objectives. Disposal of urine samples, feces, and other waste materials must also be provided by the Space Station contractors. Although the specific volumes of waste materials are presently unknown, it is envisioned that they will consist of such items as blood specimens, disposable syringes, radiosotopes, lancets, needles, fibrous materials, (viz. cotton), plastic or glass slides and reaction containers, chemicals, and electrode jellies and paste.

Consoles

The consoles, which are basically a rack and module system, will require mounting to the structure of the Space Station for operation. The location and orientation of the consoles are not critical except they should be all located in the same general laboratory area. The console and subject should be in the viewing cone of the experimenter. The interfaces between the consoles and Space Station will require provision for structural mounting, electrical power, waste management, and vacuum. Pressurizing gas may be an interface requirement but it may be included in the IMBLMS.

Peripheral Equipment

- * (1) Body Mass Measurement Device
- * (2) Bicycle Ergometer
- * (3) Specimen Mass Measurement Device
- * (4) Rotating Litter Chair
- * (5) Lower Body Negative Pressure Device

* See attached pages. These data were taken from approved EIPs for AAP medical experiments and changes may be made for Space Station experiments. All weights, sizes, and power for peripheral equipment are included in the overall IMBLMS estimate.

Note: In the case of suited IVA experiments, interfaces between suit and spacecraft are not a part of IMBLMS considerations.

Data System

The data management system of IMBLMS is a building block type of

system. It will accept, compress, handle, process, display, and condition for transmission to the ground data from measurements performed with IMBLMS. The system provides for computer operation to fulfill its normal requirements, but it has the additional capability of a limited backup non-computer mode. The building block concept of the IMBLMS data management system provides a range of options from complete self containment to varying degrees of reliance on the spacecraft data management system. The extent of this reliance will depend upon the capability and availability (timing as well as time) of the spacecraft data system to meet the somewhat heavy IMBLMS requirements. In any case, an interface will be required between the IMBLMS data management system and the space station transmitter and receiver, since IMBLMS has no transmitting or receiving capabilities other than through the spacecraft.

II. D. IBM'S PERIPHERAL EQUIPMENT COMPONENTS

BCDY MASS MEASUREMENT DEVICE (BMMD)

11

Characteristics:

Weight - 38 lbs Launch (25# BMMD 13# Storage Box)

Size - 14 cu ft Launch - 23 cu ft Operational
0 Return

Power - 2 watts, 28 VDC (supplied through IMBMS)

Spacecraft Interface

Mounting brackets are required in the Space Station for operation. These should be braced for maximum rigidity. Location and orientation of the BMMD should be in the area of the support console and in the viewing cone of the experimenter.

Environmental Constraints

Thermal (Stored and Operational)	-51 to +70°C
Atmospheric Pressure	25 psia to 1 X 10 mm Hg
Relative Humidity	15 - 100%
Acceleration	Storage Operation
	0 - 7g 0 - 1g
Vibration (Storage) Random	20 to 100 cps - linear increase (log by log plot from 0.001g ² /cps to 0.075 g ² /cps 100 to 500 cps - constant at 0.075g ² /cps 500 to 1000 cps - linear decrease (log by log plot) from 0.075g ² /cps to 0.015g ² /cps 1000 to 2000 cps - constant at 0.015g ² /cps
Shock	30g
Dimensions	Stored: 23 X 22 X 24 inches Operational: 36 X 22 X 48 inches

Time Requirements: Calibration once/week, 1 man, 25 minutes.
Test: each astronaut once/day - 5 minutes.

BICYCLE ERGOMETERCharacteristics:

Weight - 150# Launch
0 Return

Size - 12 ft³ Launch
0 Return

Power - 48 watts (supplied through IMBMS)

Spacecraft Interface

The bicycle ergometer will interface structurally with the Space Station. The mounting rails of the Space Station must be strong enough to withstand any torque applied by the astronaut during exercise.

Environmental Constraints - None

Subsystem Support

All power and recording requirements will be obtained from IMBMS.

General Operational Requirements

There are no spacecraft orientation requirements other than those required to maintain a stable thermal environment.

Dimensions Stored: 12 X 15 X 14 inches
 Operational: 30 X 36 X 14 inches

Time Requirements: 1 experiment/man/week, 120 minutes each

SPECIMEN MASS MEASUREMENT DEVICE (SMMO)Characteristics:

Weight - 14 lbs Launch (3# Storage Box + 11# SMMO)
0 lbs Return

Size - 0.3 ft³ Launch
0 ft³ Return

Power - 2 watts, 28 VDC (supplied through IMBMS)

Spacecraft Interface

Undetermined at present. May interface with Space Station for storage. May interface with IMBMS during operation.

Dimensions Stored: 6 X 10 X 8 inches
 Operational: 6 X 10 X 14 inches

Time Requirements: 90 minutes/day, operator only

ROTATING LITTER CHAIR (RLC)

14

Characteristics:

Weight - 265 # Launch (container plus equipment)
10 or Return (otolith test goggles-OTG)

Size - 11.2 ft³ Launch 38 ft³ operational
84 in³ Return (goggles)

Power - 180 watts average, 400 watts peak (supplied through IMBLMS)

Spacecraft Interface

Provision must be made for structurally mounting the rotating litter chair base to the space station. Adequate support in the form of cross members is essential to provide a stable platform for the RLC. A minimal lighting intensity of 20 ft candles is required.

Subsystem Support

None from the Space Station.

Environmental Constraints - None other.

Dimensions: Stored: 22 X 26 X 10 inches

Operational: (a) As chair, about those of a Barany chair
(b) As litter, about those of an operating room table
(exact dimensions unavailable)

Time Requirements: Each astronaut one test every second day,
Each test: 60 minutes

15

LOWER BODY NEGATIVE PRESSURE DEVICE (LBNP)

Characteristics:

Weight - 33 $\frac{7}{8}$ lb
 0 lb Return

Size - 5 ft³ Launch 10.6 ft³ operational
 Return

Power - 28 VDC

Spacecraft Interface

Operational mounting location and provisions must be provided which allow subject free access to open end of the LBNP and enough clearance for comfortable space operation. Location of the LBNP device should be in the area of the supporting console and in the viewing cone of the experimenter.

Environmental Constraints - None

General Operational Requirements

Flight Operational Requirements - None

Dimensions: Stored: 24 X 30 X 12 inches

Time Requirements: One test for every subject every fourth day, 75min/test.

II C SCHEDULE/AVAILABILITY

II C. SCHEDULE/AVAILABILITY

Phase B3 of the IMBMS effort was begun in December 1963.

Two contractors are continuing to work competitively in this 13-month phase which consists of the construction and test of an IMBMS functional breadboard. The first flight unit of IMBMS can be completed in the summer of CY73. However, schedules will be altered in accordance with manned space flight requirements. All of the AAP experiments, candidate AAP experiments, and medical/behavioral experiments currently in definition will be served by the IMBMS aboard the second dpy workshop and space station, according to present planning. During the time period between now and the flight of IMBMS new medical/behavioral experiment proposals will be received, some of which will be approved for support and ultimate flight. It is believed that the planning of the IMBMS has provided for most of these, but if additional equipment should be necessary, Workshop and Space Station planning should remain flexible enough to accommodate it.

AAP MEDICAL/BEHAVIORAL EXPERIMENTS
APPROVED AS OF July 1969

MO70 - NUTRITION AND MUSCULOSKELETAL FUNCTION (Governing Protocol)

Principal Coordinating Scientist: Paul C. Rambaut, Ph.D., MSC

Assistant Coordinating Scientists: Richard Boster, D.V.M., MSC
Miss Rita Rapp, MSC
Malcolm Smith, D.V.M., MSC

Individual Experiments or Measurements:

MO71 - Mineral Balance

Principal Investigator: G. Donald Whedon, M.D., NIH

Co-Investigator : Leo Lutwak, M.D., Ph.D.
Cornell University

MO72 - Bone Densitometry

Principal Investigator: Pauline B. Mack, Ph.D.
Texas Women's University

MO73 - Bioassay of Body Fluids

Principal Investigator: Craig L. Fischer, M.D., MSC

Co-Investigator : Carolyn Leach, Ph.D., MSC

MO74 - Specimen Mass Measurement

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator : William Thornton, M.D., MSC

* * * * *

M090 - CARDIOVASCULAR FUNCTION (Governing Protocol)

Principal Coordinating Scientist: Robert L. Johnson, M.D.

Individual Experiments or Measurements:

M091 - LBNP (Pre- and post-flight)

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator : Robert L. Johnson, M.D., MSC

M092 - Inflight LBNP

Principal Investigator: R. L. Johnson, M.D., MSC

Co-Investigator : John Ord, Colonel, USAF, MC
Brooks AFB, Texas

M093 - Vectorcardiogram

Principal Investigator: Capt. N.W. Allebach, Bureau of
Medicine & Surgery, Washington, DC

Co-Investigator : R. F. Smith, M.D., Naval Aerospace
Medical Institute, Pensacola, Fla.

* * * * *

M110 - HEMATOLOGY AND IMMUNOLOGY (Governing Protocol)

Principal Coordinating Scientist: Craig Fischer, M.D., MSC

Individual Experiments or Measurements:

M111 - Cytogenetic Studies of Blood (Pre- and post-flight)

Principal Investigator: Michael Bender, Ph.D., ORNL, Tenn.

Co-Investigator : Miss P. Carolyn Gooch, ORNL, Tenn.

M112 - Immunology Study (Pre- and post-flight)

Principal Investigator: S. E. Ritzman, M.D., University of
Texas, Galveston

Co-Investigator : W. C. Levine, M.D., University of
Texas, Galveston

ML10 - HEMATOLOGY AND IMMUNOLOGY (Continued)

ML13 - Blood Volume and Red Cell Life Span

Principal Investigator: Phillip C. Johnson, M.D.
Baylor University, Texas

ML14 - Red Blood Cell Metabolism

Principal Investigator: C. Mengel, M.D.
University of Missouri

Consultants: Wallace H. Jensen, M.D., Ohio State University
David Turner, Ph.D., Hospital for Sick Children
Scott H. Swisher, M.D., Michigan State University
Vernon Knight, M.D., Baylor University
Wolf Vishniac, Ph.D., University of Rochester

ML30 - NEUROPHYSIOLOGY (Governing Protocol)

Principal Coordinating Scientist: Milton R. DeLucchi, Ph.D., MSC

Individual Experiments or Measurements:

ML31 - Human Vestibular Function

Principal Investigator: Ashton Graybiel, M.D., Naval
Aerospace Medical Institute
Pensacola, Florida

Co-Investigator : Earl F. Miller, Ph.D., Naval
Aerospace Medical Institute,
Pensacola, Florida

ML32 - Neurological Experiment - EEG

Principal Investigator: Dr. W. Ross Adey
University of California, Los
Angeles

Peter Kellaway, Ph.D.
Baylor University, Texas

Consultant: Maitland Baldwin, M.D.

HL50 - BEHAVIORAL EFFECTS (Governing Protocol)

Principal Coordinating Scientist: Edward C. Hoesley, Ph.D., MSC

Individual Experiments or Measurements:

HL51 - Time and Motion Study

Principal Investigator: Joseph P. Kubie, Ph.D., Fordham University, New York

Co-Investigator : Edward J. McLaughlin, Ph.D., NASA Headquarters

Consultants: John T. Elrod, Ph.D.,
Jesse Orlansky, Ph.D.

* * * * *

HL70 - PULMONARY FUNCTION AND ENERGY METABOLISM (Governing Protocol)

Principal Coordinating Scientist: Edward L. Beckman, M.D.

Individual Experiments or Measurements:

HL71 - Metabolic Activity

Principal Investigator: Dr. Edward Michel, MSC

Co-Investigator : J. A. Rummel, Ph.D., MSC

HL72 - Body Mass Measurement

Principal Investigator: John Ord, Colonel, USAF, MC Brooks AFB, Texas

Co-Investigator : William Thornton, M.D., MSC

Consultants: Ulrich C. Luft, M.D., Lovelace Foundation
Wayland Hall, Ph.D., MSC
George C. Armstrong, Jr., M.D., MSC

* * * * *

ADDITIONAL AREA OF INVESTIGATION:

HL90 - MICROBIOLOGY (Governing Protocol)

Principal Coordination Scientist: James McQueen, D.V.M.

Assistant Coordinating Scientist: James K. Ferguson, Ph.D.

MEASUREMENT/BEHAVIORAL MEASUREMENT CAPABILITY
of

INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY
MEASUREMENT SYSTEM

INCLUDE

I. NEUROLOGICAL

Clinical Evaluation (to include reflexes
and sensory and motor pathways)

Agravic Perception of Personal and Extra-
Personal Space (Minimum restraint device)

Ocular Counter-Rolling

Oculogyral Illusion

Visual Task with Head Rotation

Electronystagmogram

Angular Acceleration Threshold

EEG

To be done
with litter-chair

II. CARDIOVASCULAR

✓ Clinical Evaluation

✓ ECG (Frank Lead System)

✓ Phonocardiogram

✓ Cardiac Output - (By impedance if technique
verified; by indicator-dilution
if necessary)

✓ Arterial Blood Pressure

✓ Venous Pressure - Peripheral

Blood Volume and Fluid Compartments -
See Hematology and Metabolism

Regional Blood Flow - Limb (or Digit)
(Distribution of Blood Volume)

Venous Compliance

Arteriolar Reactivity

(Limb Plethysmography)

2

INCLUDE

Arterial Pulse Contour

In-Flight Exercise

LBNP

Elastic Bandage

PROVIDE FOR INSTALLATION IF REQUIRED:

Ballistocardiogram

Carotid Body Stimulation

Thoracic Blood Flow

Venous Pressure - Central
(By Catheter if Necessary)

III. RESPIRATORY

✓ Clinical Evaluation

✓ Respiratory Rate

Lung Volumes Including Residual Volume
(For total lung capacity, and mixing
efficiency)

Pressure, Flow, and Volume (Simultaneously)
(-p Airway Resistance)

Compliance - Lung or Total
(Lung, if can)

INCLUDE

Distribution of Blood Flow and Gas in Lungs

Includes: Capillary Blood O_2 , CO_2 , and pH

Breath by Breath O_2 Consumption
and CO_2 Production

O_2 Consumption - With Measured
Exercise

Alveolar to Arterial Gradient
Breathing Air and 100% Oxygen

Diffusion Capacity (if suitable technique)
(Look into O_2 ¹⁸ method - Dr. Richard W.
Hyde, U. of Pennsylvania, Dept. of
Physiology)

IV. METABOLISM AND NUTRITION

Clinical Evaluation

Energy Metabolism (Continuous O_2 and CO_2 Analysis
with Breath by Breath Sensitivity) with Various
Levels of Activity

Oral Temperature

Skin Temperature

Caloric Intake

Body Mass In-Flight (Thornton Technique ± 0.01%)

[Lean Body Mass Pre- and Post-Flight] -
(Not a Part of IMBIMS)

Muscle Size and Strength

Balance Studies

- Fluid, including Sweat

- Nitrogen (See Area IX)

- Mineral (See Area IX)

- Electrolyte (See Area IX)

INCLUDE

Provide for : Accurate Urine Volume Measurement
Accurate Wet Weight of Feces
Return of Total Dry Stool
Accurate Fluid Intake Measurement
Return of all Food Packages Marked
by Date Time and Individual
Sweat Measurement and Sample Return

Total Body Water (Breatholator or Deuterium)

↓ Clinical Laboratory Evaluations - See List Under Area IX

PROVIDE FOR INSTALLATION IF REQUIRED:

EMG

Bone Densitometry - Isotope Technique

Gastric Pressure and pH (Endoradiosonde)

Plasma Volume On-Board

Mineral Metabolism by Isotopic Techniques

V. ENDOCRINOLOGY

Clinical Evaluation

↓ Clinical Laboratory Evaluations - See List

INCLUDE

VI. HEMATOLOGY

Clinical Evaluation

Rumple Leeds

Blood Volume and Fluid Compartment

Plasma Volume - RHISA

RBC Mass - DFP32 or Cr51

Total Body Water

RBC Survival - DFP32

Clinical Laboratory Evaluations - See List

VII. MICROBIOLOGY AND IMMUNOLOGY

Clinical Evaluation

Body Microflora (Bacterial, Viral, and Fungal)

Environmental Culturing (Bacterial, Viral, and Fungal)

Clinical Laboratory Evaluations - See List

VIRAL
A/B SENSITIVITY

VIII. BEHAVIORAL DEFECTS

Clinical Evaluation

Sensory Test Battery (See Also Neurology)

Perceptual Evaluation (If validity of Tests Established)

Higher Thought Processes

Memory - Short and Long Term

Vigilance (By measurement of operational tasks)

INCLUDE

Learned Activity (Tracking and Reaction Time)

Recording of Crew Intercommunication with
Automatic Phrase in 15 Minutes if not Sampled

Time and Motion Study

IX. CLINICAL LABORATORY EVALUATIONSReference Area

Creatine and Creatinine - Urinary	IV ✓
Urinary and Fecal: N, Ca, P, Na, K, Cl, and Mg	IV ✓
0 Macoproteins - Urinary (P1)**	IV
0 Pyrophosphates - Urinary (P1)**	IV
0 Hydroxyprolines - Urinary (probably P1)**	IV
0 Total Amino Acids - Urinary (P1)**	IV
Urinary: Osmolality, Color, Sp Gr, pH, Glucose, Protein, Bile, Blood, and Microscopic (i.e., Routine Urinal- ysis - Inflight) <i>+ ACEFONK</i>	IV ✓
Plasma Volume (probably P&P)*	IV & VI ✓
Electrolytes - Serum	IV ✓
Total Protein - Plasma	IV ✓
0 Protein Electrophoresis - Plasma	IV
Glucose - Blood (Inflight)	IV ✓
Ca and PO ₄ - Serum (probably P1)	IV ✓
0 Bilirubin - Serum	

*p&p - pre & post-flight

**p1 - post-flight evaluation of inflight samples

SPLA

<u>INCLUDE</u>	<u>Reference Area</u>
0 Cholesterol - Serum (probably P1)	IV
0 BUN (probably P1)	IV
0 Uric Acid - Blood (P1)	IV
Alkaline Phosphatase - Serum (probably P1)	IV ✓
pH, pO ₂ , and pCO ₂ - Blood	III & IV ✓
0 Bicarbonate - Blood	III & IV
0 CPK (Creatine Phosphokinase - Serum (P1))	IV
0 LDH and LDH Isoenzymes - Serum (On-board if have electrophoresis)	IV
SGOT - Serum	IV ✓
SGPT - Serum	IV ✓
0 Aldosterone - Urine (P1)	IV & V
0 ADH - Urinary and Serum (P1)	V
0 ACTH - Blood (P1)	V
0 Serum Free Thyroxin (T ₄ - Serum) (If in-flight, will require thin layer chromatography)	V
0 TTPA (probably P1)	V
0 17-hydroxycorticosteroids - Urine and blood (P1)	V
0 17-ketosteroids - Urine (P1)	V
0 VMA - Urine (Probably P1)	V
0 Metanephrines - Urine (P1)	II & V
0 Catechols - Urine (P1)	II & V
0 Histamine - Blood and Urine (P1)	II & V

2
1055
IN-RT

INCLUDEReference Area

○ 5 Hydroxy Indolacetic acid - Urinary (Probably P1)	V
Blood Cell Morphology (RBC, WBC, and Diff - Smear will suffice for platelets)	VI ✓
Reticulocyte Count	VI ✓
Hematocrit	VI ✓
Hemoglobin	VI ✓
RBC Fragility (Osmotic)	VI ✓
RBC Mass and Survival	VI ✓
Bleeding Time	VI ✓
Clotting Time	VI ✓
○ Prothrombin Consumption	VI
Clot Retraction	VI ✓
○ Lymphocyte Karyotyping (probably P1)	VI
○ WBC Mobilization (Rebuck Technique)	VI
Immunoglobulins and Fibrinogen	VI & VII
Transferrin	
Hemoglobin	
Methemoglobin	onboard if have electrophoresis
○ RBC Enzyme Studies (P1) (ref. Governing Protocol M110)	VI
○ Complement Titration	VII
○ Antibody Titration	VII

PROVIDE FOR INCLUSION IF REQUIRED:

Sulfate - Urinary	IV
TRH (P1)	V
Growth Hormone (P1)	V
Thyroid Bound Globulin (T ₃) (P1)	V

INCLUDE

REFERENCE AREA

PROVIDE FOR INCLUSION IF REQUIRED (Cont'd):

Parathyroid Hormone (Radio- Immune Technique - Serum) (P1)	V
Parathyroid Hormone - Urinary (Nelson Technique - (P1)	V
Calcitonin - Serum (P1)	V
Insulin Assay (P1)	V
Glucagon Assay (P1)	V
Serotonin (5 HIAA) - Blood (P1)	V
Platelet Adhesiveness	VI
Fibrinolytic Activity	VI
Blood Rheology	VI
Blood Lipids	VI

MEDICAL/BEHAVIORAL EXPERIMENTS

Experiment Definition

A. Ongoing Experiments in Definition

EXPERIMENT No.	TITLE	P.I.	PRIORITY
M075	Gastric Motility	M. Peterson Washington University	II
M076	Chemical Analytic Techniques	V. R. Huebner and R. Nakamura Beckman Instruments	I
M115	Endogenous CO Production	J. Laurence and H. Winchell - Univ. of California (Berkeley)	I
RB	Pulmonary Function	J. B. West - University of California (San Diego)	II
M211	Urinary Endocrine Assay	D. Nelson - University of Utah and J. E. Bethune, University of Southern California	I

APPENDIX C

B. Experiment Definition Proposals Accepted or Acceptable Proposals Expected

EXPERIMENT No.	TITLE	P.I.	PRIORITY
RB	Bone Density (Photon Absorption Technique)	J. Cameron Univ. of Wisconsin	I
M079	Glucose Metabolism	T. PIEMME (U. of Pitt. G. D. Whedon (N. I. H.))	II
M116	Special Hematological Effects	C. Fischer (MSC)	I
M191	Spacecraft Ecology- Bacteriology and Mycology	J. K. Fergurson (MSC)	I
M192	Spacecraft Ecology- Virology	J. McQueen (MSC)	I

C. Needed Experiment Definition Efforts

Cardiac Output
 Thoracic Impedance Measurement (Kubicek)
 Regional Blood Flow
 Arterial and Venous Pressure Measurement
 Vascular Reactivity and Venous Compliance
 Lean Body Mass Measurement and Body Composition
 Water, Electrolytes, Acid-Base Balance Renal Control
 Inflammatory Response
 Endocrine Changes (Pituit., Thyroid, etc.)
 Behavioral Measurements
 Information Processing
 Memory
 Activity
 Adaptability
 Group Processes
 Bio-Rhythms

All I

Mr. Vinograd

MSC ORIENTATION FOR SPACE STATION CONTRACTORS

INTEGRATED
MEDICAL AND BEHAVIORAL
LABORATORY
MEASUREMENT
SYSTEM
(IMBLMS)

Presentation Handout

N. Belasco and S. L. Pool, M.D.

September 10, 1969



IMBLMS Philosophy

Up to the present time, manned space missions have conducted medical experiments as separate and individual entities.

IMBLMS will provide a systems capability to the astronaut physician. It does this by enabling an entire comprehensive series of medical and behavioral measurements to be conducted onboard the spacecraft individually or in combinations. The systems capability includes the processing of the medical and behavioral measurement data for display, storage, playback, etc. IMBLMS provides this total system measurements capability in such a manner that each part of the IMBLMS may service many measurements or parts of measurements with the same function or different functions. Thus, the onboard astronaut physician will have available to him the means for conducting any and all medical and behavioral experiments, or series of experiments, whose measurements can be accomplished by the IMBLMS.

The IMBLMS also maintains a flexibility in its design that will permit changes in measurement capability and equipment integration from flight to flight and during missions. It intends to combine a practicality and suitability for use in early extended duration space flight experiments with a growth potential for accommodating new measurements stemming from the impact of new knowledge and the products of new technology.

WHAT IMBLMS IS

PROGRAM TO DEVELOP TOTAL SYSTEM CAPABILITY FOR MEDICAL
AND BEHAVIORAL MEASUREMENTS

COMPREHENSIVE MEASUREMENTS CAPABILITY CAN ACCOMMODATE
MOST EXPERIMENTS PRESENT AND PROJECTED

COMMONALITY

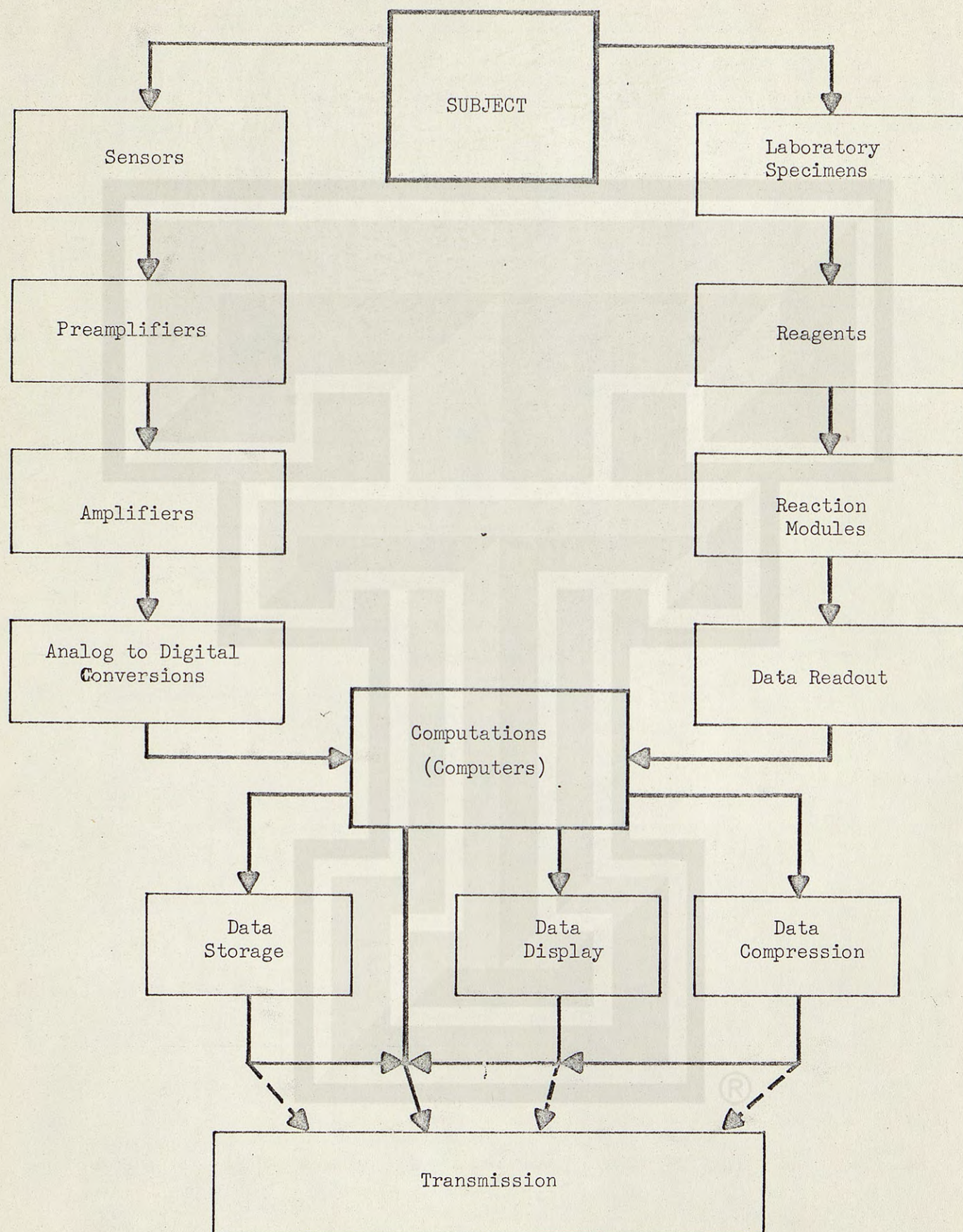
EQUIPMENT COMMON TO MANY EXPERIMENTS
MEASUREMENTS COMMON TO MANY EXPERIMENTS
COMMON INTERFACE FOR EXPERIMENTS HARDWARE

FLEXIBILITY

EXPERIMENT PLANNING
S/C INSTALLATION

PRESENT GOAL - CONDUCT EXPERIMENTS

EVOLUTION - DIAGNOSTIC, THERAPEUTIC, SURGICAL



FLOW DIAGRAM

PHASE A = (COMPLETED 1/66)

Headquarters Study - LMSC - \$366.7 K

OBJECTIVE: Define and describe integrated composite of
medical lab for spacecraft

RESULTS: Base idea feasible

FOLLOW-ON: Timeline testing and feasibility analysis of
hypothetical AAP biomed experiment program

USED: Mockups
Detail procedures of experiments
45-Day medical flight schedules

RESULTS: - Combine experiments, equipment, and measurements
for efficiency and commonality
- Crew times and procedures reasonable

PHASE B1 - START 6/27/67

Headquarters Study - Four Months Duration

Competitive - LMSC and GE - 50 K Each

OBJECTIVE: Concept Definition

TASKS:

1. Analyze and Refine Measurements and Experiments
2. Survey and Identify Equipment and Methodologies
3. System Design Approach and Definition
4. Recommend Measurement Conduct -- O.B. vs. P.F.A.
5. Identify Modular Approach
6. Define Data Management System Requirements and Approach
7. Preliminary Design Concept.

Phase B1 Contracts Completed 10/27/67

PHASE B2

Two-Month "Extension" - 100 K/Contractor

- A. Refine and Revise Measurement Technique Requirements
- B. Refine Requirements for Measurement Equipment Modules
- C. Define Measurement/Spacecraft Interface Requirements
- D. Additional Systems Engineering/Integration Efforts

"Extension" Completed 2/15/68

FINAL PRESENTATION AT MSC

IMBLMS

PHASE B3

PRIMARY OBJECTIVE:

DESIGN, ASSEMBLE, TEST AND DELIVER
A FUNCTIONAL BREADBOARD SYSTEM

EMPHASIS ON:

DEVELOPING AND VALIDATING TECHNIQUES
AND PROCEDURES

DETERMINING EQUIPMENT DETAIL DESIGN
REQUIREMENTS

IMBLMS MEASUREMENTS

1. NEUROLOGICAL
2. CARDIOVASCULAR
3. RESPIRATORY
4. METABOLISM AND NUTRITION
5. ENDOCRINOLOGY
6. HEMATOLOGY
7. MICROBIOLOGY AND IMMUNOLOGY
8. BEHAVIORAL EFFECTS
9. CLINICAL LABORATORY EVALUATIONS
10. ENVIRONMENTAL MEASUREMENTS



IMBLMS MEASUREMENTS

I. NEUROLOGICAL

1. Clinical evaluation
2. Electronystagmogram (ENG)
3. Electroencephalogram (EEG)
4. Electromyogram
5. Level of consciousness assessment

II. CARDIOVASCULAR

1. Clinical evaluation
2. ECG, VCG, sternal lead
3. Heart rate
4. Phonocardiogram
5. Cardiac output
6. Venous pressure - peripheral
7. Arterial blood pressure
8. Limb plethysmography
9. Pulse wave velocity
10. Arterial pulse contour
11. Inflight exercise
12. LBNP

III. RESPIRATORY

1. Clinical evaluation
2. Respiratory rate
3. Lung volumes
4. Pressure, flow, and volume (simultaneously)
5. Distribution of blood flow and gas in lungs
6. Diffusion capacity

IV. METABOLISM AND NUTRITION

1. Clinical evaluation
2. Energy metabolism
3. Core temperature
4. Skin temperature
5. Caloric intake
6. Muscle size and strength
7. Balance studies
8. Total body water
9. Body mass

V. ENDOCRINOLOGY (See also Section IX)

1. Clinical evaluation

IMBLMS MEASUREMENTS (Continued)

VI. HEMATOLOGY (See also Section IX)

1. Clinical evaluation
2. Rumpke Leede

VII. MICROBIOLOGY AND IMMUNOLOGY

1. Clinical evaluation
2. Body microflora (bacterial, viral, and fungal)
3. Environmental microflora (bacterial, viral, and fungal)

VIII. BEHAVIORAL EFFECTS

1. Clinical evaluation
2. Sensory test battery
3. Perceptual evaluation
4. Higher thought processes
5. Memory - short and long term
6. Vigilance
7. Learned activity
8. Time and motion study

IX. CLINICAL LABORATORY EVALUATIONS

1. Urinary Ca, P, Na, K, and Cl
2. Urinalysis
3. Plasma volume
4. Serum electrolytes (Ca, Na, K, Cl, and P)
5. Total protein - plasma
6. Blood glucose
7. Ca and PO_4 - serum
8. pH, pO_2 , and pCO_2 - blood
9. Hemoglobin
10. Hematocrit
11. Blood cell morphology
12. Reticulocyte count
13. RBC fragility (osmotic)
14. RBC mass and survival
15. Bleeding and coagulation times

X. ENVIRONMENTAL MEASUREMENTS

1. Temperature
2. Pressure
3. Humidity
4. Atmospheric composition (O_2 , CO_2 , N_2 , and H_2O in FBB)
5. Spacecraft motion

APPENDIX A

I. NEUROLOGICAL

1. Clinical evaluation
2. Electronystagmogram (ENG)
3. EEG
4. EMG
5. Level of consciousness assessment

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NOTES:

1. Agravic perception, ocular counterrolling, and oculogyral illusion measurements may be omitted from the FBB. There will be a demonstration or explanation of the use of the data processing as though the above were included in the FBB, so that if NASA at some later time wishes to add these measurements to the breadboard, that addition would be facilitated.

2. A minimum of two leads of EEG will be included in the FBB system.

3. A minimum of one lead of nuchal EMG will be included.

4. Two channels of ENG will be provided in the FBB in order to enable simultaneous display and recording of the vertical as well as the horizontal components of the electronystagmogram.

5. The Adey-Kellaway EEG experiment currently being proposed for AAP

must be included in IMBLMS planning, if not in the functional breadboard itself.

6. Criteria for approvals of testing of ENG, EMG, and EEG will require a demonstration of signals which, when compared with standard methods done simultaneously, show no significant difference. The length of the runs should be sufficient to assure that the equipment is functioning in an acceptable manner.

7. The use of the computer should not deteriorate the quality of the signals as compared to the standard.

8. A continuous period during which the subjects exhibit levels of sleep and arousal from deep sleep to excitement should be employed to demonstrate the capability of the system to acquire and manage the spectra of information content required for level of consciousness assessment.

II. CARDIOVASCULAR

1. Clinical evaluation
2. ECG, VCG, sternal lead
3. Heart rate
4. Phonocardiogram
5. Cardiac output
6. Arterial blood pressure
7. Venous pressure - peripheral (invasive technique during venapuncture)
8. Limb plethysmography (for use with LBNP and vascular occlusive techniques)
9. Pulse wave velocity
10. Arterial pulse contour (readout only - if falls out of other measurements)
11. Inflight exercise
12. LBNP

* * * * *

NOTES:

1. ECG shall provide options of Frank lead system, standard lead system, or sternal leads. These measurements
will not require testing beyond demonstrating that they
are not significantly different from standard methods done simultaneously
with those taken on the FBB. Conditions under which these tests are
performed must include measurements made before, during, and following
both exercise and exposure of the subject to the application of lower body

negative pressure. Operational acceptability, calibration techniques, and data processing shall form the major areas for adequacy of these measurements.

2. The function of a cardiometer to display heart rate should be tested, along with and similar to procedures noted above.

3. Since heart rate is a variable of interest in several of the experiments, adequate automatic data handling capability must be demonstrated for this physiological parameter.

4. Phonocardiogram system requirements are to be capable of fidelity of information content from 0 to 500 cps with filtering capabilities in the ranges of 0 to 20 cps, 10 to 30 cps, and 30 to 500 cps.

5. The phonocardiogram/vibrocadiogram must be tested to assure that its frequency response is within acceptable limits. This is basically an engineering test; however, normal subject testing is also required to ensure that the microphone has no idiosyncrasies which destroy validity when employed on human subjects.

6. Cardiac output is a measurement for which testing and criteria for testing should be more extensive than with some other measurements. The exact procedures and testing criteria are to be spelled out by the contractor and included in the respective end products of appropriate tasks. It is preferred that human subjects be used for this testing.

7. The least acceptable level of testing would utilize animals in lieu of human subjects. Furthermore, each proposed method should be analyzed to reveal physiological state during which maximum error would be expected, and actual laboratory comparisons obtained under these conditions.

8. Measurements should be carefully examined and programmed to remove as much doubt about their usefulness as possible and to establish some reliability limits for them. Hence, whatever methods are to be eventually selected, they should exhibit an acceptable level of repeatability.

9. Cardiac output will be displayed in liters/minute.

10. The method for measuring systolic and diastolic blood pressures should input systolic and diastolic in digital format into the data management system. Testing should be standardized against clinical auscultatory technique. Measurements should be taken recumbent, sitting, standing, and during exercise.

11. Limb plethysmography will require careful testing and intensive effort to establish a calibration technique.

12. Pulse wave velocity is a measurement for which extensive testing is not considered necessary. The same holds true for arterial pulse contour.

13. Venous pressure measurement will not require extensive testing. The method employed for calibration should receive attention.

14. Ballistocardiogram not to be included in breadboard, but breadboard design sketches shall indicate approach to providing ballistocardiogram input and data handling.

III. RESPIRATORY

1. Clinical evaluation
2. Respiratory rate
3. Lung volumes including residual volume and timed vital capacity
(with provision for calculation of total lung capacity, minute respiratory volume, alveolar ventilation, etc.)
4. Pressure, flow, and volume (simultaneously - to calculate airway resistance and total compliance)
5. Distribution of blood flow and gas in the lungs - includes:
 - Capillary blood O_2 , CO_2 , and pH (see Section IX)
 - Breath by breath O_2 consumption and CO_2 production
 - O_2 consumption and CO_2 production with measured exercise
 - Alveolar: arterial gradient breathing air and 100% oxygen
6. Diffusion capacity

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NOTES:

1. Respiration measurements made must be in agreement with standard laboratory principles and practice.
2. Consideration of application of measurement principles to future flight hardware should be given prime consideration.
3. Diffusion capacity is considered to be a prime measurement for flight versions of IMBLMS; hence, consideration of methodologies and automatic data processing of this raw data is of importance even at the breadboard stage. If the contractor feels that this meets any of the criteria for exclusion from FBB as defined in Task I, then he shall so designate and document that exclusion as part of Task I.

IV. METABOLISM AND NUTRITION

1. Clinical evaluation
2. Energy metabolism (continuous O_2 and CO_2 analysis with breath by breath sensitivity) with various levels of activity - commonality with respiratory measurement equipment)
3. Core temperature (ear canal)
4. Skin temperature
5. Caloric intake (assume preflight caloric assays of flight food)
6. Muscle size and strength
7. Balance studies (fluid, nitrogen, mineral, electrolyte)
8. Total body water
9. Body mass (see Note 2)

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NOTES:

1. Ear canal ("core") temperature and average skin temperature methods should be given a thorough engineering testing followed by brief subject testing.
2. The data management system shall be designed to completely interface with the NASA-Thornton instrument for body mass measurement when the FBB is delivered to MSC. NASA will provide such information as required to facilitate this switch of equipment. It will be tested against standard engineering specifications.
3. Methods used to measure muscle size and strength should be tested from an engineering standpoint with minimal subject testing required. These

measurements should not be isolated from the rest of the functional unit but should interface with the FBB data system.

4. Total body water measurement should be given validation testing.

5. Although not a part of the functional breadboard, it is important to note that in order to successfully accomplish the investigations planned it will be essential for IMBLMS to provide techniques for:

- a. Accurate urine volume measurement with each micturition
- b. Accurate fluid intake measurement
- c. Return of all food packages marked by date, time, and individual
- d. Accurate wet weight of feces
- e. Return of total dry stool
- f. Sweat measurement and sampling return
- g. Accurate identification and labeling of all samples and specimens by date, time, and individual

IX. CLINICAL LABORATORY EVALUATIONS

1. Urinary Ca, P, Na, K, and Cl
2. Urinary: color, Sp. Gr., pH, glucose, protein, bile, blood, and microscopic (i.e., routine urinalysis - inflight)
3. Plasma volume
4. Serum electrolytes (Ca, Na, K, Cl, and P)
5. Total protein - plasma
6. Blood glucose
7. Ca and PO_4 - serum
8. pH, pO_2 , and pCO_2 - blood
9. Hemoglobin
10. Hematocrit
11. Blood cell morphology (RBC, WBC, and diff - smear will suffice for platelets)
12. Reticulocyte count
13. RBC fragility (osmotic)
14. RBC mass and survival
15. Bleeding and coagulation times

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NOTES:

1. The testing of techniques may be on standard and unknown specimens; however, specimen handling techniques peculiar to the spacecraft environment constraints must be demonstrated.

2. Clinical laboratory evaluations on B2 list will be retained in

planning for follow-on phases as either postflight analyses on preserved specimens or pre- and postflight determinations. Provision for them on an individual basis is not expected to be reflected in the IMBLMS breadboard except for the demonstration of sample identification, labeling, preservation and storage techniques for general categories of sample sources (i.e., blood, plasma, serum, urine, etc.)

3. Inflight bone densitometry and gastric pH and pressure are not to be included in the IMBLMS breadboard. However, breadboard design sketches shall indicate contractor approach to inputs and data handling.

V. ENDOCRINOLOGY (SEE ALSO SECTION IX)

1. Clinical evaluation

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VI. HEMATOLOGY (SEE ALSO SECTION IX)

1. Clinical evaluation
2. Rumpke Leede

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VII. MICROBIOLOGY AND IMMUNOLOGY

1. Clinical evaluation
2. Body microflora (bacterial, viral, and fungal)
3. Environmental microflora (bacterial, viral, and fungal)

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NOTES:

1. Bacterial, fungal, and viral culturing may be omitted from the FBB, labeling, but techniques for/handling, sampling, preservation, and storage of specimens will be demonstrated in the FBB.

VIII. BEHAVIORAL EFFECTS

1. Clinical evaluation
2. Sensory test battery (see also Neurology)
3. Perceptual evaluation (may rely on sensory test)
4. Higher thought processes
5. Memory - short and long term
6. Vigilance (by measurement of operational tasks)
7. Learned activity
8. Time and motion study

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NOTES:

A major concern in this area is that the behavioral measurement system is adaptive to the flight IMBIMS and interfaces to the maximum possible extent with the data management system of the FBB.