RATIONALE FOR MEDICAL INVESTIGATIVE STUDIES PROPOSED FOR THE SKYLAB PROGRAM

PURPOSE

This paper discusses the rationale for and represents the outline of the major inflight medical experiments and defines those critical for qualifying man for space operations of extended durations.

BACKGROUND

The major challenge to the discipline of space medicine is the characterization of the nature and degree of all the major changes in man's functional capabilities resulting from prolonged exposure to the space environment. Two circumstances make the problem difficult to solve. First, knowledge is relatively limited on the normal or functional capabilities of the human organism for use as comparative or control information. Second, the specific consequences of certain environmental changes on the functional capabilities of man have not been defined, making this a primitive field of study where theories predominate and findings are often controversial. Faced with this situation, the first NASA programs were aimed at verifying theoretical predictions through a series of increasingly comprehensive flight observations. As new data were gained, attention turned to the fundamental questions about the suitability of man as an inhabitant of the space flight environment for long periods of time.

At the outset it was conceded that man is not inherently qualified for space missions. His function as a total human organism, and the function of significant body systems, must be evaluated in response to the stresses of space flight just as the engineer evaluates the spacecraft systems. In an attempt to provide a safe and biologically sound method of grossly qualifying man for the next step, a technique of roughly doubling the duration of exposure to the flight environment was adopted. This technique reached its zenith with the completion of the four-, eight-, and fourteen-day missions. The overall performance of the crew and the detailed physiological findings available were reviewed after each step before man was exposed to the next longer increment in flight duration. The immediate objective of the program to date has been to qualify man for the lunar mission and, thus, durations of eight and fourteen days were most significant. The objective was to observe system changes in relation to the duration of exposure of the two crewmen on each flight. The elucidation of specific etiologies and mechanisms responsible for observed changes were to become a part of more complex studies in future programs. More sophisticated physiological and behavioral studies are now required to qualify man for continued space flight.

All of the flight programs to date have been aimed at developing a capability to get man into the space environment reliably and provide the assurance that both the men and the equipment sustaining them would function for the required flight duration. We are reminded here of General Armstrong's remark during an early space symposium: "Aerospace medical research should be completed before the engineers sit down at the drawing board to design a spacecraft." We fully agree that this should be the case, but technology has forced us to the position in the flight program where we are trying to do many things simultaneously. This has put great significance on the confirmation of ground-based research by flight observations.

It is important to emphasize the significant role that man has in the conquest of space. Questions are again being raised concerning man's limitations in space. It is being asserted that unmanned exploration would not be hampered by human limitations. Today it is untenable to hold that the machine can do all that man can. The tremendous range and flexibility of such human functions as pattern recognition, problem solving, intelligence, initiative, and recognition of goals cannot be duplicated by the machine except in the most rudimentary fashion. These exclusively human attributes should be exploited in space as elsewhere. Man has become an increasingly important part of the total spacecraft systems since Project Mercury, and he has shown himself to be a good performer. With adequate medical support based on a well-planned program of medical evaluation, the weight of evidence favors the belief that man can do the tasks which will be required of him in space flights of the future.

The role of space medicine is to provide operational support and in association with the medical research community to design the experiments necessary to qualify man to meet the special biomedical problems of space. Space medicine also advises on engineering design. This substantial effort required close and constant liaison at all stages of design, manufacture, test, check-out, and flight in order that reliable advice can be provided concerning the follow-on missions. Significant natural features of the space flight environment include the null gravity state, altered ionizing radiation flux from that encountered within the earth's atmosphere and an altered exposure to sunlight and darkness. Spacecraft design results in other factors such as the atmospheric composition and pressure, the volume available for living and working, noise and vibration levels, and a multitude of others, which, when combined, make space flight truly unique in the history of human experience. Space Medicine must understand these effects both singly and in combinations in order to make appropriate recommendations to engineers and crews.

Over the years there have been a number of dire predictions concerning man's response to space flight. These predictions have involved both the environment and the reaction of man's physiology to it. The flight program to date has at least begun to give some insight into the validity of ground-based predictions concerning man's responses. Great harm can result by unwarranted predictions of disaster and also by over-optimistic projections of man's responses. Documentation of man's proven capability, or lack of it, must be continued at every space flight opportunity.

"NASA has, in addition, the responsibility to collect scientific data on the effect of subnormal gravity on human function and performance. This kind of information will ascertain to what extent earth medical observations and concepts may be restricted to the gravitational environment we happen to find on earth."

The scientific questions to be answered, which are appropriate to manned space flight, are as diverse and inexhaustible as those common to earthbound laboratories. There is no foreseeable end point for space related biomedical studies. There are, however, a series of what can be characterized as major plateaus of knowledge to be achieved sequentially in order to proceed rationally with increasingly complex flights, and with justifiable expectation of success. Ground-based laboratory studies, combined with the knowledge gained from observations made during the Mercury, Gemini, and Apollo programs, have carried us to at least two such plateaus.

The first plateau: The null gravity state cannot be produced for any appreciable length of time except by actual space flight. Therefore, the first orbital flights of animals by the U. S. and Russia were necessary to refute untested, but plausible, theories which predicted catastrophic failures of various vital functions in an organism suddenly thrust into an environment without gravitational force. Our first plateau, then, was achieved when knowledge gained in the Mercury program demonstrated that man could expect to remain alive and operationally effective for brief excursions into space. The Mercury flights were cautiously extended in duration to terminate with the day-and-a-half flight of MA-9 (Table I). The Mercury program produced positive evidence to indicate that significant physiological changes were appearing and were similar to those observed in man during prolonged bedrest or water immersion.

The second plateau: The studies conducted during the Gemini program were directed toward evaluating the magnitude of flight-related changes first noticed late in the Mercury program. In addition, the validity of conflicting reports of possible central nervous system and cardiac disturbances were evaluated. These reports arose, in part, from isolated interpretations of scattered and incomplete data from Russian manned space flights. It was necessary, also, to identify and characterize the importance of other physiological changes that might occur in manned flights lasting up to two weeks in duration. Since the principal changes observed in Mercury were concerned with alteration of cardiovascular reflexes that regulate the flow of blood against hydrostatic pressure in the gravity field, heavy emphasis was placed on evaluating the cardiovascular system during the Gemini program. The pre- and post-flight measurements and the inflight evaluations accomplished during Gemini were largely qualitative and were intended to detect gross alterations in the functional status of the major human systems as flight durations lengthened. The total missions flown may be seen in Table II.

The results of the Gemini studies have been reported in detail in a number of publications (References 1 through 8). The negative as well as the positive findings are of interest. Testing procedures were fairly extensive for the cardiovascular, hematological, and skeletal systems, while other areas received moderate or minimal coverage (Ref. 1). It was demonstrated that some of the major human physiological systems exhibit consistent and predictable changes after exposure to space flight, that these changes are completely reversible and should not be expected to degrade human performance or crew safety during missions required to achieve the goals of the Apollo program. Changes were detected in the cardiovascular system, the musculoskeletal system, the composition and quantity of body fluids including the circulating blood, hormone levels, and in the white cells of the blood, which afford defense against stressful environmental factors and invasion by harmful microorganisms. The fact that changes were not detected in other systems observed means, merely, that if changes occurred, they were not of sufficient magnitude to be detected by the methods employed.

Figures 1 and 2 describe what little is now known of the time course of observed physiological changes in six parameters of interest in the Gemini program and are indicative of the most significant positive physiological findings obtained. The loss of bone density in the os calcis peaked at 14% in the eight-day flight and returned to 2.5% loss in the fourteen-day mission (Ref. 14). The measurements of loss of bone density in the os calcis are remarkable for their inconsistency and indicate the need to correlate (if not control) levels of calcium intake and physical activity for more reliable interpretation of these bone densitometric observations. The crew of Genini VII provided a remarkable contribution by participating in the first semi-controlled metabolic study in space, involving regulated dietary intake and collection of all excreta for 10 days prior to the flight, during 14 days aloft, and for four days immediately following (Ref. 15). Changes in urinary calcium and calcium balance were considerably less in space flight than in earlier studies of a similar period of restricted bed rest. This first space study suggested: (1) the need to evaluate in earth studies the relative influences of physical activity, atmospheric composition, and pressure on calcium metabolism; and (2) the need for additional controlled metabolic studies in space to predict accurately the degree of mineral loss and whether countermeasures should be instituted.

The fourteen-day flight produced nitrogen and phosphorus metabolic data indicating a small, but significant, loss of muscle tissue, the time course of which is unknown. As was the case of loss of bone density, the changes that might be expected on flights of longer duration are entirely unknown.

With respect to the loss of red cell mass, there appears to be a tendency for the loss to subside, and perhaps level off as time progresses. The 20% loss in the eight-day flight was duplicated by that in the fourteen-day flight. This is entirely conjectural, however, and there are no data to support the hypothesis that the loss of red cell mass is a self-limiting phenomenon.

Two measurements relate to the cardiovascular deconditioning. The post-flight tilt pulse rate changes and the tilt blood pressure changes are essentially inconclusive because there were remarkable differences in the eight- and fourteen-day flights with respect to food and water intake, exercise, and thermal comfort. It will be remembered that the crew of Gemini VII were permitted to doff the space suits for a considerable portion of the flight. The reduction in sweating and overall increase in thermal comfort may account in some part for the apparent improvement in the physiological status relative to flight duration.

The spacecraft volume and the operational and technological complexities which had to be mastered during the Apollo program made it necessary to defer attempts to conduct more elaborate and meaningful inflight biomedical studies until after the lunar landing goal had been achieved. We do plan to confirm the Gemini data with adequate pre- and post-flight observations on every possible flight. These will involve blood volume and red cell mass studies, lower body negative pressure, X-ray densitometry, biochemical (blood and urine) studies and exercise response. This documentation will only place us on a firmer footing on the second plateau. We have not, and still will not, obtain any data on real-time changes prior to the follow-on programs to Apollo. A new requirement has resulted from our quarantine requirement on lunar return. The crew and spacecraft microbial flora has been documented pre- and post-flight.

The third plateau: A third plateau can be reached during the Skylab Program because it will, for the first time, permit the performance of certain real-time controlled, sequential, inflight biomedical and behavioral measurements. It probably will also be the first opportunity for a trained biomedical observer to participate as a flight crew member.

Nonmedical components of the Manned Space Flight team have questioned whether or not it is necessary to acquire medical and behavioral data throughout the full duration of all missions. Space Medicine elements strongly believe that such a requirement is fully justified and the following paragraphs support this thesis.

One of the prime objectives of this program is the qualification of man for longer duration flight. Certain critical inflight biomedical measurements are required to assure success in manned missions lasting two months or longer. Physiological changes have consistently been observed which could reduce the overall capability of man to cope effectively with the stresses of re-entry and landing and with inflight emergencies. It is impossible with our present knowledge to describe the rate of onset of potentially significant physiological changes, or to determine the relative importance of weightlessness as the primary causative factor. Very little is known of the influence of such man-made environmental features as physical confinement and oxygen-rich atmosphere or the acceleration profiles encountered. If the magnitude of changes observed are a function of mission duration, significant difficulty upon landing after a two-month mission is probable. The capability of the human organism to accommodate or adapt to various environmental stress factors--singly, in combination, static or changing in magnitude or combinations--must be assessed and understood.

The general similarity in the post-flight condition of the astronauts in the eight- and fourteen-day missions is encouraging, but it is vitally important to confirm whether or not this represents a natural process of acclimatization rather than gradual and progressive deterioration of the body. The inflight medical experiments proposed for the initial manned mission in the Skylab Program will provide the first bits of new knowledge required to explain the nature and extent of human acclimatization to the space flight environment in each orbit. Attainment of this goal will bring us to the edge of the desired third plateau of knowledge, i.e. instead of identifying only what happens, we will begin determination of why, when, and how it happens.

Flight data thus far indicate that physiologic change occurs during the early hours of exposure to space flight environment. All data thus far has been derived from missions of fourteen days or less duration. Evidence of readaptation to a 1g environment has been seen in post-flight measurements and information must be obtained concerning the inflight adjustments that occur throughout the flight phase. It is imperative, therefore, that critical data be obtained from the proposed experiments from the first day of flight. Preparations to do this are being made by placing the medical experiment equipment in the multiple docking adaptor which will allow its use before the SIVB workshop is activated. This approach will permit us to evaluate, for the first time, changes which occur both in the initial and later stages of flight; the time course of these changes throughout the duration of flight; and the post-flight readaptation processes of the crewman to these changes. To do less would continue the data gaps about which we could only continue to speculate.

What are the medical studies deemed critical and which are proposed to verify man's capability for extended space activities? A summary of some of the necessary experiments may be seen in Appendix A. Others are being evaluated at this time for inclusion in the list. Additional candidate experiments are listed in Appendix B. A set of medical investigative procedures has been evolved which are feasible and within the scope of current plans for Skylab missions. They are all addressed to the areas of greatest medical interest in establishing the qualification of man for long duration space flight. They all depend, however, upon the provision of hardware which will meet the physiological specifications. There are seven major areas of interest presently scheduled for investigation in Skylab:

1. Nutrition and Musculoskeletal Function

2. Cardiovascular Function

3. Hematology and Immunology

4. Neurophysiology

5. Behavioral Effects

6. Pulmonary Function and Energy Metabolism

7. Microbiology

Each of these governing protocols has a number of specific measurements, or tests which give a clearer picture of the function of that particular body system. The cardiovascular study, for instance, involves the use of lower body negative pressure, pre-flight, inflight, and post-flight. The device tests the cardiovascular system reflexes that normally operate to regular regional perfusion pressure in distribution of blood throughout the body as postural changes occur in the earth's gravitation field. This is a vitally important measurement of cardiovascular system response. The inflight measurement will allow us, for the first time, to establish the onset, the rate of progression, and the severity of adverse functional changes in the protective reflex responses. This procedure requires a medically trained observer on the crew. The cardiovascular investigation also includes the obtaining of a vectorcardiogram during given workloads on a bicycle ergometer. The value of an anti-deconditioning garment will also be investigated.

The conduct of the metabolic and musculoskeletal experiments will require that the habitability hardware, food, water, waste management, personal hygiene, and sleep stations be configured in the best state-of-the-art knowledge, and made available for the early portion of the flight. The workshop itself will be utilized to test advanced concepts in habitability and to try various experimental concepts.

The investigative procedures described are ones which appear feasible within the scope of current plans for the Skylab Program. Consolidated agency plans for continuing ground-based and inflight investigations for Space Medicine and Biotechnology are under development (Ref. 9, 10, 11, 12). The material contained in these documents, which were generated by both in-house personnel and consultants, will continue to be integrated into a single working document to serve as guideposts for a continuing program (Ref. 13).

What is necessary, then, to qualify man for still longer duration space flight? Data must be obtained from an adequate sample, preferably a minimum of six crewmen, for flight durations of up to six months in order to provide adequate prognostic capability for flights in excess of this flight duration. A six-month period should provide ample time for all of the body's systems to show evidence of significant change including adaptation, except possibly for some extremely subtle cellular or subcellular effects.

To support the experimental program an 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. 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.

SUMMARY

The biomedical observations gained from the Mercury, Gemini, and Apollo operations, although limited, have provided valuable clues as to the functional systems most susceptible to the effects of the space flight environment. The Skylab medical investigative program, with its strong emphasis on measurements and sampling under expert professional supervision while the astronauts are in orbit, will offer unique opportunities to establish the rate of change in certain of the observed variables and permit discrimination between deteriorative trends and acclimation or adaptation. It is most important that as many observations as possible be accomplished during the first 24 hours in orbit.

The requirements to accomplish critical medical experiments for the first three manned Skylab Program missions include the provision of functional hardware and adequate working volume. The experimental procedures include collection of the required specimens of body wastes to accomplish quantitative assessment of nutritional status and musculoskeletal function, cardiovascular function, pulmonary function, and energy metabolism. These activities must start as soon as possible after the crew and vehicle cluster are established in orbit. The data from these measurements are of paramount importance in establishing the nature, time course, and significance of physiological changes that have been observed to occur during flights of less duration and in starting to identify and evaluate subtle effects of prolonged space flight which are presently unknown or obscure.

The development of a flexible and sophisticated system for inflight laboratory analysis will make it possible to further explore and evaluate inflight medical changes.

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NASA-S-66-12064

MERCURY MANNED FLIGHTS

TABLE I

FLIGHT	CREW	LAUNCH	HRS	MIN
MR-3	SHEPARD	5-5-61		15
MR-4	GRISSOM	7-21-61		15
MA-6	GLENN	2-20-62	4	56
MA-7	CARPENTER	5-24-62	4	56
MA-8	SCHIRRA	10-3-63	9	14
MA-9	COOPER	5-15-63	34	20

TABLE I.- MERCURY MANNED FLIGHTS

NASA-S-66-9462 SEP 22

GEMINI MANNED FLIGHTS

FLIGHT	CREW	LAUNCH	DESCRIPTION	DURATION DAYS	DURATION HRS	DURATION MIN
G-III	GRISSOM YOUNG	3-23-65	3RD REV MANNED TEST		4	52
G-IV	MC DIVITT WHITE	6-3-65	1ST EXT DURATION AND EVA	4		56
G-V	COOPER CONRAD	8-21-65	1ST MEDIUM DURATION FLT	7	22	56
G-VII	BORMAN LOVELL	12-4-65	1ST LONG DURATION FLT	13	18	35
G-VI	SCHIRRA STAFFORD	12-15-65	1ST RENDEZVOUS FLT	1	1	53
G-VIII	ARMSTRONG SCOTT	3-16-66	1ST RENDEZVOUS AND DOCKING FLT		10	41
G-IXA	STAFFORD CERNAN	6-3-66	2ND RENDEZVOUS AND DOCKING 1ST EXTENDED EVA	3	1	04
G-X	YOUNG COLLINS	7-18-66	3RD RENDEZVOUS AND DOCKING 2 EVA PERIODS; 1ST DOCKED AGENA-PROPELLED HIGH APOGEE MANEUVER	2	22	46
G-XI	CONRAD GORDON	9-12-66	1ST RENDEZVOUS AND DOCKING INITIAL ORBIT; 2 EVA PERIODS 2ND DOCKED AGENA-PROPELLED HIGH APOGEE MANEUVER; TETHER EXERCISE	2	23	17

TABLE II.- GEMINI MANNED FLIGHTS

NASA-S-67-6125

TIME COURSE OF OBSERVED PHYSIOLOGICAL CHANGES IN GEMINI

- LOSS OF RED CELL MASS

- POSTFLIGHT TILT PULSE RATE CHANGE

  % INCREASE OVER PREFLIGHT MEAN TILT VALUES

- POSTFLIGHT TILT PULSE PRESSURE CHANGE

  % DECREASE OVER PREFLIGHT MEAN TILT VALUES

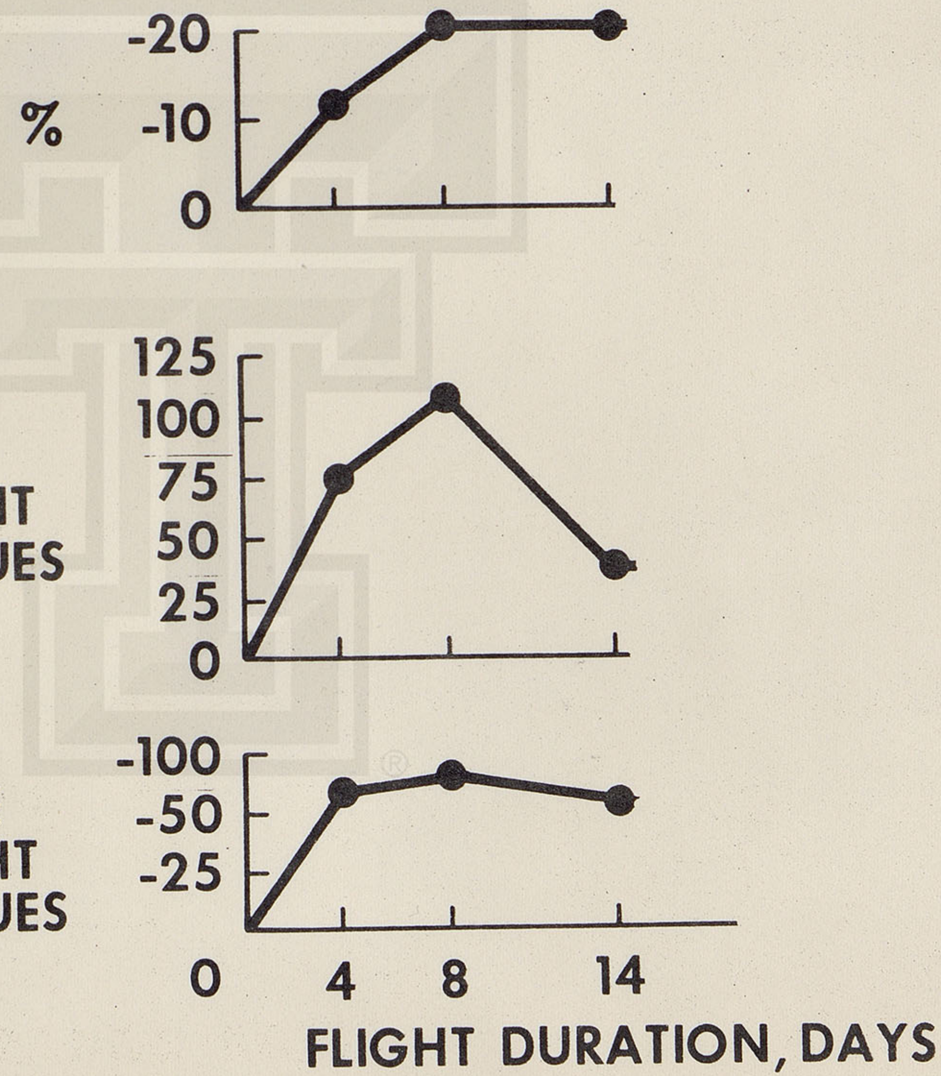


Figure 1 - Time course of observed physiological changes in Gemini.

NASA-S-67-6124

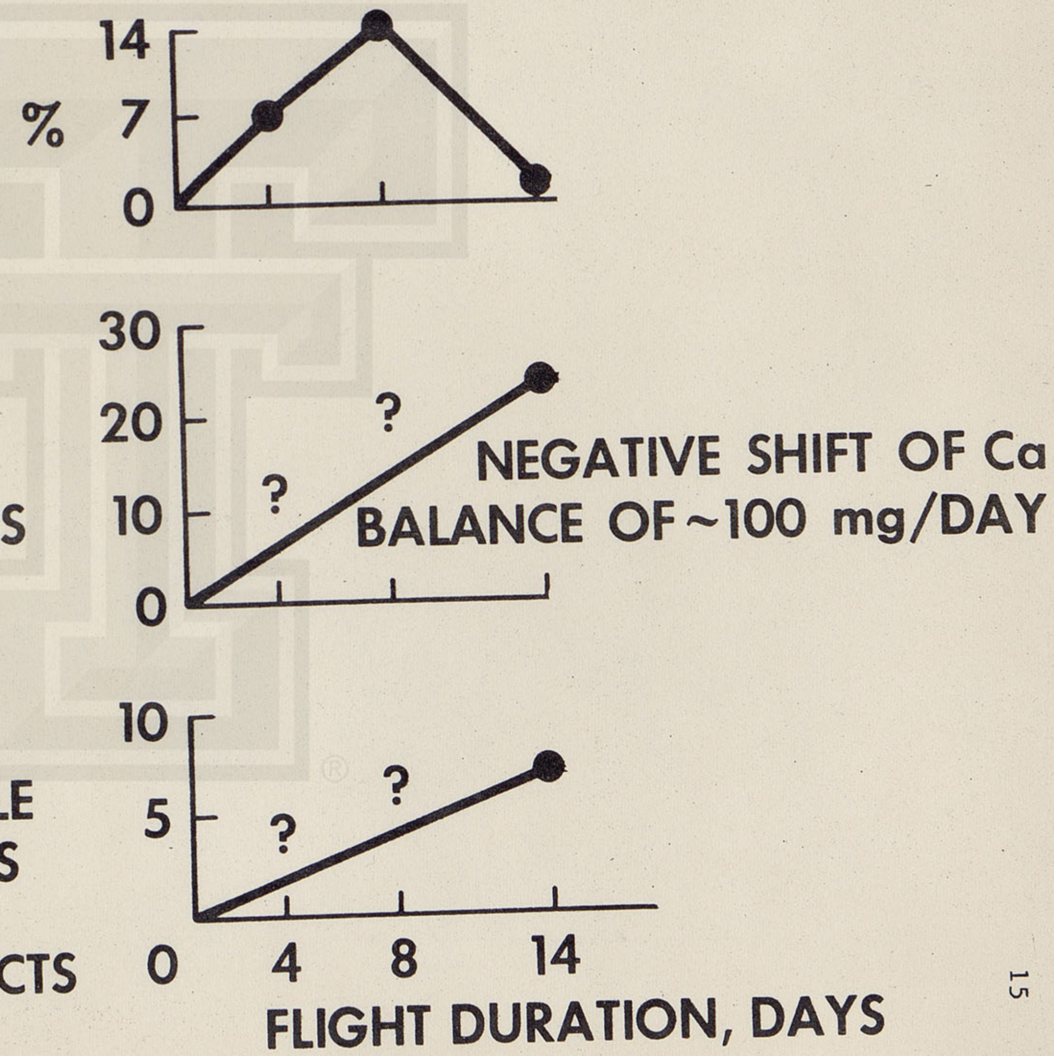
TIME COURSE OF OBSERVED PHYSIOLOGICAL CHANGES IN GEMINI

(MUSCULO-SKELETAL)

- LOSS OF BONE DENSITY (OS CALCIS)
- SKELETAL CALCIUM LOSS*

  % INCREASE, 2ND WEEK Ca EXCRETION OVER CONTROL VALUES
- MUSCLE NITROGEN LOSS

  EQUIVALENT MUSCLE TISSUE LOSS IN LBS



*BEDREST EQUIVALENT SUBJECTS EXHIBIT ~100% INCREASE

Figure 2 - Time course of observed physiological changes in Gemini.

Figure 3 - PRELIMINARY LATA

	APOLLO 7			APOLLO 8		
	A*	B	C	A	B	C
Weight Loss (lbs)	6.3	10.0	8.0	8.75	7.8	4.0
RBC Mass (% Change)	-0.5	-9.4	-0.3	+2.3	-2.2	-4.0
Plasma Volume (% Change)	-5.3	-3.5	+1.1			

APOLLO VII (% of Preflight Control)

	REST			LBNP		
	A*	B	C	A	B	C
Mean Heart Rate	137	100	121	137	152	143
Mean Syst. Bl. Pr.	103	84	91	109	81	75
Mean Diast. Bl. Pr.	97	84	94	106	94	87

APOLLO VII (Change of Mean Work Performance for Given Heart Rate

HEART RATE		WORK PERFORMANCE
120	BPM	-72.0%
140	BPM	-41.0%
160	BPM	-19.5%

*A, B, C refers to the individual astronauts

APOLLO MANNED FLIGHT

FLIGHT	CREW	LAUNCH	DESCRIPTION	DURATION (HRS.)
VII	W.M. Schirra D.F. Eisele W. Cunningham	11 Oct. 68	Rendezvous with S IV Stage	259
VIII	F. Borman L.A. Lovell W.A. Anders	21 Dec. 68	First Manned Saturn V flight, 10 lunar orbits	147
IX	J. McDivitt D. Scott R. Schweickart	3 March 69	Test of Lunar Module	241
X	E.A. Cernan J.W. Young T.P. Stafford	18 May 69	Test of LM in Lunar Environment	192
XI	N.A. Armstrong M. Collins E.E. Aldrin	16 July 69	First manned lunar Landing	195
XII	C. Conrad, Jr. R.F. Gordon, Jr. A.L. Bean	14 Nov. 69	Second manned lunar landing	245

Figure 4.

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

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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, Texas

M093 - Vectorcardiogram

Principal 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.

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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.

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

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

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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

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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.

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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

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ADDITIONAL AREA OF INVESTIGATION:

M190 - MICROBIOLOGY (Governing Protocol)

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

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

APPENDIX B

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

February 1970

IV. Metabolism

Ear Canal Temperature

O_2 Consumption, CO_2 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 Susceptibility

VIII. Behavioral

Sensory

Vision

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. Microbiology

Bacteria/Fungi

Culture/Sensitivity

Stain

Observe

Identify

Transmit

Photograph

X. Laboratory Analysis

Blood

Hemoglobin

Hematocrit

pH

pCO_2

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

pO_2

Plasma

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