Microbiological Problems.

1.) Extraterrestrial Organisms

2.) Mutation of Terrestrial Organisms

3.) Lowered Resistance

4.) Microbiological Shock on Return to Earth

THE
COLLEGE OF MEDICINE
FACILITIES

THE OHIO STATE UNIVERSITY

Department of Medicine

410 West 10th Avenue
Columbus, Ohio 43210

May 21, 1968

Sherman P. Vinograd, M.D.
Space Medicine, Manned Space Flight
National Aeronautics and Space Administration
Washington, D.C. 20546

Dear Sherm:

Enclosed is the renovation of the questions for the Black Book. I will send on within a day or so the rewritten introduction to the Hematology Section.

With kindest regards.

Sincerely,

Walley

Wallace N. Jensen, M.D.
Professor and Vice-Chairman

WNJ:pds

Enclosure

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

a. Red Cell Mass Loss

1. What is the time-dose relationship of space environment to red cell mass? — I-O------ I-S

2. Does SPACEFLIGHT hyperoxia of approximately 200-300 mm Hg pO_2 cause suppression of rates of red cell formation? — I-O------ I-S

3. If so, what is the magnitude of such change and is a new steady state achieved? — I-O I-S------

4. Does SPACEFLIGHT hyperoxia of 200-300 mm Hg pO_2 cause accelerated hemolysis? The ground level experiments of Zalusky indicate that hemolysis does not occur, but more precise methods than Cr51 must be used, the experiments (008) by Fischer and Mengel give insufficient data, but are important because methemoglobinemia occurred and red cell phosphofructokinase deficiency was seen. The data obtained on astronauts in Gemini IV and VII by Berry and Fischer is inadequate to allow conclusions concerning rates of red cell destruction. The data of Republic Aviation Corporation in which hemolysis was described in one person during hyperoxia was a person with a pre-existent hematologic abnormality (thalassemia minor). — I-O------ I-S

5. If suppression of rates of production and increased rates of destruction of red cells occur IN SPACEFLIGHT and are due to hyperoxia, what are the mechanisms of these responses? Is hemolysis due to oxidative changes in hemoglobin, peroxidative changes in red cell membrane lipids, inactivation of energy production, or of electrolyte pumping mechanism or other mechanisms? — I-O------ I-S

6. Does total pressure (i.e., 1/3 atmosphere ~~as compared with 1 atmosphere)~~ AS IN PAST SPACEFLIGHT have an effect on hemopoeisis? — I-O------ I-S

7. What are the ranges of body and ambient temperatures and times of exposure tolerable, before red cell damage takes place? (DOES THE TIME-TEMPERATURE EXPOSURE NEEDED FOR RED CELL DAMAGE DIFFER IN SPACE FLIGHT FROM GROUND LEVELS?) (Studies in humans, at 30-90 min., 160° F, show changes in osmotic fragility and MCV but life span studies are not available. Clinical suggestions, i.e., burns, indicate hemolysis can occur. In vitro studies show that hemolysis occurs when temperature is elevated to 45° centigrade.). — II-O------ II-S

8. Does exposure ~~in vivo~~ to SPACEFLIGHT vibration ~~of a particular frequency and duration~~ PATTERNS cause IN VIVO red cell destruction? — II-O II-S

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
1.	Animal flights should be done where data on man is not, or will not be available. Biopsy specimens of bone and marrow could be done in animals.	II - O II - S
2.	Does hyperoxia of 200-300 mm Hg pO_2 plus flight cause suppression of rate of red cell formation, does an animal respond to alterations of a new steady state in normal fashion?	II-O I-S
3.	Will phlebotomy or transfusion of red cells cause a response similar to that of the normal animal in a normal environment? OR ARE STEADY STATE KINETICS ALTERED BY SPACEFLIGHT?	II - O II - S
4.	Are there marked species differences in hematologic effects of moderate 200-300 mm Hg pO_2 hyperoxia? In the normal mouse, overt hemolysis occurs at 70 hours exposure with 100% O_2 at 1 atmosphere pressure (i.e., 760 mm Hg pO_2). Comparison of flight to ground simulation may give, by difference, an idea of the effects of weightlessness.	II-O I-S
5.	Flight animal studies would not be of added value.	--
6.	Flight animal studies would not be of added value.	--
7.	Animal studies in flight are unnecessary.	--
8.	Animal studies in flight are unnecessary.	--

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

b. Plasma Volume

9. Does plasma volume change during space flight? In what fashion may plasma volume and cardiac function be related? — I-O------ I-S

10. If plasma volume is decreased, is it secondary to water deprivation, compartmental maldistribution, altered Na metabolism, serum protein alterations, portal-venous baroreceptor alteration, or other factors? — I-O------ I-S

11. Does weightlessness induce the plasma volume abnormality ~~alteration~~? If so, by what mechanism? — I-O------ I-S

c. Coagulation

12. Are coagulation proteins, platelet function, and vascular friability normal before and after modestly prolonged space flight? — II-O------ II-S

d. Body Defense Mechanism

13. Is the inflammatory cycle normal during space flight? — I-O------ I-S

e. Chromosomes & Cell Cultures

14
15 } As is in book - questions 13 & 14

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
9.	Animal studies are of value, but there is difficulty in extrapolation of data to humans.	II-O I-S
10.	Animal studies in flight are unnecessary.	--
11.	Only acceptable where human study not available.	III-O II-S
12.	Animal studies would probably not be greatly informative.	--
13.	Is bacterial infection of one type more likely to occur than others? Comparison of type of bacteria and of propensity of infection of one system or another may be made. Is the CNS, alimentary, respiratory, or GU tract particularly vulnerable to infection? Are viral infections modified by conditions of weightlessness?	II-O II-S

GENERAL

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

	PRIORITY
Radiation Effects:	
In-flight validation of the findings of ground based research efforts on the effects of radiation on blood cells in the cases of low earth orbits, highly elliptical orbits, synchronous orbits, and lunar missions.	I
Are peripheral blood cellular responses good indicators for rate effects at low doses of ionizing radiation? What does protraction of low dose do?	

Chromosomes and Cell Cultures:

Chromosomal karyotypes may be of value in recognition of abnormalities induced by weightlessness, prolonged physical inactivity or hyperoxia, but would more specifically be of interest as a biologic indication of radiation injury. Others than from drugs, ~~or~~ radiation, OR VIBRATION there is ~~no~~ LITTLE reason AT THIS TIME to suspect that chromosomes would be altered in type or number.

Done

Placed at end of his introduction

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

		PRIORITY
a.	Red Cell Mass Loss	
1.	What is the time-dose relationship of space environment to red cell mass?	I-O------ I-S
2.	Does hyperoxia of approximately 200-300 mm Hg pO_2 cause suppression of rates of red cell formation?	I-O------ I-S
3.	If so, what is the magnitude of such change and is a new steady state achieved?	I-O I-S------
4.	Does hyperoxia of 200-300 mm Hg pO_2 cause accelerated hemolysis? The ground level experiments of Zalusky indicate that hemolysis does not occur, but more precise methods than Cr51 must be used, the experiments (008) by Fischer and Mengel give insufficient data, but are important because methemoglobinemia occurred and red cell phosphofructokinase deficiency was seen. The data obtained on astronauts in Gemini IV and VII by Beery and Fischer is inadequate to allow conclusions concerning rates of red cell destruction. The data of Republic Aviation Corporation in which hemolysis was described in one person during hyperoxia was a person with a pre-existent hematologic abnormality (thalassemia minor).	I-O------ I-S
5.	If suppression of rates of production and increased rates of destruction of red cells occur and are due to hyperoxia, what are the mechanisms of these responses? Is hemolysis due to oxidative changes in hemoglobin, peroxidative changes in red cell membrane lipids, inactivation of energy production, or of electrolyte pumping mechanism of other mechanisms?	I-O------ I-S
6.	Does total pressure (i.e., 1/3 atmosphere as compared with 1 atmosphere) have an effect on hemopoeisis?	I-O------ I-S
7.	What are the ranges of body and ambient temperatures and times of exposure tolerable, before red cell damage takes place? (Studies in humans, at 30-90 min., 160° F, show changes in osmotic fragility and MCV but life span studies are not available. Clinical suggestions, i.e., burns, indicate hemolysis can occur. In vitro studies show that hemolysis occurs when temperature is elevated to 45° centigrade.).	II-O------ II-S
8.	Does exposure in vivo to vibration of a particular frequency and duration cause red cell destruction?	II-O II-S

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
1.	Animal flights should be done where data on man is not, or will not be available. Biopsy specimens of bone and marrow could be done in animals.	II
2.	Does hyperoxia of 200-300 mm Hg pO_2 plus flight cause suppression of rate of red cell formation, odes an animal respond to alterations of a new steady state in normal fashion?	II-O I-S
3.	Will phlebotomy or transfusion of red cells cause a response similar to that of the normal animal in a normal environment?	
4.	Are there marked species differences in hematologic effects of moderate 200-300 mm Hg pO_2 hyperoxia? In the normal mouse, overt hemolysis occurs at 70 hours exposure with 100% O_2 at 1 atmosphere pressure (i.e., 760 mm Hg pO_2). Comparison of flight to ground simulation may give, by difference, an idea of the effects of weightlessness.	II-O I-S
5.	Flight animal studies would not be of added value.	--
6.	Flight animal studies would not be of added value.	--
7.	Animal studies in flight are unnecessary.	--
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QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

		PRIORITY
b. Plasma Volume		
9.	Does plasma volume change during space flight? In what fashion may plasma volume and cardiac function be related?	I-O------ I-S
10.	If plasma volume is decreased, is it secondary to water deprivation, compartmental maldistribution, altered Na metabolism, serum protein alterations, portal-venous baroreceptor alteration, or other factors?	I-O------ I-S
11.	Does weightlessness induce the plasma volume abnormality alteration? If so, by what mechanism?	I-O------ I-S
c. Coagulation		
12.	Are coagulation proteins, platelet function, and vascular friability normal before and after modestly prolonged space flight?	II-O------ II-S
d. Body Defense Mechanism		
13.	Is the inflammatory cycle normal during space flight?	I-O------ I-S

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
9.	Animal studies are of value, but there is difficulty in extrapolation of data to humans.	II-O I-S
10.	Animal studies in flight are unnecessary.	--
11.	Only acceptable where human study not available.	III
12.	Animal studies would probably not be greatly informative.	
13.	Is bacterial infection of one type more likely to occur than others? Comparison of type of bacteria and of propensity of infection of one system or another may be made. Is the CNS, alimentary, respiratory, or GU tract particularly vulnerable to infection? Are viral infections modified by conditions of weightlessness?	II-O II-S

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL
INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

Radiation Effects:

In-flight validation of the findings of ground based research efforts on the effects of radiation on blood cells in the cases of low earth orbits, highly elliptical orbits, synchronous orbits, and lunar missions. I

Are peripheral blood cellular responses good indicators for rate effects at low doses of ionizing radiation? What does protraction of low dose do?

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Chromosomal karyotypes may be of value in recognition of abnormalities induced by weightlessness, prolonged physical inactivity or hyperoxia, but would more specifically be of interest as a biologic indication of radiation injury. Others than from dmugs or radiation, there is no reason to suspect that chromosomes would be altered in type or number.

Graduate School of Arts and Sciences

FORDHAM UNIVERSITY Bronx, N.Y. 10458

Department of Psychology

Sept 6, 1968

Dear Sherm

Congratulations on the excellent quality of the DRAFT — MED. REQUIREMENTS! It's a tedious, thankless job that demands an inordinate amount of time and attention

I also share your concern about the unevenness of the document: (1) in the relative emptiness of some sections (2) the problem of the Neurological Area.

I agree that "Bioinstrumentation and Measurement Techniques" would be a better title to Section ID.

Here & There I have made notations upon my first reading of the document. I shall reread the draft again before our meeting so that I can better formalize any suggestions I'd like to make.

One minor suggestion: It is difficult to shift from left page to right page i.e. Human questions → Animal experimentation. I would suggest that all animal experimentation comments be placed immediately below the question that needs to be answered re human. Ex

VERY GOOD

7. What are optimal wakefulness-sleep schedules for long and short space flights. [I-O ; II-S]

[An. Exp: Not relevant]

8. What are - - - .

[An. Exp: Not relevant]

etc.

Perhaps we might invite O. Schmitt for inputs to the "Bioinstrumentation" section and also to Section III.

Hope & wish all is well with you & yours and that Congress doesn't legislate our scientific ideas and plans out of existence -- merely because of political expediency.

My very best.

Sincerely

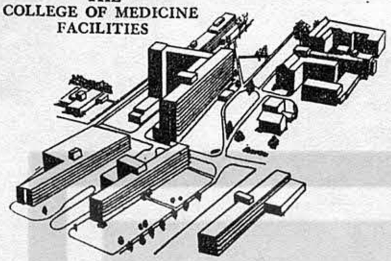
Joe

Dr. M, both of these arrived in the same envelop today —

8-27-68

[illegible]

THE COLLEGE OF MEDICINE FACILITIES



Department of Medicine

THE OHIO STATE UNIVERSITY

410 West 10th Avenue
Columbus, Ohio 43210

August 20, 1968

S. P. Vinograd, M.D., Director
Medical Science and Technology
Space Medicine, Manned Space Flight
National Aeronautics and Space Administration
Washington, D.C. 20546

Dear Sherm:

I am slow in writing you on several matters. First, I have received the latest draft of the "Medical Requirements Document." Although I cannot honestly say I have looked it over word for word, I have perused it with a fair amount of care and believe it is in good order. I am inclined to agree with you that the assignment of priorities in operational and scientific categories is a little complicated. The whole priorities' matter is difficult, and it always involves a matter of comparison to what. With this in view, I would be inclined to make it as simple as possible. At any rate, I agree with the points outlined in your letter.

I believe that by this time you have received my suggested revision of the first paragraph of my little piece on the need for biomedical research in space. I am not sure it is any better but see what you think of it.

I will be most interested in the discussion we had regarding personal bio-engineering experience. If you wish to pursue the matter any further, let me know; and I will be happy to arrange some discussions here at The Ohio State University. It was good to see you, and I hope you have a good summer vacation. All signals remain "go" on the African trip so we are living in a period of some excitement and a little bit of apprehension about the job to be done.

Sincerely yours,

James V. Warren /mh

James V. Warren, M.D.
Professor and Chairman
Department of Medicine

JVW:mh
enc.
(dictated but not read)

RECEIVED
AUG 26 1968
OMSF - MM

Joyce:

We're in the process of breaking in a new secretary for Dr. Warren; consequently, there was a mis-communication regarding the urgency of this. Sorry for the delay.

Micki

The role of man in future and more prolonged space flights is, at this time, unclear. Should man participate in interplanetary flight or should man's participation end after successful lunar landing with further flights accomplished by non-manned probes? This is a difficult decision and depends on many factors. One, of course, is man's ability, on a physiologic and psychologic basis, to participate in longer missions. In one way or another, it is probable that man himself will continue in the exploration of space after the lunar landings. To aid in providing the answer to this critical question, one must pursue a course of investigation that will indicate man's safety and ability to perform in prolonged space flight. Must this be determined by incremental flights of increasing duration or could it be determined more rapidly by other means? Either way, the lead time is undoubtedly long so that to obtain the answers in a reasonable period of time we must push forward rapidly. Substantial scientific problems have been raised by already accomplished space flights. Man has performed well but not without observable functional change. The question is more complicated than "qualifying" a piece of hardware that is to be used in space flights. First, man must be qualified (rated) for long-term space flights; but secondly, and perhaps even more importantly, are there any adverse, long-term effects?

James V. Warren, M.D.

revision of first paragraph of
The Case for Biomedical Research
in Space

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : MM/Dr. Vinograd

DATE: April 10, 1968

FROM : MM/Colonel Pickering

SUBJECT: Space Medicine Consultants Meeting (April 9, 1968)

Following the discussions yesterday and after taking note of the comments made, I have reviewed the draft requirements document and prepared the following comments. They are as you will see referenced by section and page, some are just statements of concurrence while others are either corrections or additions.

Section I. A/B

1. Page 9: May be of great interest to radiation sickness.

2. Page 58: Do you say "peripheral blood cellular responses"?

   Add: What is the difference of response in the peripheral blood following exposure to alphas, protons, or electrons (Q.F.-Quality Factor question).

3. Page 64, paragraph 2: Needs a little rewording to be accurate in statements made.

4. Page 71: Seems ok still.

Section I. C

1. Page 85: 5, 6, and 7 should include radiation both protons and electrons. Also these stresses should be applied in combination.

2. Page 74: Very important also for "radiation sickness".

3. Page 86; #10: These stresses should also be done in combination for synergism, antagonism, and/or additivity.

4. Page 88: Ok and important for lunar mission, particularly if aerosolized lunar dust is in the Command Module.

   Might want to cross reference again. The filter efficiency of LiOH scrubbers against microbial and/or aerosolized material.

5. Pages 90, 91: Determine performance degradation resulting from emergency change in planned work-rest cycles, when combined with other stresses, i.e. radiation.

Section I.D

1. Page 103: Consider adding: (this may be too foolish or naive)

   6. Technique for rapid semi quantitative self evaluation for hematologic depression following radiation exposure.

   or

   Simple safe micro means for determining hematologic depression following radiation exposure. (Like 1 on page 99)

2. Page 103+: = Microbiology and Immunology Section

   What are the effects of aerosol dusts (i.e. lunar) upon human organisms in vivo?

Section II.

1. Page 113; #6: Change "prompt detection" to "accurate forecasting".

   Page 113: Loren's comment: Dose rate effect, 0-6 day flight? No difference in low earth orbit - equatorial - for 60 days protraction likely to be effective.

2. Page 113; #6: Add: . . . transmitting "and updating" this . . . "flare".

Section III.

1. In the general sections, 1, 2, 3, 4 - item 2^{1} might be "elliptical orbits".

2. Make "solar flare data" as $1a^{1}$ to include protons, alpha particles, energy dose rate (build up, decay), etc.

3. Page 118: Under 1a and "energy".

If there are other things which I may contribute please let me know.

U of C-AUA-USAEC

ARGONNE NATIONAL LABORATORY

April 22, 1968

Dr. Sherman P. Vinograd
Director, Medical Science and Technology
Space Medicine Directorate
Office of Manned Space Flight
National Aeronautics and Space Administration
Washington, D. C. 20546

Dear Sherm:

I apologize profusely for not having given you some comments sooner on the medical requirements document. I have become involved in so many activities these few months that I am never sure what I have overlooked. To at least give you a little information, I am sending along pages lifted from the document upon which I have handwritten suggestions or questions. I think my comments will all be self-explanatory.

Since I will be out of the office more than in over the next five weeks, I would not suggest your trying to reach me by phone, but rather by letter. Incidentally, I will be in the COSPAR Meeting in Tokyo. I was asked to give a lecture at the Space Radiation Symposium and will discuss "Early response of man to whole body ionizing radiation." It will be largely a condensation of information in the Panel report plus some new thoughts I have about recovery from radiation injury. Another thought, I will be talking to the Engineering Study Group at Ames Research Center this summer for John Billingham. That time on radiation hazards for lunar occupation. Can you write a TA and TR for me for that activity in early July?

With best regards.

Sincerely yours,

Doug

Douglas Grahn
Division of Biological
and Medical Research

RECEIVED
APR 23 1968
OMSF - MM

DG/maw
Enclosures

9700 South Cass Avenue, Argonne, Illinois 60439 · Telephone 312-739-7711 · TWX 910-258-3282 · WUX LB, Argonne, Illinois

Chromosomes and Cell Cultures

Chromosomal karyotypes may be of value in recognition of abnormalities induced by any aspect of space environment, such as weightlessness, prolonged physical inactivity or hyperoxia, but would more specifically be of interest as a biologic indication of radiation injury. Other than from drugs or radiation, there is no reason to suspect that chromosomes would be altered in type or number.

?

Some USSR data indicate that chromosome alterations such as changes in number (aneuploidy) may occur as a consequence of situational, G+ and 0 G loads.

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

Radiation Effects

In-flight validation of the findings of ground based research efforts on the effects of radiation on blood cells in the cases of low earth orbits, highly elliptical orbits, synchronous orbits, and lunar missions. — I

Are peripheral blood cellular responses good indicators for ~~rate~~ dose effects at low doses of ionizing radiation? What does protraction of low dose do?

You need to substantiate the diagnostic and prognostic value of small changes in peripheral blood picture re the complex of stresses involved; radiation is only one and may well be overwhelmed by other factors producing similar endpoints.

You will not answer this question in flight operations

E - HAZARD PROTECTION

PRIORITY

1. Development of a self-contained emergency breathing apparatus for use inside the capsule as protection against atmospheric contaminants.

2. Research and development concerning in-flight detection of atmospheric contaminants.

3. Development of a miniaturized hand-operated, ejection fire extinguisher (e.g., liquid CO_2, N_2, or fabric mesh-covered pellet which, when propelled against a burning surface, would adhere and release fire extinguishing gaseous material).

4. The development of a prompt fire warning system.

5. Development of a sealant for capsule perforation.

6. The development of methods enabling the prompt detection of solar flares and means of transmitting this information from ground-based stations to spacecraft.

7. For the low earth orbit case,

   (a) determine the effect of low dose rates of $\frac{1}{4}$ rad/day. Are there ~~demonstrable~~ measurable effects? At what energies? —? your concern here is for mean do[se] at biologically important depths [in] tissue; — I

   (b) determine the effect of dose protraction at two different low dose rates $\frac{1}{4}$ rad/day to 1 rad/day. Are there ~~demonstrable~~ measurable effects? At what energies? ? — I

   a. skin
   b. eye lens
   c. marrow
   d. midgut

   essentially redundant — best to assume no differences below 1 rad/day

8. For highly elliptical orbits, the establishment and determination of differences in proton and electron response at the expected dose rates. The skin is likely to be the most responsive in this region. What is the depth dose pattern? (only important unknown) — I

9. For synchronous orbit, the determination of the response of blood cells to low energy electrons ~~at~~ ~3 rad/day. — I

   ? again - a matter of depth dose in tissue

   bone marrow, skin, eyes,

   secondary X-rays from these can be penetrating

HAZARD PROTECTION (Continued)

PRIORITY

10. For lunar missions, predictable proton effects in an acute exposure ~~pretty well known~~ or will be from on-going research. Solar flares could be the limiting factor in the LM and/or on surface of the moon. I

11. Determine where best to measure radiation absorbed dose to detect blood changes. Need an up-to-date measure of the distribution of active bone marrow in the adult human male. Also need to know the migratory behavior of marrow stem cells from one compartment to another. This is critical to the understanding of long range value of partial body shielding. I

D R A F T

M A N N E D   S P A C E   F L I G H T

M E D I C A L   R E Q U I R E M E N T S   D O C U M E N T

SPACE MEDICINE
NASA HEADQUARTERS
FEBRUARY 1968

D R A F T

TABLE OF CONTENTS

Page

GENERAL DESCRIPTION, ORGANIZATION AND CONTENT iv

PREFACE xiii

I. SPACE FLIGHT MEDICAL INVESTIGATION

A. Questions to be Resolved by Space Flight Medical Investigation (Medical Experiments Program)

B. Potential Role of Space Flight Animal Experiments Toward Resolution of Medical Questions

1. Neurology
   - Introduction 3
   - Questions and Tasks 9

2. Respiration
   - Introduction 16
   - Questions and Tasks 19

3. Circulation
   - Introduction . . . .
   - Questions and Tasks 22

4. Metabolism and Nutrition
   - Introduction . . . .
   - Questions and Tasks 27

5. Endocrinology
   - Introduction . . . .
   - Questions and Tasks 44

6. Hematology
   - Introduction 51
   - Questions and Tasks 54

7. Microbiology and Immunology
   - Introduction . . . .
   - Questions and Tasks . . . .

8. Behavioral Effects
   - Introduction 64
   - Questions and Tasks 66

9. General
   - Questions and Tasks 71

Page

C. Ground Based Studies Required in Support of Flight Medical Investigation

1. Neurology 74

2. Respiration 77

3. Circulation 79

4. Metabolism and Nutrition 81

5. Endocrinology 83

6. Hematology 85

7. Microbiology and Immunology 88

8. Behavioral Effects 90

9. General . . . .

D. R&D Efforts to Increase Capabilities of Flight Medical Laboratory (IMBLMS)

1. Neurology 94

2. Respiration . . . .

3. Circulation 97

4. Metabolism and Nutrition 99

5. Endocrinology 101

6. Hematology 103

7. Microbiology and Immunology . . . .

8. Behavioral Effects 106

9. General . . . .

Page

II. SPACE FLIGHT CREW SUPPORT; R&D REQUIREMENTS

A. Atmosphere and Space Suits 109

B. Metabolic Factors (Food, Water, and Waste Systems) . . 110

C. Living Conditions and Standards 111

D. Group Integrity 112

E. Hazard Protection 113

F. Clinical Medical Support and Safety Monitoring 115

G. Inertial Forces 116

H. CREW OPERATIONAL PERFORMANCE

III. INFORMATION REQUIRED OF NASA PHYSICAL SCIENCES FOR SPACE FLIGHT MEDICAL INVESTIGATION AND SUPPORT 118

GENERAL DESCRIPTION, ORGANIZATION AND CONTENT

The purpose of this document is to define questions to be resolved and tasks to be accomplished in the medical investigation and support of man in manned space flight. It is a statement of current manned space flight medical needs with an indication of priority for each. Its objective is to bring to bear the integrated capabilities of the NASA life sciences on the resolution of medical questions and the advancement of supportive knowledge and technology to meet manned space flight medical requirements.

ORGANIZATION*

Requirements are defined in three major areas:

I. Space Flight Medical Investigation

II. Space Flight Medical Support

III. Information Required of NASA Physical Sciences for Space Flight Medical Investigation and Support

Within area I, Space Flight Medical Investigation, requirements are addressed to four subareas:

A. Questions to be Resolved by Space Flight Medical Investigation (Medical Experiments Program)

B. Potential Role of Space Flight Animal Experiments Toward Resolution of Medical Questions

C. Ground-Based Studies Required in Support of Flight Medical Investigation

D. Research and Development Efforts to Increase the Capabilities of the Flight Medical Laboratory (IMBLMS)

Because the comments on flight animal experiments in item B relate directly to each question stated in item A, these two areas are presented together on opposing pages, the statement of questions (item A) appearing on the left hand page and the comments concerning flight animal experiments (item B) on the right hand page directly opposite. The task statements listed under "C" and "D" are given sequentially thereafter.

*Outlined in Table of Contents

All questions and statements of tasks within area I, Space Flight Medical Investigation, are organized and presented by human functional systems. These are:

1. Neurology
2. Respiration
3. Circulation
4. Metabolism and Nutrition
5. Endocrinology
6. Hematology
7. Microbiology and Immunology
8. Behavioral Effects
9. General

A complete outline of the organization of functional systems used for this purpose is shown in Figure 1. A sample of the organization of area I using "Circulation" as a specific example is shown in Figure 2.

Area II, Space Flight Medical Support, consists of statements of research and development task requirements, each with an indication of relative priority. These R&D needs are categorized into seven subareas of endeavor:

A. Atmosphere and space suits
B. Metabolic factors (food, water, and waste systems)
C. Living conditions and standards
D. Group integrity
E. Hazard protection
F. Clinical medical support and safety monitoring
G. Inertial forces

Area III is an indication of information needed for manned space flight medical investigation and support which can be provided by those elements of NASA concerned with the physical sciences in space flight. Although this is a relatively short list of requirements the amount of information needed is substantial owing to the multitude of specific zones and circumstances about which it must be known. Because of the applicability of this area to both space flight medical investigation and space flight medical support, it is presented here as a separate section, Area III.

Done

PRIORITY

An indication of priority is given after each question and statement of tasks throughout the entire document. A three-level system of priority is used which, with the exception of ~~Area~~ subsection IB, can be verbally interpreted:

I. Essential

II. ~~Desirable~~ ~~Important~~ HIGHLY DESIRABLE

III. ~~Of Interest~~ DESIRABLE

In ~~area~~ SUBSECTION IB, --Role of Space Flight Animal Experiments--, the assignment of priorities is intended to convey a special meaning which is generally consistent with the above but has the following specific connotation:

I. Essential and warrants an unmanned animal flight

II. HIGHLY Desirable ~~or essential aboard a manned space flight~~ BUT DOES NOT JUSTIFY AN UNMANNED ANIMAL FLIGHT. HIGHEST PRIORITY ANIMAL EXPERIMENT FOR MANNED SPACE FLIGHT.

III. ~~Of Interest~~ DESIRABLE ~~(aboard either manned or unmanned flight~~ - does not justify an unmanned flight)

In ~~areas~~ SUBSECTIONS IA and IB, two priority listings are given. One is given from the point of view of importance to the extension of manned space flight, and is therefore designated by the letter "O" (for the word "operational") after the appropriate Roman numeral for priority. The other conveys an indication of relative importance from the stand point of scientific gain, and carries the designator "S" (for the word "science") after the Roman numeral for priority. As an example, a priority designation of Roman numeral III-O; I-S would indicate that the pursuit of that question or task would be extremely beneficial scientifically but of relatively low priority value from the point of view of its potential contribution to the extension or enhancement of manned space flight.

All priorities given throughout the text are an indication of group value judgment as to relative importance of the question or task. No attempt was made to separate the concept of priority into its many component points of view or to employ a mathematical or systems approach to this assessment. The only exception is the differentiation represented by the letters "O" and "S" as outlined above.

It is ~~recommended~~ RECOGNIZED that this listing of medical requirements for manned space flight will be in need of revision as new information is gained and state-of-the-art advancements are made. It is presently anticipated that this updating will take place on an annual basis.

S. P. Vinograd, M.D.

Done

ORGANIZATION OF FUNCTIONAL SYSTEMS

TABLE ~~FIGURE~~ I

Same order as Table of contents

1 NEUROLOGICAL

1. Central Nervous System
    a. Sleep
    b. Alertness

2. Sensory
    a. Special Senses
        1) Eye
        2) Hearing
        3) Taste
        4) Smell
        5) Vestibular
        6) Modalities (except proprioceptive)

3. Motor

4. Autonomic

3 CIRCULATION

1. Blood Flow
    a. Total (Cardiac Output)
    b. Regional

2. Blood Pressure
    a. Arterial
    b. Venous

3. Cardiac Function
    a. Electrical
    b. Mechanical
    c. Heart Rate

4. Blood Volume
    a. Total
    b. Regional
        1) Venous Compliance

4 METABOLISM AND NUTRITION

1. Metabolism (Energy)
    a. Total
    b. Carbohydrate
    c. Fat
    d. Enzymes
    e. Protein
    f. Total Body Mass
    g. Lean Body Mass

Done

2. Neuromuscular
    a. Mechanics muscle-size and strength
    b. EMG
    c. Biochemistry (includes)
        1) Nitrogen Balance
        2) Creatine Metabolism

3. Mineral
    a. Skeletal
        1) Balances
        2) Densitometry
        3) Isotope
    b. Stone Formation

4. Fluid and Electrolytes
    a. Water Balance
    b. Electrolyte Balance - Na, K, Cl
    c. Acid Base

5. Renal Function
    a. Clearances
    b. Urine (Urinary Constituents)

6. Gastrointestinal
    a. Motility
    b. Absorption
    c. Hepatic Function
    d. Secretory

7. Temperature Regulation
    a. Heat Production
    b. Heat Loss
    c. Body Temperatures

8. Integument (Skin included under Life Support)

6 HEMATOLOGY

1. ~~Loss of~~ ALTERED Red Cell Mass

2. Altered Plasma Volume

3. Radiation Effects on Hemopoetic Nucleated Cells

4. Coagulation

5. Mobilization of Body Defenses
    a. Leukocyte Function
    b. Immuno-globulin Systems

6. Chromosomal Integrity

Done

8 BEHAVIORAL

1. Information Processing
   a. Vigilance
   b. Sensory
   c. Perceptual
   d. Higher thought processes (problem solving)

2. Information Storage
   a. Short-term memory
   b. Long-term memory

3. Activity
   a. Reflex
   b. Learned
      1) Simple-Sensory-Motor
      2) Complex-Sensory-Motor

4. Adaptability
   a. Learnining
   b. Reaction to Stress
      1) Hormonal
      2) Muscular
      3) Subjective
      4) Mood
   c. Stress Tolerance
      1) Inter-personal reaction
      2) Group functioning

5. Decision Making

2 RESPIRATION

1. Mechanics
   a. Ventilation
   b. Lung Capacity
   c. Gas Flow Rate
   d. Pressure Flow and Volume
   e. Mixing

2. Alveolar Gas Exchange AND RESPIRATORY CONTROL
   a. Diffusion
   b. Venous Admixture or Shunting
   c. Ventilation Perfusion Ratio
   d. ~~Pulmonary Defenses~~ RESPIRATORY RATE ?
   ~~e. Respiratory Control~~

3. PULMONARY DEFENSES

Done

5 ENDOCRINE

1. Hypothalmus
2. Posterior Pituitary Urinary ADH
3. Anterior Pituitary
   - ACTH
   - FSH (Gonadotropin)
   - TSH
   - Growth Hormone
4. Thyroid
   - PBI
   - TBG
   - BEI
   - Thyroxine
5. Parathyroid
   - Serum Calcium
   - Tubular reabsorption phosphate
   - Calcium Infusion
   - Parathyroid hormone

5. Parathyroid
   Thyrocalcitonin

6. Pancreatic Islet
   - Insulin
   - Glucagon
7. Adrenal Cortex
   - 17-ketosteroids
   - 17-OH corticosteroids (ACTH Stim.)
   - Aldosterone
8. Neuro-humeral
   - Serotonin
   - Histamine
   - Catecholamines
   - Epinephrine
   - Norepinephrine
9. Gonads
   - 17-ketosteroids
   - Spermatozoa
   - Testicular biopsy

MICROBIOLOGY AND IMMUNOLOGY

1. Microbiological Evaluation
   Ecology variations

2. Immunological Evaluation

Done

ILLUSTRATIVE WORK CHART FOR SECTION I - (CIRCULATION)

~~EXAMPLE OF ORGANIZATION OF SECTION I (CIRCULATION)~~
~~(WORK CHART ON CIRCULATION)~~

TABLE
~~FIGURE~~ II

PROBLEM	a Man In-Flight Experiments	b Animal In-Flight Experiments	c Ground-Based Study	d FLIGHT MEDICAL LABORATORY (IMBLMS) Support
CIRCULATION 1. Blood Flow a. Total (Cardiac Output) b. Regional 2. Blood Pressure a. Arterial b. Venous 3. Cardiac Function a. Electrical b. Mechanical c. Heart Rate 4. Blood Volume a. Total b. Regional 1) Venous Compliance				

PREFACE

THE CASE FOR BIOMEDICAL RESEARCH IN SPACE

Are manned space voyages coming to an end? Will man himself participate in the more distant planetary flights following the already planned lunar explorations? If so, should he participate in a program of prolonged earth orbital flights as a prelude to longer missions? These are very real questions. Most of us would agree that further exploration will not be limited to non-manned probes and that man will desire to go on. If this is to be the case, or even a probability, one must prepare evidence of man's safety and his ability to participate. If man is to go on longer space flights, even many years from now, we should get on with the business of determining his fitness. The question about him is no different than any piece of hardware that is to fly; namely, is man qualified ("rated") for long-term space flights?

Man has tolerated short-term space flight remarkably well. Despite many dire predictions and a long list of potential problems, he has performed in short-term space flights with minimum difficulty; so little, in fact, that it may give us unwarranted security regarding his ability to participate in longer flights. Some changes in his body functions have been noted, however, that should alert us to possible difficulties for even longer duration flights.

As an example, perhaps the most striking observation to date has been the apparent decline in the total number of red cells in his blood. The ability of the human body to maintain a "normal" mass of these cells and to regulate their production and destruction is a fascinating story of modern biomedical science. A multitude of factors and control mechanisms are involved in this dynamic equilibrium. The reasons for the decline in red blood cell mass in space flight have not been resolved. Most likely, it is due to some change in the atmosphere within the space vehicle, but extensive studies of all possible mechanisms are underway at the present time. The loss of cells has not been anywhere near a dangerous amount; indeed, it may not have been noticed by conventional medical examinations with ordinary blood counts. It represents a medical discovery that will probably lead to more than just an explanation of what goes wrong in space flight but to a better understanding of the factors that influence blood cell biology in man. It is important in the present context that it is a subtle indicator of something's going wrong that might become more severe in more prolonged space flight. Its implications, however, are greater than this. The cells of blood are relatively unique in that they can be counted and measured with relative accuracy. The number of cells lining the stomach or contained in the liver are not susceptible to much measurement. The fact that we have found changes in one area of the body that is susceptible to study should be a warning to us that perhaps other systems less readily observed are also involved in a similar deleterious way in space flight. In some body systems such as the circulation, although overt cellular damage cannot be demonstrated, some small evidence of disfunction has been demonstrated. It would appear that the lesson to be learned here is that, although man superficially responds remarkably well to short-term space flight, careful observations in some areas where we are able to do so have indicated minor change in body function. Without being an alarmist, they signal that more comprehensive and careful studies must be obtained. Some of these can, and should be, carried out on the ground. For instance, prolonged observations on the effect of cabin atmospheres can be studied by this mechanism. Others require the unique features of space flight itself. We must investigate not only the obvious but the relatively hidden possible changes from prolonged space flight.

There has been considerable discussion of the role of animal observations in evaluating the hazards of prolonged space trips. There should not be a sense of competitiveness in the sense of animal versus man, but animal studies can be used to supplement observations on the basic species: man. Animals can be sent on longer and more hazardous flights and following these would be more susceptible to biopsy and detailed analysis not only of their red blood cells but other cells of the body. In such flights the animal could ride with minimum equipment for in-flight observations. More complicated studies of the neurologic and circulatory systems have been proposed. These studies, when conducted without the watchful assistance of man, would represent a remarkable tour de force of automation. Whether they should precede man's participation in such flights or accompany it is a problem for decision. It would be clear, however, that in the final analysis rating of man for space flights must be documented by studies on man himself, although it may be strongly supported and dependent on animal observations.

A decision to have man participate in prolonged space flight clearly requires further documentation of man's ability to withstand such flight. This should include behavioral as well as somatic factors. Not only should the immediate and superficial ability be considered, but the hidden or prolonged potential should also be considered. Radiation exposure, for example, may not bring damage that is immediate and obvious but may take time to develop. Studies to evaluate this type of hazard should be included in any program to "rate" man for prolonged flights. Such a program of biomedical research in space is necessary now so that we can answer the questions about man's ability to participate in prolonged space missions when they are asked. The answers cannot be obtained overnight.

SECTION I

SECTION I

SECTION I - A/B

NEUROLOGICAL

NEUROLOGICAL

Vestibular

In planning for space flights measured in years the chronic effects of exposure in a weightless spacecraft are largely unknown, a situation made worse in travel to other planets where exposure becomes obligatory. During such long flights the generation of artificial gravity may prove to be desirable or even essential. In this event, rotation of the spacecraft would represent the ideal solution short of linear acceleration in a true space ship.

Exposure either in a weightless or rotating spacecraft inevitably will affect man's hemeostatic mechanisms. Although here, attention will be focused mainly on the role of the vestibular organs, their effects must be considered not only in relation to other sensory modalities with which they interact, notably vision and nonvestibular proprioceptor mechanisms but also their participation in the analyzer-integrative functions of the great intermediate net. The operational problems in a rotating vehicle are quite different and far more important than in a weightless spacecraft and will be considered separately. It is important to point out, however, that observations made in a weightless spacecraft will help solve problems in a rotating vehicle.

When man is exposed to artificial force environments, the receptors in the vestibular organs slavishly respond to the acceleration patterns within the limits of their response characteristics, and both the otolith apparatus (often with a contribution from non-otolithic proprioceptor inputs) and the semicircular canals and both in combinations are responsible for specific types of functional disorder including spatial disorientation (1), illusory phenomena (2,3,4), visual decrement (5), psychomotor disturbances (6), mental confusion and motion sickness (7, 8, 9, 10). The important force parameters include strength and patterns of linear and angular accelerations, the rate of change and duration of exposure. The peripheral organs are not readily injured, hence, all otherwise tolerable accelerations are within the noninjurious range.

Discussion of vestibular research needs with respect to manned space flight lends itself to the following organization:

I. Space Flight Medical Investigation

   A. Effects of Weightlessness on the Vestibular Receptors

   B. Effects of Rotary Movement in Space on the Vestibular Receptors

II. Crew Support

A. Spacecraft Design Factors

B. Astronaut Prelaunch Preparations

C. In-Flight Operational Factors

I. Space Flight Medical Investigation

A. This investigative area is centered about determining the extent to which lifting the gravitational load on the otolith organs, semicircular canals and nonvestibular proprioceptors affect their function and thereby man's behavior in a weightless spacecraft.

B. The generation of artificial gravity by causing a spacecraft to rotate would result in certain advantages and disadvantages. From the biomedical standpoint, the advantages would come under such headings as habitability and general fitness, and the disadvantages under the heading of side effects. The problem then involves at once preventing side effects and ensuring "satisfactory" habitability and, if deemed necessary, general fitness. Assuming a satisfactory level of centripetal force the side effects are mainly a consequence of Coriolis accelerations generated by man's rotaty and translatory motions. Side effects fall into three categories with reference to abolition through the mechanisms of habituation and adaptation; abolition may be nil, partial, or complete. To the extend that side effects are abolished, they represent disturbances (in hemeostatic mechanisms) resulting from too sudden a change in the force environment. Thus, one means of prevention is to ensure gradual exposure. For example, by matching the change in angular velocity of the spacecraft to the rate at which hemeostatic mechanisms operate effectively, such side effects as motion sickness and certain illusions are prevented and ataxia minimized. During prolonged missions, the ideal level of artificial gravity might be lower than that required to prepare man for return to Earth, pointing up the desirability of operational control over a wide range of subgravity levels. Early on the space program, ideal requirements are unrealistic and the problem of defining envelopes based on departures from the ideal are difficult and in some particulars uncertain because of the impossibility of simulating adequately space flight conditions. Moreover, there are many trade-offs to be considered which fall into at least a three-cornered interplay: benefits, side effects, and engineering constraints.

Briefly summarizing experiments reported elsewhere in detail (10, 15-21), it was found that normal subjects exposed to angular velocities in a Slow Rotation Room above 3 rpm manifested moderate symptoms unless or until habituated and that sudden exposure to 10 rpm not only caused severe symptoms but also there were residual complaints even on the 12th day of rotation. On the other hand, with a sufficiently gradual increase in angular velocity up to 10 rpm, even rather susceptible subjects had no complaints attributable to the force environment.

II. Crew Support

The data gathered in the experimental program in Part I above is designed to answer many of the questions with regard to life support and habitability. The collective term habitability comprises different elements, any one or more of which may be a limiting factor in terms of (general) habitability. With respect to vestibular mechanisms, habitability level envelopes (ideal, comfortable, tolerable, unacceptable) could be defined in terms of critical parameters of a rotating spacecraft environment. Special consideration also must be given to the necessary transitions the astronaut makes during launch and re-entry and possible transitions incidental to EVA, transfer between spacecrafts and possible landing on another planet. Behavioral aspects can be summarized as consisting of three facets which to a considerable degree are mutually dependent: (1) spacecraft design, (2) prelaunch preparations involving the astronaut, and (3) operational considerations aloft. Research and development task recommendations for these areas will be found in ection II G, Inertial Forces.

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A

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

NEUROLOGY IA

PRIORITY

a.

1. What is the change in susceptibility to motion sickness as a function of time aloft? In orbital flight some Russion cosmonauts described symptoms characteristic of motion sickness (11, 12). Observations on a small number of subjects using a provocative test in the weightless phase of parabolic flight suggests that susceptibility to motion sickness changes; susceptibility is reduced in the majority and increased in the minority. Inasmuch as symptoms of motion sickness (anorexia, adypsia, drowsiness, epigastric discomfort, and nausea) are also characteristic of many diseases and disorders, it would be important to learn not only if susceptibility to these symptoms changes on entering weightlessness but also whether habituation occurs. — I-O, II-S

2. What is the susceptibility to motion sickness under simulated rotating spacecraft conditions? Utilizing the 3-5 foot radius of the modified litter chair, small amounts of centripetal force could be generated and the change in susceptibility with small subgravity loads could be determined.

3. What is the effect of unusual flight modes on motion sickness susceptibility? Examples are unprogrammed linear and angular accelerations such as occured in the GT-VIII and SOYUZ I flights. Stepwise incremental exposure to such stresses would be necessary. — II-O

4. What are the effects of loss of gravitational cues on sensory perceptions (taste, stereognosis, kinesthesis, smell, visual acuity, touch, pain, hearing) and perception of personal and extrapersonal 3-D space? It is generally held that physical space is not perceived by a specific quality of sensations themselves but by a construct placed upon them. It is acquired as man becomes aware of the external environment in relation to himself. Under natural living conditions, the most important cues for the perceived direction of space are furnished by the visual and gravitoinertial force environments, and the best concordance between the two is manifested with man upright. In the absence of vision, orientation to the spacecraft may be provided by direct contact. It is noteworthy, however, that even the combined visual and contact cues did not prevent a "feeling" of being upside down in the case of some Russian cosmonauts (12), indicating a tendency toward disorientation and the need for adaptation (13, 14).

B

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS TOWARD RESOLUTION OF MEDICAL QUESTIONS

NEUROLOGY IB

		PRIORITY
1.	It would be worthwhile to determine whether the effects on subhuman primates are similar to the effects on man.	III-O II-S
2.	It would be worthwhile to determine whether the effects on subhuman primates are similar to the effects on man.	III-O III-S
3.	In the event that subhuman primates demonstrate susceptibility to motion sickness compared to man, they would serve to extend the range of stressful accelerations beyond that acceptable for experimentation on astronauts.	II-O
4.	If convenient, in connection with another experiment, it would be interesting to determine whether the effects on subhuman primates are similar to the effects on man.	III-O III-S

A

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

NEUROLOGY I A (CONT.)

PRIORITY

5. To what extent does deafferentation of the otolith organs affect the otolith sensory system, the canalicular system and vestibular servation (useful purposes)? Russian scientists emphasize the role of the otoliths in vestibular function by terming it the "controller organ." Under terrestrial conditions it is continuously stimulated by gravity and entrance into weightlessness is analogous not only to closing the eyes in the case of vision but "closing them" for the first time under adequate experimental conditions. The weightless spacecraft offers not only the possibility to make observations of great operational importance but also to conduct experiments of high scientific merit. The possibilities will increase pari passu with increasing sophistication of man and equipment aloft. Early on it will be possible to begin to gather information along the following three investigative lines:

(a) Determine the role of the otolith organs (and by inference the roles of the spontaneous discharge of the canals and otoliths) in providing tonic modulating vestibular inputs influencing, among other things, stretch receptors and muscle tonus. — II-O, I-S

(b) Change in response to stimulation of the canals. In weightlessness the physiological stimulus to the canals, inertial angular accelerations incidental to head motions is the same or nearly the same as under terrestrial conditions, but the responses will differ in all likelihood due to the deafferentation of the otoliths. — I-O, I-S

(c) Change in response to stimulation of otoliths. In a weightless spacecraft the otoliths will be stimulated by inertial forces above threshold incidental to man's active motions and when passively subjected to linear accelerations (14a). The thresholds of response may differ and the information furnished would rarely accord with the visual upright for purposes of orientation. Start-stop inputs while walking might be disturbing rather than useful unless or until adaptation had occurred.

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS
NEUROLOGY IB (CONT.)

PRIORITY

5.

(a) The use of animals would be required to conduct electro-physiological studies in depth, e.g., experiments requiring invasion techniques.

(b) Studies on animals essential for investigation of underlying mechanism but must await definition in ground-based laboratories. III-0 II-S

A

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

NEUROLOGY I A (CONT.)

PRIORITY

6. What is the time course of changes in susceptibility to motion sickness when astronauts are exposed to changing velocities of rotation in a spacecraft? There are a number of variables to be taken into account: 1) rate of change in angular velocity, 2) terminal or constant angular velocity, 3) variations in G loading, 4) activities of the astronaut involving motions of the head out of the plane of rotation of the spacecraft, 5) individual susceptibility of the astronaut and, 6) secondary etiologic factors not directly involving the vestibular organs. Ground based simulation studies will provide fairly accurate information for final validation aloft. — I-O - - - - - - - - II-S

7. To what extent is postural disequilibrium and ataxia manifested in rotating spacecraft and to what degree is it reduced through the mechanisms of habituation and adaptation? It is important to point out that the benefits here should be judged by comparison with behavior in a weightless vehicle. Also, it should be empahsized that ground based simulation studies not only are difficult but may have limited validity. One difficulty is related to the fact that both vestibular and nonvestibular proprioceptors are involved. The great limitation is the impossibility of manipulating, adequately, the gravitational stimulus to the otolith organs. — I-O - - - - - - - - III-S

8. To what extent will the astronaut be handicapped by difficulties in spatial and geographic orientation, fine sensorimotor activity, visual illusions, visual tracking, and visual decrement due to nystagmus? In all likelihood the measures taken to prevent motion sickness will also prevent visual decrement, the Coriolis illusion, and will reduce to some extent spatial disorientation but all must be studied in actual flight. — I-O - - - - - - - - II-S

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS
NEUROLOGY IB (CONT.)

		PRIORITY
6.	Animal studies useful in elucidating underlying mechanisms.	III-O III-S
7.	Not applicable.	-----
8.	Not applicable.	-----

RESPIRATION

Done

RESPIRATION

a. Effects of High G Forces on the Lungs During Launch and Re-entry (General Priority I)

At the present state of our knowledge, impairment of respiratory function which might possibly jeopardize safety and performance of astronauts can be anticipated with certainty only for the launch and re-entry phases of flight where gravitational and inertial forces may seriously interfere with pulmonary gas exchange and under certain conditions may lead to rupture of pulmonary parenchyma and blood vessels. The mechanisms which cause these changes have been studied extensively in animals and man in centrifuge experiments (1).

It has been shown that transverse acceleration gives rise to large gradients in transpulmonary pressure between different parts of the lungs so that in some areas the alveoli are grossly overdistended and have little blood flow while others are compressed to the point of atelectasis but are overperfused. The resulting inequality of ventilation and perfusion relationships causes arterial hypoxia and increases the alveolar dead space.

Significant degrees of hypoxia occur consistently on exposure to more than $4 + G_X$ and increase in severity with the G-load and duration of exposure. Increased partial pressure of oxygen in the atmosphere attenuates but does not eliminate the acute hypoxia. On the other hand, high oxygen concentrations favor atelectasis which may persist for longer periods after exposure (3). Animal experiments in which the intrathoracic pressure profiles were established under transverse G clearly indicate that transpulmonary pressure gradients sufficient to tear the parenchyma and blood vessels may occur depending upon the rate of onset, magnitude and duration of the G forces applied (7). The tolerances of the human lungs are not known but critical conditions must be anticipated above $10 + G_x$.

b. Metabolic Gas-Exchange and Energy Expenditure in the Zero G Environment with and without the Pressure Suit (General Priority I)

The bioenergetics of human activities in the weightless state cannot be predicted with certainty because it is extremely difficult to simulate subgravity traction on earth and parabolic flights are too short to provide information on this point. Theoretical analyzes of these conditions suggest that in general less energy will be required for most activities including locomotion after a period

Done

of adjustment to the weightless condition. Experimental results of partial simulation of subgravity traction are contradictory and it is apparent that valid answers can be obtained only in actual space flight (4,5,6).

Ground based determinations of energy requirements while exercising in a pressurized space suit indicate that metabolic rate may be 2-3 times more than usual for walking and other maneuvers mainly due to additional effort required to overcome tubular rigidity and to compensate for limitations in mobility. How far the effects of weightlessness and those of the pressure suit may be additive or may cancel each other to some extent is purely a matter of speculation.

Precise knowledge of the metabolic energy cost of all levels of activity during space flight including extra-vehicular activity is essential for the proper design and control of life support systems and the scheduling of work-rest cycles. Current efforts in progress at NASA-MSC (M-050) to develop suitable equipment for metabolic rate measurement in future manned flights should be given high priority.

c. Decompression Sickness on Transition from 5 psi (70% O_2 + 30% N_2) to 3.5 psi (100% O_2) (General Priority I)

Contrary to theoretical considerations recent human experiments have shown that symptoms of decompression sickness (bends) do occur on decompression to 3.5 psi (100% O_2) from an atmosphere 5 psi (70% O_2 + 30% N_2 or He), particularly if equilibration with the latter atmosphere is not complete (2). In view of the plans to employ mixed gas atmospheres in future space operations, this might give rise to serious difficulties during EVA.

Simulation studies in low-pressure chambers should be performed on adequate numbers in which all comtemplated operational pressure-time profiles with the appropriate gas combinations are employed to ascertain the incidence of decompression symptoms. Possible preventive measures such as additional periods breathing 100% O_2 at 5 psi prior to the transition to 3.5 psi should be explored.

d. Effects of Weightlessness Combined with Cabin Gas Atmosphere on the Mechanics of Breathing (General Priority III)

Certain alterations in the mechanics of breathing can be predicted for the weightless state, since normally respiratory muscles of the chest cage and abdomen interact with forces of gravity. The functional residual capacity and mid-volume of the lungs will be reduced and the elastic recoil of the lungs at the end-tidal level will be less with concomitant reduction of conductance of the air-ways, as seen in transition from the erect to supine posture on earth. On the other hand, breathing at 5 psi or 3.5 psi increases airway conductance due to reduced density, so that the net effect of the space flight environment is expected to facilitate airflow.

Simultaneous measurements of flow and volume during a maximal effort Vital Capacity maneuver (Flow-Volume Loop) should be made at regular intervals as in-flight experiments and as part of the IMBLMS program.

e. Alveolar Gas Exchange and Control of Respiration (General Priority II)

With the exception of the marked effects of excessive gravitational stress during launch and re-entry upon alveolar gas exchange and their possible sequelae, no serious disturbances are to be expected on the basis of present knowledge in this area. Indeed, with regard to the distribution of ventilation and blood flow within the lungs, conditions may be more favorable in a gravity-free environment than on earth. Nevertheless, changes in total circulating blood volume and its distribution between systemic and pulmonary circulation at zero G and factors favoring atelectasis in the event of airway obstruction in an O_2-rich environment may produce unforeseen complications.

Simultaneous determinations of alveolar P_{O2} and P_{CO2} should be obtained with arterial (capillary) P_{O2}, P_{CO2}, and pH combined with measurements of total gas exchange. Data obtained in this manner will reveal any disturbance in blood gas exchange, ACID-BASE BALANCE, or alterations in the control of respiration during extended space IN missions. In view of the equipment required these studies should be assigned to the IMBLMS program.

f. Deposition of Aerosols in the Respiratory Tract (General Priority III)

While public health problems related to air pollution, radioactive fall-out and industrial dust exposure have been the object of intensive research, the behavior of aerosols in spacecraft, where the absence of sedimentation by gravity and effects of reduced barometric pressure affect the airborne stability of particles and their deposition and retention in the respiratory tract, requires special investigation. Furthermore, the self-cleansing mechanisms of the lungs, namely, (1) coughing, (2) ciliary activity of the epithelium of the air passages, and (3) macrophage activity and lymphatic drainage in the broncholi and alveoli may be adversely affected by weightlessness and the gas environment in space vehicles.

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I A QUESTIONS TO TO ANSWERED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

— RESPIRATION —

PRIORITY

a. Mechanics of Ventilation

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? — III-O - - - - - - - II-S

b. Alveolar Gas Exchange and Respiratory Control

2. 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? Measurement: Oximetry (earpiece) — I-O - - - - - - -

3. 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 (atelectasis, redistribution of blood volume)? Measurements: (1) Simulttaneous collection of expired gas, recording of alveolar (end tidal) O_2, CO_2 (N_2) and arterial or "arterialized" capillary blood for O_2, CO_2, pH and hemoglobin. (2) Determination of pulmonary diffusion capacity. — II-S - - - - - - - -

4. What is the energy cost (metabolic gas exchange) at rest and during activity in the space cabin with and without the suit in flight and during EVA. Measurement: Indirect calorimetry. — I-O - - - - - - -

c. Pulmonary Defenses

5. What is the aerosol content and composition in manned space vehicles in flight? — II-O - - - - - - -

Done

I B POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

— RESPIRATION —

PRIORITY

---------- 1. Not sufficiently applicable to man. ---

---------- 2. Not sufficiently applicable to man. ---

---------- 3. NOT SUFFICIENTLY APPLICABLE TO MAN ---

---------- 4. Information not applicable to man. ----

---------- 5. What is the aerosol deposition and retention in animals exposed to operational cabin atmospheres with known aerosols of various particle sizes. III-0

C I R C U L A T I O N

A

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

	PRIORITY
a. Blood Flow	
1. Is cardiac output adequately maintained in prolonged space flight? It is the best single indicator of total circulatory system function. Most likely methods would be an indicator dilution technique or impedance plethysmograph, if validated.	I - - - - - - - - - -
2. Once adequate methods are vailable, cardiac output measurements under a variety of stresses should be made, such as exercise, LBNP, and the like to test the responsiveness of the system.	I - - - - - - - - - -
3. Especially in the presence of inadequate cardiac output levels, determinations of regional blood flow may be desired. The most readily available will be measurements of limb (forearm, hand, finger) flow by plethysmographic methods.	II- - - - - - - - - -
b. Blood Pressure	
4. Studies of arterial pressure control system function are of fundamental importance during and after prolonged space flight.	I - - - - - - - - - -
5. An adequate measure of central venous pressure is required for a total evaluation of circulatory integration.	I - - - - - - - - - -
6. An importance factor in maintaining central venous pressure is venous compliance and its adjustment to physiologic stimuli. Does this mechanism remain normally operative in prolonged space flight?	I - - - - - - - - - -
c. Cardiac Function	
7. The most readily observed important partial determinant of pumping action of the heart. Responds to many and varied stimuli. Although functional and of great importance, not to be studied as an isolated function and included in several other proposed studies.	I - - - - - - - - - -

ß

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
--------- 1.	In-flight animal studies may be carried out if studies on the more definitive species, man, are not feasible.	II
--------- 2.	In the lack of adequate opportunity to do the above, studies could be carried out on animals but would be less meaningful.	II
--------- 3.	Animal studies may be of value in a limited sense.	III
--------- 4.	Animal studies may supplement but not replace above.	II
--------- 5.	Animal studies may be useful in development or exploratory studies but cannot provide final and definitive observation to evaluation man.	II
--------- 6.	Animal studies again can supplement but not replace observation on human studies.	II
--------- 7.		

A

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

8. A study of both the amount of blood and the efficiency of ventricular ejection is basic to the evaluation of heart function. Further studies before, during, and after prolonged space flight are needed to answer the question of possible deterioration of heart function after prolonged space flight. — I ---------

9. The measurement of more complete and sophisticated electrocardiograms over the simple abbreviated methods used to date is highly desirable as a possible indicator of heart malfunction. — II ---------

d. Blood Volume

10. Maintenance of an adequate blood volume is necessary for proper functioning of the circulatory system. See venous compliance and hematology sections. — I ---------

11. Is the blood volume "normally" distributed during space flight? Any evidence of circulatory malfunction should be studied, in part, by such observations. — II ---------

e. Tests of Systemic Function

12. Various testing methods have been utilized to apply stress to the circulatory system and test its response capabilities. Exercise, tilt table, LBNP, "Flack tests," emotional stimuli, and many others have been used. These have a place in the study of the effects of prolonged space flight to screen for any deleterious effects. — I ---------

B

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
--------- 8.	Animal studies can provide test situations for the techniques to be utilized in man and limited physiologic data.	II
--------- 9.	Animal studies may complement but not replace above.	III
--------- 10.		
--------- 11.	Animal studies of such problems probably of little value.	III
--------- 12.	Studies of the sort in animals in most instances have extremely limited value.	III

METABOLISM AND NUTRITION

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

a. Metabolism (Energy)

1. What are the absolute caloric requirements and the variations in caloric utilization under varying work loads and under varying configurations of space suit constraints in a long-duration weightless environment? To what extent will specific measurements of caloric expenditure during space flight modify present estimates of flight diet calorie level and composition? — I - - - - - - - - - I-O, I-S

2. What compositions of diet will provide for best nutrition of the flight crew as well as allow the proper evaluation of food intake for experimental studies? — I - - - - - - - - - I-O, II-S

3. Do eating habits of flight crews undergo any changes in flight that would require adjustment of food components? Can one expect dietary composition to remain reasonably constant if selectivity of diet components are allowed during flight? — I - - - - - - - - - I-O, II-S

4. For extended space flight (in excess of 60 days), are dietary formulations sufficiently evaluated to prevent nutritional deficiencies which might accompany loss of some micronutrient activity or failure to include some important dietary micro-constituent? — I - - - - - - - - - I-O, II-S

5. Are there any unusual stress conditions (heat, vibration, noise, etc.), or physiological responses that might change the requirements for water or salt intake during flight? — I - - - - - - - - - I-O, I-S

6. Do certain selected components of diet offer unusual contributions to the welfare or adversely affect the physical comfort of a flight crew? — I - - - - - - - - - I-O, II-S

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
- - - - - - - - - 1.	Animal flight experiments may show variations of oxygen utilization with carbon dioxide production, providing an estimate of absolute energy expenditure and requirement, but will not be directly applicable. and will be difficult to interpret.	II II-O, II-S
- - - - - - - - - 2.	Animal flights will probably not provide direct data unless an experimental diet is to be evaluated for long term flight.	III III-O, II-S
- - - - - - - - - 3.	Animal experiments may indicate if selectivity between diets change during space flight.	III III-O, III-S
- - - - - - - - - 4.	Animal experiments may be utilized to evaluate loss of micro-nutrient potency.	II II-O, II-S
- - - - - - - - - 5.	Animal evaluations won't necessarily reflect the changes that might be expected in man.	III III-O, III-S
- - - - - - - - - 6.	Animal experiments not appropriate.	---

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

7. Are the predicted increases in energy required to perform physical tasks in space as compared to I-G environment factual? If real, are they a continuing function of "inefficient" body or limb movement in space or can astronauts learn efficient movement in the new environment? If the latter, how long a training period will be required? — I — I-O, I-S

8. Since continuous minute-to-minute charted patterns of oxygen utilization or of carbon dioxide production can be used to determine the length and quality of sleep, to what extent and in what ways are sleep quality and duration affected by space flight and the weightless environment? — I — I-O, I-S

9. Is there any change of glucose utilization rate during flight phases where pure oxygen is used or when dietary components are grossly varied? — II — II-O, I-S

10. Since glucose tolerance is impaired in long duration bedrest, is glucose metabolism changed under a variety of work schedules or under varying conditions of gravity? — I — I-O, I-S

11. Is there any change of glucose-tolerance factor (GTF) or in insulin activity which might be attributed to the space environment or to production of artificial gravity? Experiments with man in the Coreolis Chamber at Pensacola, Florida (Naval School of Aviation Medicine), suggest GTF is affected by rotational motion and reflected by increased rates of glucose utilization (1.5%/min to 4.0-7.5%/min) which attained a stabilized level, differing from the initial level, after three days and remained until the rotational experience was terminated. Fasting blood glucose levels were reduced during the time of increased utilization. Within 48 hours of termination, both utilization rate and fasting levels for glucose were returned to the pre-experiment values. As noted in 10 (above), on the other hand, the opposite effect (impaired glucose tolerance) has been noted in long duration bed rest. — I — I-O, I-S

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
7.	Animal experiments probably not suitable.	---
8.	Animal flight observations may be useful in a preliminary assessment of this problem.	II II - O, III - S
9.	Animal flights of 30 days or more can give useful data in this evaluation.	III III - O, II - S
10.	Animal flights of 14 days or more can provide useful data to assess gravity increment.	II II - O, II - S
11.	Animal flights could provide useful data.	III III - O, III - S

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL
INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

	PRIORITY
12. Is there any changing requirement of the body for dietary fat during space flight?	II (III-O, III-S)
13. Is there any variation of lipid metabolism during flights where a pure oxygen atmosphere is provided? Some evidence from Manned Spacecraft Center (Fisher et al) suggests a change in the unsaturated lipid components of blood cells.	II (II-O, II-S)
14. Do dietary habits of man change under varying gravity influences and under conditions of space flight? Again, referring to the Coreolis Chamber experiments (glucose above), the men consumed larger amounts of high energy foods (butter, bacon, bread, etc.), while glucose utilization was increased during rotational motion.	II-O, II-S
15. Is there any changing requirement for protein under gravity influences or during space flight? During the Coreolis Chamber experiments (glucose above), intake of protein foods was decreased to favor fat and carbohydrate increases.	II (II-O, II-S)
16. Is protein utilization in the space environment the same as that of the man in a normal gravity work situation?	II (II-O, II-S)
17. Are there changes in body enzyme activity which may reflect any deteriorative changes which might be useful in assessing the biological cost of space flight? Enzymes suggested for study are lactic dehydrogenase, aldolase, transaminases, malic dehydrogenase, phosphatases, and isozymes.	II (II-O, II-S)
18. Are variations ~~of~~ 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?	II (II-O, II-S)

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
- - - - - - - - 12.	Animal experiments designed to evaluate loss or gain of fat deposits in the animal body could provide useful information.	~~II~~ III - O, III - S
- - - - - - - - 13.	Animal experiments, designed for metabolic evaluations, could provide useful information regarding lipid metabolism and metabolites by use of properly labeled isotope material and by evaluation of animal fat deposits.	II II - O, II - S
- - - - - - - - 14.	Animal experiments might not be of much value in selectivity of components of diet during gravity influences.	III III - O, III - S
- - - - - - - - 15.	Animal experiments to evaluate selectivity of components would be very difficult to evaluate and translate to men.	III III - O, III - S
- - - - - - - - 16.	Animal metabolic experiments might furnish useful data for evaluation of muscle activity, for amino acid utilization, creatinine production and similar parameters.	II II - O, II - S
- - - - - - - - 17.	Animal experiments would furnish useful preliminary data to evaluate such enzyme responses as lactic dehydrogenases, aldolase, transaminases, malic dehydrogenase, phosphatases, and isozyme variations during space flight where varying gravity weightlessness, and varying cabin atmospheres are used.	II II - O, II - S
- - - - - - - - 18.	Animal experiments, in a proper caloric chamber, could provide highly useful data for evaluation of this problem.	II II - O, II - S

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

19. Are the changes in body mass thus far noted during space flight, of such magnitude that long term experience would be a threat to the physical performance of the flight crew members? I
I - O, II - S

20. Are there changes in lean body mass of a man during prolonged space flight that might reflect changed metabolic requirements during the flight experience? III
III - O, III - S

21. Is there sufficient change of lean body mass in space flight to change the ability of a flight crew to perform? III
III - O, III - S

b. Neuromuscular

22. Are there changes in muscle size and strength which could adversely affect the performance of man in space flight? (An adequate ergometer with exercise standardization would be an extremely useful device for on-board evaluations.) I
I - O, I - S

23. Are adequate physical measurements available - including muscle size by standardizing on measurement of muscle areas - to adequately assess the potential variations of muscle size and strength? I
I - O, I - S

24. Are conditions of space (work schedules, body position, gravity load, etc.), sufficiently different to expect changes of muscle activity during flight? I
I - O, I - S

25. What degree or extent of change in muscle mass and protein metabolism will take place in long duration space flight and weightlessness as reflected in shift toward negative nitrogen balance? (Nitrogen balance studies of bed rest have indicated significant losses of muscle protein.) ~~II~~
I - O, I - S

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
19.	Animal experiments not pertinent.	---
20.	Properly designed animal experiments for prolonged periods would provide valuable information to indicate any variations in the metabolic patterns.	II II-O, II-S
21.	Metabolic experiments with animals studying the effect of an exercise regimen can provide parallel data for assessment of effects of changing lean body mass.	III III-O, III-S
22.	Animal experiments not directly applicable to man.	---
23.	Animal experiments not directly applicable to man.	---
24.	Animal experiments not directly applicable to man.	---
25.	Balance studies in animals would be extremely difficult to set up and carry out in weightless flight.	III-O, III-S

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

c. Mineral

26. What is the time course and degree of skeletal changes (loss of bone mass) due to weightless flight? Since ground studies of skeletal effects of immobilization and paralysis show different degrees of mineral loss in different parts of the skeleton, will losses be so great in some parts as to predispose to fractures of a critical nature? — I — I-O, I-S

What are the relative influences on mineral loss from the skeleton from the following factors:

27. ~~To what extent are bone changes due to~~ weightlessness, ~~as compared with~~ relative inactivity, atmospheric environment ~~and other factors~~? ? — I — I-O, I-S

28. What are the mechanisms by which bone changes take place in space flight? Radioisotopic kinetic studies most likely to yield data pertinent to mechanisms. — I — I-O, I-S

29. By comprehensive, well-controlled balance studies before, during and after long flights, what are the correlated changes, in addition to those in calcium metabolism, of phosphorous, nitrogen, potassium and magnesium? ~~as an aid to assessment of~~ What is the relative importance of these elements and losses thereof in development of skeletal demineralization and weakness? — I — I-O, I-S

30. What means can be used to predict dangerous levels of bone deterioration ~~will~~ while in flight? — I — I-O, I-S

31. What are the best preventive or restorative techniques against bone deterioration due to space flight? Should evaluate various forms of exercise on man in-flight. Check resistive versus inertial exercises of various types and regimens. Although considerable prior ground-based studies have been carried out on this problem (without regard to space), definitive such studies to determine the best procedure(s) to prevent or diminish bone and muscle deterioration due to inactivity have not yet been done. — I — I-O, I-S

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POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
26.	Animal flight experiments will be useful for indicating total bone loss (by x-rays and bone biopsy) but time course information in flight will not be possible unless urine collection or densitometry techniques applicable to animals in flight can be developed.	~~III~~ II-O, II-S
27.	Can evaluate with animal studies by differential restraint on flights having different atmospheres, etc. Should include if animals are flown (pre- and post-flight bone x-rays and biopsies).	II II-O, II-S
28.	Changes in animal bone morphology post-flight can be compared with changes induced by other means on the ground. Ground-based studies needed here.	II II-O, II-S
29.	Flight animal mineral balance studies very difficult but should be included if animals are flown and techniques will permit.	II II-O, II-S
30.	Animal flights can help here if reasonable predictive indices can be developed to evaluate. May try urinary output of calcium or hydroxyproline or in-flight bone density measurement (radioisotope source) as possible indicators, but thorough ground-based study will have to precede. Should evaluate in animal flights when ready.	II II-O, II-S
31.	Difficult to study in animal flights. Would be useful if satisfactory means of control can be devised. If can be done, should be incorporated into planned animal flight. Answers can be more practicably obtained, however, by ground-based study at this time.	II II-O, II-S

Done

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

32. By interval examination of urine specimens before, during and following space flights, what various factors believed to be related to the etiology of calculi appear or, if normally, present, are altered in amount as a result of long space flight? The various factors now under study are pyrophosphate, oxalate, magnesium, manganese, zinc, mucoproteins and related bio-colloids, calcification-inhibiting agent of Howard, in addition to total mineral and solute concentration. — II; II-O, II-S

d. Fluid and Electrolytes

33. What is the effect of weightlessness in long-duration flight on water balance? Based on prior Earth observations of changes in fluid balance associated with changes in body position, does weightlessness promote mobilization of fluid from tissues to bloodstream and an increased urinary volume? If fluid losses occur consistently, are they of a degree which might result in significant hypovolemia, potential syncope and possible impairment in temperature regulation? — I; I-O, I-S

34. What are the added or separate effects on water balance (including urinary, fecal and sweat losses) of such anticipated stresses in flight as heat, cold, threat of danger, and confinement, and what interplay is exerted by circadian rhythm and possible changes therein? — I; I-O, I-S

35. Does prolonged space flight, through weightlessness or other stresses, have significant effects, through urinary, fecal, or sweat routes of loss, on sodium, potassium or chloride balance? Do losses of these elements occur to an extent which might (through muscular weakness) affect astronaut performance as would occur with severe losses? — I; I-O, I-S

36. Will hypercapnia (retention of carbon dioxide) occur under planned atmospheric and environmental conditions in the space vehicle and/or with possibly reduced chest ventilatory movement? If hypercapnia occurs, will it be of sufficient degree to result in a level of acidosis which would affect muscle and bone metabolism? — II; II-O, II-S

37. In relation to possible changes in fluid and electrolyte balance, what changes may occur in plasma renin, and in plasma and urinary aldosterone and anti-diuretic hormone? — I-O, I-S

Done

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

PRIORITY

- - - - - - - - 32. Related observations in animals in flight could be carried out, with and without solids inserted in the urinary bladder as a nidus for concentration. — II; II-O, II-S

- - - - - - - 33. Animal in-flight experiments would be of interest but extremely difficult in weightless state unless techniques can be devised for satisfactory specimen collection in this situation. — III; III-O, III-S

- - - - - - - - 34. Animal in-flight experiments of interest but difficult to control, and assessment of results would not be easy. — III-O, III-S

- - - - - - - - 35. Same as 34. — III-O, III-S

- - - - - - - - 36. Same as 34. — III-O, III-S

37. Same as 34. — III-O, III-S

Done

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

e. Renal Function

38 ~~37~~. Will the various conditions of space flight change the ability to remove toxins and end products of metabolism from the circulating blood? Are there particular influences on kidney function from different levels of gravity forces? — III — III-O, III-S

39 ~~38~~. Do the conditions of space flight exert any effects upon renal function which can be detected by measurement or observation of the usual constituents sought in routine urine examination? Such examinations, incidentally, can detect the possible but unlikely incidence of renal tract infection. — I — I-O, II-S

f. Gastrointestinal

40 ~~39~~. Will the altered gravity and diminished atmospheric pressure of space flight have any effect upon the motility and transit time of the intestinal tract? — ~~III~~ — II-O, II-S

41 ~~40~~. Will the conditions of space flight alter intestinal absorption of a variety of dietary constituents, including protein, fat, carbohydrate and minerals, as measured by a number of tests of absorptive function, some involving the use of radioactively tagged materials? — ~~III~~ — II-O, II-S

43 ~~42~~ 41. May the alterations in atmospheric pressure or possible changes in intestinal motility or in circulation have any effects upon the principal liver functions, as determined by various tests involving dye clearance, chemical conjugation, etc? — II — II-O, II-S

44 ~~43~~ 42. If altered hepatic function is detected, to what extent is such dysfunction the result of altered hepatic circulation? — III — III-O, III-S

~~42~~ 43. Will conditions of space flight have any deleterious effect on digestion, and more specifically on the presence and amount of a variety of digestive secretory substances, such as gastric acid and intestinal and pancreatic enzymes? — ~~III~~ — II-O, II-S

Done

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

PRIORITY

~~37.~~ 38. Same as 34. — III-O, III-S

~~38.~~ 39 Animal experiments of limited value. — III-O, III-S

~~39.~~ 40. For all of the various aspects of gastrointestinal function, a number of animal studies could be devised but would not be urgently needed at an early time in the space experiments program. — ~~II~~ III-O, III-S.

~~40.~~ 41.

~~41.~~ 43.

~~42.~~ 44.

~~43.~~ 42.

Done

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

g. Temperature Regulation

~~44~~ 45. Do hypogravity and the other conditions of space flight alter the heat production processes and metabolic mixture (as determined by R.Q.) in the resting post-absorptive state or following ingestion of standard meals? The methods of measurement (respiratory gas exchange) are those employed in studies of total energy metabolism. — ~~III~~ II-O, II-S

~~45~~ 46. In view of the possibility that 5 psi atmospheric pressure may diminish the effectiveness of the convective route of heat loss, will this or other conditions of space flight affect this and other mechanisms of internal temperature regulation? Specifically, will weightlessness or other conditions have an effect upon the various routes of heat loss (evaporative, convective and conductive) or possibly on central neurologic centers of heat regulation? — ~~III~~ II-O, II-S

~~46~~ 47. As the net or resultant index of effects on heat production and heat loss mechanisms, as possibly affected by numerous physical and physiological influences, will the body temperature be maintained within normal limits during prolonged space flight? In contrast to the situation on Earth, will significant differences be deteced between deep rectal and deep ear temperature measurements of the internal body or "core?" — ~~II~~ II-O, II-S

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS TOWARD RESOLUTION OF MEDICAL QUESTIONS

PRIORITY

~~44.~~ 45. Suitable animal (monkey, pig) experiments could be devised and carried out, attended by man, to provide information on these temperature regulation questions, but all of this group of studies are much better done in man. ~~II~~ III-O, III-S

~~45.~~ 46.

~~46.~~ 47.

E N D O C R I N O L O G Y

Done

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

a. Hypothalamus

1. Does space flight, in particular weightlessness, have any influence on hypothalamic-pituitary releasing factors, hormonal substances of recently developing importance? — III - - - - - - - - - III-0, III-S

2. What other aspects of neuro-endocrine function may be affected by the various stress of space flight, including weightlessness, vibration, noise, threat of danger, etc.? — III - - - - - - - - - III-0, III-S

b. Posterior Pituitary, Urinary ADH

3. In view of the known changes in body water distribution and balance with changes in body position, will weightlessness per se bring about losses of fluid and, if so, will they occur in association with inhibition of anti-diuretic hormone? Are the fluid losses in astronauts observed to date due to poor thermal control of the spacecraft, to inadequate attention to fluid intake or to endocrine or circulatory influences, including altered ADH secretion? — II - - - - - - - - - II-0, II-S

c. Anterior Pituitary

4. Are any of the possible disturbances in endocrine function in space flight based on disturbance in anterior pituitary function? Does space flight, including weightlessness, have a measurable influence on assayable trophic hormones, such as ACTH, FSH, LH, TSH and growth hormone? — III - - - - - - - - - III-0, III-S

d. Thyroid

X 5. Will the various stress(es) of long duration space flight lead to increased thyroid hormone production, as indicated by changes in circulating thyroxine? What affect, if any, will space flight have on the transport proteins of thyroid, TBG and TBPA? — III - - - - - - - - - III-0, III-S

Done

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
1.	Animal in-flight studies, attended by man, could be useful but satisfactory urine collection system would have to be devised.	III-O, III-S
2.	Same as 1.	III-O, III-S.
3.	Animal inflight studies could contribute to solution of these questions provided adequate collection techniques can be devised for the weightless environment.	III III-O, III-S
4.	Same as 3.	
5.	Same as 3.	

Done

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

e. Parathyroid

6. 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? (In contrast to the other hormones for which effective radioimmunoassays have been developed, PTH protein is weakly antigenic so that a sensitive assay has yet to be developed. Assays in development for urinary excretion of this hormone have thus far been non-specific. This means that assessment of parathyroid hormone function in space flight will have to depend for the present on indirect measurements or indications, such as serum calcium, tubular reabsorption of phosphate, and response to calcium infusion. The question of possible suppression of thyrocalcitonin in association with bone resorption will also have to await development of an assay.) — III
III-O, III-S

f. Pancreatic Islet

7. In view of the known impairment of glucose tolerance in bed rest studies, will long-duration space flight accompanied by weightlessness result in changes in insulin and glucagon secretion? — III
III-O, III-S

g. Adrenal Cortex

8. In view of the numerous stress of space flight, particularly attendant to lift-off and landings, will these stresses be reflected in altered excretion of 11-17-OH-corticosteroids, 17-hetosteroids, or aldosterone? In extremely long-duration flights with continuing physical and environmental stresses, is it at all possible that sufficient continuing increased steroid production and excretion would occur that adrenal cortical exhaustion could take place? — II
II-O, II-S

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

PRIORITY

6. Animal in-flight studies await development of assays as well as of collection techniques. III-O, III-S

7. Same as 3.

8. Animal in-flight studies, accompanied by man, would provide useful information on these questions by in-flight blood assays and pre- and post-flight urine analyses until methodology for in-flight urine collection on animals is developed. III

III-O, III-S

Done

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

h. Neuro-humeral

9. In view of the numerous stresses of space flight, will there be significant responses in the excretion of various neuro-humeral substances, such as serotonin, catecholamines, epinephrine and norepinephrine? II - - - - - - - -
II-O, II-S

i. Gonads

10. Although alteration in gonadal function in space flight seems unlikely, will any such impairment occur in long duration flight as reflected by decreased urinary 17-ketosteroid excretion? III- - - - - - - -
III-O, III-S

Done

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

PRIORITY

9. Same as 3.

10. Animals in long duration flight could be subjected to post-flight testicular biopsy in answer to this question. — III

IIn – O, III – S

HEMATOLOGY

HEMATOLOGY

The known factors for consideration include man, the screening procedures to identify "normality of man," gaseous environment, temperature, vibration, acceleration, and weightlessness.

Red Cell Mass

There is evidence from the Gemini flights that the astronauts' red cell mass was decreased during space flight. There was no apparent relation of time of space flight (4 days Gemini IV, versus 14 days Gemini VII) to degree of red cell loss. The mechanisms and causes of this abnormality are not known. The possible more remote effects are unknown in man or in animals, but red cell mass apparently was restored in the astronauts. There are several observations pertinent; these include Fischer, Beery, Zalusky, and Fischer and Mengel. Work done on hyperoxia and red cell formation and destruction in animals up to 1945 was summarized by Bean but pertinent observations as to the mechanism of anemia are few. The work of Mengel provides the only systematic approach and data of the effects of hyperoxia of one aspect of space environment on red cell lysis.

Coagulation

There is little reason to expect alterations in platelet or plasma coagulation protein function. Vascular trauma imposed by suits, skin and mucous membrane care, gaseous environment, thermal variance, and forces of acceleration and decceleration are more likely as causes of bleeding. It is of importance to know that hemostasis will not be a problem in space.

Body Defense Mechanism

There is little reason to suggest that granulocyte function is altered, but sufficient data has not been obtained. The complex definition of "resistance to infection" includes the skin and mucous membranes as physical barriers, some immunoglobulins (IgA) in mucous membranes, vascular supply to an area, available graunulocytes with normal function, normal reticuloendothelial cells and immunocytes with normal immunoglobulin production.

A simple test of whether or not infections will be properly managed by persons in space flight is observation of an inflammatory cycle. The method described by Rebuck is appropriate and could be adapted for space flight.

Chromosomes and Cell Cultures

Chromosomal karyotypes may be of value in recognition of abnormalities induced by any aspect of space environment, such as weightlessness, prolonged physical inactivity or hyperoxia, but would more specifically be of interest as a biologic indication of radiation injury. Other than from drugs or radiation, there is no reason to suspect that chromosomes would be altered in type or number.

A

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

a. Red Cell Mass Loss

1. What is the time-dose relationship of space environment to red cell mass loss? — I-O - - - - - - - - I-S

2. Does hyperoxia of the 200-300 mm Hg pO_2 range cause suppression of red cell formation? If so, what is the magnitude of change and is a new steady state achieved? — I-O - - - - - - - - I-S

3. Does hyperoxia of 200-300 mm Hg pO_2 cause accelerated hemolysis, which partially or totally caused the red cell mass decrement observed in the astronauts in the Gemini flights? The ground level experiments of Zalusky indicate the hemolysis does not occur, but more precise methods than Cr^{51} must be used, the experiments (008) by Fischer and Mengel give insufficient data, but are important because methemoglobinemia occurred and red cell phosphofructokinase deficiency was seen. The data obtained on astronauts in Gemini IV and VII by Beery and Fischer is inadequate to allow conclusions concerning rates of red cell destruction. The data of Republic Aviation Corporation in which hemolysis was described in one person during hyperoxia was a person with a pre-existent hematologic abnormality (thalassemia minor). — I-O - - - - - - - - I-S

4. If suppression of rates of production and increased rates of destruction of red cells occur and are due to hyperoxia, what are the mechanisms of these responses? Is hemolysis due to oxidative changes in hemoglobin, peroxidative changes in red cell membrane lipids, inactivation of energy production, or of electrolyte pumping mechanism or other mechanisms? — I-O - - - - - - - - I-S

B

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
---------1.	Animal flights should be done where data on man is not, or will not be available. Biopsy specimens of bone and marrow could be done in animals.	II
-------- 2.	If hyperoxia of 200-300 mm Hg pO_2 plus flight causes suppression of rate of red cell formation, does the animal respond to alterations of a new steady state in normal fashion? Will phlebotomy or transfusion of red cells cause a response similar to that of the normal animal in a normal environment.	II-O I-S
---------3.	Are there marked species differences in hematologic effects of moderate 200-300 mm Hg pO_2 hyperoxia? In the normal mouse, overt hemolysis occurs at 70 hours exposure with 100% O_2 at 1 atmosphere pressure (i.e., 760 mm Hg pO_2). Comparison of flight to ground simulation may give, by subtraction, an idea of the effects of weightlessness.	II-O I-S
---------4.	Flight animal studies would not be of added value.	

A

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

	PRIORITY
5. What are the ranges of in vivo and ambient temperatures and times of exposure tolerable, before red cell damage takes place? Studies in humans, at 30-90 min, 160°F, show changes in osmotic fragility and MCV but life span studies are not available. Clinical suggestions, i.e., burns indicate hemolysis can occur. In vitro studies show that hemolysis occurs when temperature is elevated to 45° centigrade.	II-O II-S

b. Plasma Volume

6. Does plasma volume change during space flight? In what fashion may plasma volume and cardiac function be related?	I-O I-S
7. If plasma volume is decreased, is it secondary to water deprivation, fluid compartmental maldistribution, altered Na metabolism, serum protein alterations, portal-venous baroreceptor alteration, or other factors?	I-O I-S
8. Does the factor of weightlessness or other environmental change induce the plasma volume abnormality?	I-O I-S

c. Coagulation

9. Are coagulation proteins, platelet function, and vascular friability normal before and after space flight, up to weeks of time?	II-O II-S

d. Body Defense Mechanism

10. Is the inflammatory cycle normal during space flight?	I-O I-S

B

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
-------- 5.	Animal studies in flight are unnecessary.	
-------- 6.	Animal studies are of value, but there is difficulty in extrapolation of data to humans.	II-O I-S
-------- 7.		
-------- 8.	Only acceptable where human study not available.	III
-------- 9.	Animal studies would probably not be greatly informative.	
-------- 10.	Is bacterial infection of one type more likely to occur than others, another more hazardous; for instance, comparisons of type of bacteria and of propensity of infection of one system or another may be made. Is the CNS, alimentary, respiratory or GU tract particularly vulnerable to infection? Are viral infections modified by conditions of weightlessness?	II-O II-S

B

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS TOWARD RESOLUTION OF MEDICAL QUESTIONS

PRIORITY

MICROBIOLOGY AND IMMUNOLOGY

BEHAVIORAL EFFECTS

BEHAVIORAL EFFECTS

As the space program continues to develop, certain quantitative changes will inevitably occur: flights will be longer, vehicles will be larger, and spacecrews will increase in size. Technical improvements will eliminate some problems presently associated with spaceflight, but the natural growth of the program will inevitably introduce new problems that will demand careful attention. Among these, behavioral considerations will assume greater importance. As of the present, however, no behavioral problems have been observed on any of the flight missions.

Longer flights imply that some hazards, real or potential, will increase the probability of irreversible damage, as for example, radiation and weightlessness. These effects may be subtle but nonetheless cumulative. It is recognized, however, that the effects of weightlessness cannot be clearly differentiated from other stresses involved in spaceflight. But should the effects of weightlessness be real and cumulative, changes produced in the physiological mechanisms may, in turn, induce modifications of the behavioral repertoire available to the astronaut. Further, longer flights may accentuate the impact of isolation or confinement on the mood, attitudes, and morale of the crew.

With larger space vehicles, the effects of confinement will undoubtedly diminish. On the other hand, weightlessness will become a decided "nuisance" factor. Objects will have to be tethered, astronauts will need stable platforms for the accomplishment of many seemingly trivial tasks (for example, turning a dial, flipping a switch), locomotion and physical interaction of crewmen in the performance of group tasks will involve the development of new behavior patterns. As a matter of fact, new standards of performance for operating under these conditions will have to be established. Though crewmen can adapt to weightlessness as a "nuisance" situation, behavioral efficiency and energy expenditure undoubtedly will be affected. Should the decrement in behavioral efficiency and the energy penalties prove too costly, the introduction of some type of artificial "g" would have to be considered. But if artificial "g" becomes necessary, its effect on the performance of many tasks in flight will have to be evaluated.

Multi-man spacecrews are the natural outcome of a developing space program. There are obvious advantages in having a crew versus a single astronaut on a spaceflight. A group increases efficiency, it supplies backup and redundancy, and it eliminates social isolation. However, new problems associated with group structure and functioning must be anticipated. There are the inevitable interpersonal adjustments and interactions, the problems of maintaining group intensity, and the relation of these to the "human density" factor. Defined in terms of the number of cubic feet of living or work space per astronaut, human density is, naturally enough, closely related to the confinement factor.

Information Processing

As information processing functions, vigilance and perception are considered of primary importance in monitoring operations. Under certain conditions, they may also serve as indicators of the efficiency of brain functioning.

Information Storage

Activity

Under conditions of weightlessness, performance of many tasks will most likely differ either in the time they take, in the manner of doing them, or in the energy expended in their performance. The basic activities and tasks common to all types of spaceflight operations need to be identified and analyzed in respect to time, patterning, and energy consumption. Such a "catalogue" of performance and learning norms should be developed for intra-vehicule and EVA modes. These norms will enable us to plan more efficiently and with greater safety for long flights. At the least, they would help us establish realistic time-lines.

Adaptability

Man has adapted very well to spaceflights of short duration. With possible cardiovascular and muscle tissue changes induced by prolonged periods of weightlessness, tolerance limits to various stressors may change in extended spaceflight.

Decision Making

Group Integrity and Efficiency (Also Interpersonal Relations) - See Section II

Interpersonal relations among men having to live and work in very confining quarters may deteriorate over time. As a result, group integrity and efficiency may be threatened. "Social engineering" procedures to structure "compatible" groupings need to be considered.

Done

A

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

a. Information Processing

1. Because a prolonged weightless state may induce cardiovascular and muscular changes which, in turn, may affect such functions as are measured by the EEG, GSR, RT, etc., what criteria are the best indicators of changes in vigilance on an extended space flight? I-0 II-5

2. Studies indicate that there is mutual interrelation of perceptual and motor activities. In prolonged weightlessness (and consequent diminution and/or change in motor feedback), will perceptual efficiency remain unaffected? I-0 II-5

b. Information Storage

c. Activity

3. What changes in time and/or pattern of activity will make performance of tasks in space most efficient? Most comfortable for the astronaut? I-0 III-5

4. What are the energy expenditures for tasks inflight compared to corresponding energy expenditures for the same tasks performed under simulated flight conditions? I-0 I-5

5. What are the optimal inflight work-rest periods (especially in EVA) based on factors of (1) fatigue, (2) energy loss, (3) discomfort, and (4) other stress indicants? I-0 II-5

5. What are the performance and learning norms (or standards) for the basic activities and tasks common to many spaceflight operations? Such a "catalogue" of performance and learning norms should be developed for intra-vehicle and EVA modes. I-0 III-5

Done

B

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

		PRIORITY
1.	Animal flight studies might establish changes in the vigilance function, either in perceptual monitoring or in learning situations.	III - 0 II - 5
2.	As in above, animal flight studies may prove useful in clarifying these issues.	III - 0 II - 5
3.	Animal studies do not seem to be relevant.	
4.	Animal studies could provide information as to basic mechanisms.	II - 0 I - 5
5.	~~Animal studies do not seem to be relevant.~~	
6.	Animal studies do not seem to be relevant.	

A

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

PRIORITY

d. Adaptability

7. Because of possible cardiovascular and muscle tissue changes resulting from prolonged periods of weightlessness, will the hormonal, behavioral, and subjective reactions to stress change over time in long duration spaceflights? In particular, what changes in the tolerance limits to stress occur over time in extended periods of weightlessness? Will the reactions to stress be more intense, of longer duration, and more disruptive of ongoing physiological and behavioral activities? I - - - - - - - - - -

e. Decision Making

B

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS

	PRIORITY
7. Preliminary and intensive long duration flights of animals would seem to be warranted to determine the time course (speed and duration) and the degree to which irreversible changes may occur. Extrapolation to man would, of course, be very guarded.	II

GENERAL

A

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

	PRIORITY
1. What is the filter efficiency of LiOH or other scrubbers for microbial burden? What is microbial burden of drink gun, urine collector, potable and waste water interface?	O-I - - - - -
2. Where is ionizing radiation dose measurement most meaningful with respect to human effects - inside or outside spacecraft? Do tissue equivalent values have more meaning than flux? Where best do you measure radiation absorbed dose to detect blood changes?	O-I - - - - -

B

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS
TOWARD RESOLUTION OF MEDICAL QUESTIONS
Hematology IB

		PRIORITY
11.	Animal studies are of value, and would supplement information obtained by human studies.	II-O II-S
12.	Only of value in event of unavailability of man or as suggested by finding of abnormality in the previously suggested experiments.	II - O IV - S
13.	Animals are of value only in absence of the human.	III - O II - S
14.	Only of interest in absence of human availability, or if abnormalities of human are found, then certain species would be of interest.	II - O II - S

GROUND BASED STUDIES REQUIRED IN SUPPORT OF FLIGHT MEDICAL INVESTIGATION

	PRIORITY
1. Obtain crew baseline data on the microbiological flora of body surfaces, urine, feces, blood, and the variation with time in a closed environment.	I
2. Determine degree of cross contamination during prolonged confinement.	I

B

POTENTIAL ROLE OF SPACE FLIGHT ANIMAL EXPERIMENTS TOWARD RESOLUTION OF MEDICAL QUESTIONS

PRIORITY

1.

2.

SECTION I - C

NEUROLOGY

GROUND BASED STUDIES REQUIRED IN SUPPORT OF FLIGHT MEDICAL INVESTIGATION

	PRIORITY
1. Comprehensive experimental program dealing with all aspects of motion sickness, i.e., etiology, symptomalogy, and prevention. Reliable tests for predicting susceptibility must be devised and such associated phenomena as conditioning, habituation, and transfer effects investigated. Although many factors are of etiologic importance in causing motion sickness it has its genesis in the vestibular organs. We have still to learn the individual and collective roles of these organs in causing motion sickness and the precise underlying neural and neurohormonal mechanisms. Better tests of vestibular function are needed, and the relation of functional decrements to behavioral responses determined. Studies conducted under simulated conditions in a weightless spacecraft are needed for predictive purposes. Susceptibility tests should be conducted on all astronauts for validation aloft.	I-O I-S
2. Neurological studies during brief free-floating periods provided by parabolic flight. Use of water immersion and labyrinthine-defective subjects.	
3. Ground based simulation studies are essential to provide design criteria for rotating spacecraft and to prepare the astronauts for exposure aloft. Slowly rotating rooms simulate in many important respects conditions aloft even including man's orientation at right angles to the axis of rotation (21). One significant variable not controlled in rotating rooms is the G loading and short exposures in parabolic flight are of limited value. Studies on human subjects with normal vestibular functions and subjects with bilateral loss of function complimented by studies on subhuman primates are needed to provide background information. Ideally, preflight ground based measurements on astronauts should have high predictive value for conditions aloft where validation is possible. Postflight measurements on astronauts would complete the gathering of information useful for future flights.	

Done

		PRIORITY
4.	Develop means to test for postural equilibrium and taxis and conduct ground based studies as above.	
5.	Ground based studies as above with provisions for measuring fine sensorimotor activity and visual tracking.	I-O II-S

RESPIRATION

GROUND BASED STUDIES REQUIRED IN SUPPORT
OF FLIGHT MEDICAL INVESTIGATION

PRIORITY

1. Determine mechanical tolerances of the lungs to high sustained G-force such as may occur during launch and reentry on large animals and human corpses. I O

2. The integrity of pulmonary function during long range exposure to 100% oxygen at 5 psi has not been established in man. If such an atmosphere (operational or back-up) is contemplated for longer missions, goundbased validation studies on human subjects are indicated I O

CIRCULATION

GROUND BASED STUDIES REQUIRED IN SUPPORT OF FLIGHT MEDICAL INVESTIGATION

		PRIORITY
1.	Ground-based studies to develop adequate technique for in-flight determination of cardiac output will be required.	I
2.	The need for an adequate arterial pressure monitoring device is a glaring and long-standing deficiency.	I
3.	A non-invasive technique for the measurement of central and peripheral venous pressure will be important.	I
4.	Ground-based studies will be required to adapt available techniques for the measurement of venous compliance to spacecraft situations.	I
5.	Ground-based studies are required to develop and test techniques of measuring mechanical aspects of heart function in space. The use of the ballistocardiograph, vibrocardiograph, phonocardiograph, and measurement of the phases of systole and their deviations will be required.	I
6.	Ground-based studies of techniques to measure regional blood volume distribution will be required.	I
7.	The development of spacecraft applicable and normalized dynamic tests of circulatory response should be the subject of continued ground-based studies.	I

METABOLISM AND NUTRITION

GROUND BASED STUDIES REQUIRED IN SUPPORT OF FLIGHT MEDICAL INVESTIGATION

		PRIORITY
1.	The study of calcium metabolism at various phases of training under various conditions during preflight to establish baseline levels for each potential astronaut is recommended. Each man must serve as his own control in addition to furnishing data for statistical evaluation of space flight.	I-O, I-S
2.	Determine time course and degree of skeletal changes induced by various forms of inactivity and of atmospheric compositions and pressures. Study mechanisms, determine predictive techniques and most effective remedial measures. In those studies use balance and densitometric studies on humans and animals for very long periods. Bone, muscle, and other morphological studies can be employed in animal investigations.	I I-O, I-S
3.	The effects of environmental gas compositions on acid-base balance should be determined by ground-based study.	II II-O, II-S
4.	Develop and test new and improved bone densitometric techniques for greater accuracy and suitability for space flight use.	I I-O, I-S
5.	Develop and test accurate inflight urine volume measurement and sampling techniques.	I I-O, I-S
6.	Develop and test sweat sampling methodology and ~~techniques~~ equipment.	I I-O, I-S

ENDOCRINOLOGY

GROUND BASED STUDIES REQUIRED IN SUPPORT OF FLIGHT MEDICAL INVESTIGATION

PRIORITY

1. Ground based studies would be of interest on the serotonin-histamine relationships to sleep and to motion sickness. III
III-O, III-S

2. In association with metabolic studies of time course and degree of skeletal changes induced by various forms of inactivity and of atmospheric compositions and pressures, measure possible decrease in thyroid function and changes in posterior-pituitary-ADH excretion, in parathyroid hormone and thyrocalcitonin when assays sensitive and reliable, and in neuro-humoral and adreno-cortical function. II-O, II-S

HEMATOLOGY

GROUND BASED STUDIES REQUIRED IN SUPPORT OF FLIGHT MEDICAL INVESTIGATION

		PRIORITY
1.	Ground based studies in man and animals would allow measurements of the effects of all environmental factors except for weightlessness on red cell mass.	I-O I-S
2.	Ground based studies providing accurate measurement of rates of red cell formation (erythrokinetics) will give answers as to the relation of hyperoxia of modest degree to altered red cell mass.	II-O I-S
3.	Ground based studies on animals are needed for supplementation of data on the effects of moderate hyperoxia (200-300 mm Hg pO_2) on hemolysis which cannot reasonably be obtained in the human (i.e., available bone marrow-spleen tissue and chemical and structural studies) and on species differences in response.	I-O I-S
4.	Ground level studies could provide answers to questions concerning the mechanisms of red cell responses to hyperoxia, i.e., whether due to oxidative changes in hemoglobin, peroxidative changes in red cell membrane lipids, inactivation of energy production, electrolyte pumping mechanisms, etc.	I-O I-S
5.	Determine the effects of vibration as a cause of destruction of red cells <u>in vivo</u> in humans and animals.	I-O I-S
6.	Determine the effects of acceleration forces as a cause of red cell abnormality and accelerated destruction rate.	I-O I-S
7.	Ground level studies should be done to determine the ranges of ambient temperatures and times of exposure tolerable before <u>in vivo</u> red cell damage takes place.	I-O I-S
8.	Ground studies of effects of suits, acceleration, hyperoxia, and temperature, etc., on coagulation factors (proteins, platelet function, and vascular friability) can be done.	

GROUND BASED STUDIES REQUIRED IN SUPPORT OF FLIGHT MEDICAL INVESTIGATION

		PRIORITY
9.	Save for weightlessness all studies of the effects of space flight on response and resistance to infection may be done at ground level in animals and humans.	I-O I-S
10.	Ground based studies on effects of vibration, heat, cold, radiation, hyperoxia, etc., on lympholyte chromosome numbers and types have been or could be done.	II
11.	Ground based studies have provided, could provide adequate information on lympholyte transformation capabilities, cell division and replication as affected by the space environment except for effects of weightlessness.	II

MICROBIOLOGY AND IMMUNOLOGY

GROUND BASED STUDIES REQUIRED IN SUPPORT
OF FLIGHT MEDICAL INVESTIGATION

		PRIORITY
1.	Obtain crew baseline data on the microbiological flora of body surfaces, urine, feces, blood, and the variation with time in a closed environment.	I
2.	Determine degree of cross contamination during prolonged confinement.	I

BEHAVIORAL EFFECTS

GROUND BASED STUDIES REQUIRED IN SUPPORT OF FLIGHT MEDICAL INVESTIGATION

		PRIORITY
1.	Study prolonged exposure to the flight environment to determine if it leads to perceptual satiation and, perhaps, to illusory experiences or loss of meaning.	I
2.	Conduct an evaluation program on tests or techniques which will detect even a slight trend toward cerebral impairment as a result of psychological concomitants of confinement as well as physiological changes, which is designed to: (a) establish sensitivity of tests to space capsule conditions, and (b) collect normative data under these conditions.	I
3.	Because one indicator may not prove discriminating or reliable, develop a multivariate index of vigilance, with a capacity for retaining a lower-order index if one or more indicators deteriorate.	I
4.	Determine to what extent the index of vigilance is an idiosyncratic function of the individual. In other words, must we develop a unique index for each individual?	I
5.	Develop the methodology, preferably on a non-interference basis, and the required instrumentation for acquisition and processing of vigilance indicators to provide opportunity for periodic or continuous monitoring if and when necessary.	I
6.	Ground-based studies should provide preliminary "earth-bound" norms for the performance and learning of standard operations to be used in spaceflight. These norms should be of two sorts: (1) obtained under ordinary conditions but within the spatial and confining situations simulating spaceflight; (2) obtained under conditions simulating the weightless state, as, in neutral buoyancy and parabolic flights.	I
7.	Determine if we can utilize the rate, tempo, and other objective characteristics of speech as indicants of stress, tension, mood change, etc.	II

GROUND BASED STUDIES REQUIRED IN SUPPORT
OF FLIGHT MEDICAL INVESTIGATION

		PRIORITY
8.	Determine if subjective expressions of stress are reliable. (It has been reported that a person's evaluation of his subjective state is often at variance with the physiological monitors.)	II
9.	Determine the most effective behavioral methods of managing and controlling reactions to (a) emergency stresses, (b) slowly evolving stresses.	I
10.	Determine what personal and personality characteristics of members must be considered in the formation of a viable and integrated groups. What characteristics among individuals tend to disrupt the group, endanger group integrity. How can we accurately measure these characteristics?	I
11.	Determine the effect of "human density" on (1) the probability of interpersonal friction, (2) group efficiency.	I
12.	Determine the effect of training of astronauts in group dynamics to enhance (1) morale, and (2) toleration of interpersonal stresses on long flights.	II
13.	Evaluate the problems of group leadership in astronaut groups for degree of similarity to those in ordinary or in military groups. (It has been suggested that astronauts, who as test pilots were accustomed to make critical decisions by themselves, might exhibit group interactions somewhat different from those found in ordinary groups.)	II
14.	Investigate methods of determining an individual's contribution to group functioning.	I
15.	Determine the best criteria of group efficiency in spaceflight operations.	I
16.	Conduct simulations of specified missions manned with astronauts or astronaut-like crew members for durations equal to mission time. Measurements related to human reliability regarding flight control and allied mission tasks should be made. Also of prime importance are measurements regarding the nature of group dynamics and the effects which may be generated as a result of these interactions. In addition, the tests of the sensory, perceptual, and high mental processes should be conducted as they would on an extended space mission.	I

G E N E R A L

SECTION I - D

NEUROLOGY

R&D REQUIREMENTS TO INCREASE CAPABILITIES OF FLIGHT MEDICAL LABORATORY (IMBLMS)

		PRIORITY
1.	Develop rotating litter chair system with stimulus control and recorder/signal display.	O-I
2.	Develop helmet device to obtain triaxial linear and angular accelerations on astronauts.	P-II
3.	Develop rotating TEST device capable of tumbling mode with stimulus control.	
4.	Develop technique and equipment to test for postural equilibrium and taxis.	

R E S P I R A T I O N

R&D REQUIREMENTS TO INCREASE CAPABILITIES OF FLIGHT MEDICAL LABORATORY

Priority

1. Mass-spectrometer for recording respiratory gases (O_2, CO_2 N_2). This instrument should be design for alternative monitoring of the cabin atmosphere, of mixed expired gas or for breath-by-breath analysis. S-I

2. Device for measuring instantaneous flow rate and integrated volume for respiratory measurements, which would be used for the study of mechanics of breathing as well as for metabolic rate in conjunction with the mass-spectrometer. S-I

3. Electrode systems for micro-analysis of P_{O2}, P_{CO2} and pH on samples of "arterialized" capillary blood and an appropriate method for the determination of hemoglobin concentration. S-I

4. Method for measuring pulmonary diffusing capacity with the single-breath or the re-breathing technique. This requires a highly sensitive CO-analyzer which could be used alternately for monitoring the cabin atmosphere, for diffusing capacity or the measurements of individual endogenous CO production as an index of red cell destruction (see Hematology, page 103) S-I

CIRCULATION

R&D REQUIREMENTS TO INCREASE CAPABILITIES OF FLIGHT MEDICAL LABORATORY (IMBLMS)

		PRIORITY
1.	Develop a non-invasive technique for the accurate determination of cardiac output.	I
2.	Develop imrpoved technique(s) for the measurement of regional blood flow.	II
3.	Continuing improvement of blood pressure measurement system for greater accuracy is indicated.	I
4.	Improved techniques to measure the mechanical efficiency and timing of ventricular systole are necessary for inclusion aboard IMBLMS. Such techniques as phono, vibro-, or ballisto-cardiography should be differentially evaluated and improved.	I
5.	The development of IMBLMS applicable and normalized circulatory provocative tests should be the subject of continuing ground based studies.	I

METABOLISM AND NUTRITION

R&D REQUIREMENTS TO INCREASE CAPABILITIES OF FLIGHT MEDICAL LABORATORY (IMBLMS)

	PRIORITY
1. Develop simple, safe, and micro means of determing serum and urine Ca, P, and hydroxyproline, on board IMBLMS.	I I-O, I-S
2. Develop suitable bone densitometry technique for IMBLMS use. Radioisotope techniques appear the most promising at present.	I I-O, I-S
3. Development of instrumentation enabling the accurate measurement of acid-base balance in flight is highly desirable.	II II-O, II-S
4. Urine samples properly collected and preserved are an invaluable source of information for the assessment of most end responses of metabolic processes. The requirement for careful handling, accurate measurement of urinary volumes with each and every voiding, and the proper attention to the division of samples of each collection to assure that the analyzed sample reflects the constituents of the original collection cannot be emphasized too strongly. In the past, critically needed data have been lost through failure to observe these conditions. From a biological and biochemical standpoint, the urine represents a critical body fluid sample of great practical and scientific importance which is available at essentially no cost to the astronaut. Methods of preservation of labile constituents warrants much consideration to assure maximum economy of collection and to assure that proper volumes of all necessary samples be provided.	I-O, I-S
5. Develop sweat sampling methodology and equipment.	II-O, II-S
6. Develop and test methods of blood sample collection, separation of serum and plasma, preservation and storage.	I-O, I-S
7. Develop improved methods of stool collection, preservation and storage.	I-O, I-S
8. Develop and test new analytical chemistry methods for all biological fluids suitable for accurate and repeated use in spacecraft, such as mass spectrometry.	I-O, I-S

ENDOCRINOLOGY

R&D REQUIREMENTS TO INCREASE CAPABILITIES
OF FLIGHT MEDICAL LABORATORY (IMBLMS)

PRIORITY

1. Sensitive assays for parathyroid hormone and thyrocalcitonin have not yet been produced and should be ~~sought.~~ developed. II-0, II-S

HEMATOLOGY

R&D REQUIREMENTS TO INCREASE CAPABILITIES
OF FLIGHT MEDICAL LABORATORY (IMBLMS)

		PRIORITY
1.	Advancement of technologies for measurement of erythropoeitic mass and/or functions would be very desirable. For example, the evaluation of carbon monoxide evolution as a reflection of rates of red cell destruction and the development of hardware for this.	
2.	Development of CO analyzers with simplified sampling and analytic procedures would allow the use of multiple methods (i.e., gasometric CO and isotopic means) for more accurate determination of red cell life span.	II
3.	Design of instrumentation for electrolytes, and for enzyme kinetics, for protein characterization, measurements would facilitate the study of mechanisms of red cell response to hyperoxia, but present methods are good.	III
4.	Techniques for measurements of coagulation proteins and platelet function are available. Measurements of vascular friability are quite crude and require more precision.	
5.	Techniques for automated counting of cells and for cell identification (i.e., image recognition) would be of value.	

MICROBIOLOGY AND IMMUNOLOGY

BEHAVIORAL EFFECTS

R&D REQUIREMENTS TO INCREASE CAPABILITIES OF FLIGHT MEDICAL LABORATORY (IMBLMS)

PRIORITY

1. Develop criteria of vigilance in-flight to compare them with corresponding criteria developed in simulated flights. The necessary equipment should be a part of IMBLMS.

2. Many sensory-perceptual tasks and a number of the performance tasks should be included within the IMBLMS capability.

3. IMBLMS physiological and behavioral data should be capable of correlation with stress events since responsiveness may change as a function of duration of flight.

4. IMBLMS should provide for the measurement of some of the effects of group functioning. These measurements, their development and improvement should be the subject of continuing ground based study.

5. Develop instruments and/or test procedures to make in-flight measurements of cerebral deficit or deterioration which are directly comparable to ground-based measurements.

G E N E R A L

SECTION II

SECTION II

A - ATMOSPHERE AND SPACE SUITS

PRIORITY

1. Research designed to elucidate the mechanism of the occurrence of atelectasis and the associated pulmonary arterial venous shunts during exposure to acceleration should be carried out and the relationship of the susceptibility to these pulmonary derangements to the pressure and composition of the gas mixture being breathed should be delineated. — I

2. Essential to the establishment of firm life support criteria for atmosphere selection are further ground based studies to clarify the potential incidence of dysbarism following either premeditated operational or emergency decompressions from anticipated spacecraft atmospheres to the 3.7 psi (absolute) pressure suit atmosphere. The goal is to develop the relation of incidence of dysbarism vs time of equilibration at operationally important atmospheres and to determine what equilibration time is needed to reduce essentially to zero the probability of a dysbaric event. — I

   Secondly, when dysbarism occurs under these experimental circumstances, the efficacy of simple recompression to the original intravehicular atmosphere ⊗ should continue to be evaluated as a counter-measure.

3. Continuing research is necessary to determine the extent of risk with various combinations of inert gas with oxygen in the pressure range of 3.7 psi to 14.7 psi. Since gravity dependent factors are involved in fire, the critical tests may require carefully controlled validation in the weightless state. — I

   Further studies of materials with primary interest in vapors and flammability are important.

4. Determine the microbial filter efficiency of LiOH and other scrubbers which may be used in flight. — I

⊗ with the additional suit pressure (5.0+3.8 psi)

B - METABOLIC FACTORS (FOOD, WATER, AND WASTE SYSTEMS)

PRIORITY

1. Studies of nutritional acceptability and palatability for extended periods of such potential foods as algae, reconstituted liquid or semi-liquid diets of natural products should be continued. It is recommended that an investigation be made as to the possibility of extending a natural diet by means of a concentrated, high-density, synthetic diet which can be consumed periodically during the flight program. I

   As it may be necessary in extended flights to use high caloric density foods, preliminary data are required to assess the potential use of such food sources.

2. Continued work in the field of food packaging to enable the accurate measurement of intake of food constituents is important. I

3. Continued development of improved urine and fecal collection devices to improve both metabolic balance studies as well as improving sanitation for the pilot is necessary. I

4. Further research and development on the recycling of water, with purification to acceptable standards of potability for human use, should be made. I

5. Determine the microbial burden of the drink gun, urine collector, and potable and waste water interfaces. I

C - LIVING CONDITIONS AND STANDARDS

	PRIORITY
1. The development of techniques and materials for the accomplishment of body cleansing in space.	
2. The development of techniques and equipment for shaving, haircutting, and nail paring in space.	
3. Development of a closed-circuiting mechanical device which would fit tightly against the skin and could be moved over it in order to cleanse the surface of the body with a cleansing solution self-contained within the washing device.	
4. Determine hygienic requirements and logistics support to maintain a constant microbial burden during prolonged space simulation studies.	I
5. Explore the development of microbial cabin monitor ideally capable of both qualitative and quantitative evaluation.	I
6. The development of techniques and equipment for the laundering of clothes in space.	
7. The investigation of optimal clothing fabrics for space existence considering weight, skin tolerance, ease of laundering, ease of storing, and/or disposal (in lieu of laundering).	
8. Trial and long-term occupation of fixed-based simulators employing variations in lighting and color. Note effects on crew well-being and performance and interactions with other variables.	
9. Preflight trial of displays in simulator.	

D - GROUP INTEGRITY

PRIORITY

1. Expand psychological test battery to include tests and techniques which will evaluate candidate potential for positive group interaction. Develop procedures (tests, ratings, etc.) to evaluate:

   a. group efficiency
   b. adaptation to group stresses
   c. flexibility to adjustment within different groups
   d. deterioration of morale and group efficiency over time, and
   e. leadership potential and decision making ability

   Procedures should be developed to provide a rating of an individual's potential for positive group interaction, whether this be done by test or by life-history analysis.

2. Develop a program to identify which specific crew characteristics serve as criteria for "good" and "poor" crews (the extremes of efficiency in performance).

3. Perform habitability studies which will answer the questions:

   a. What are the psychological effects of prolonged spatial confinement with its concomitant social restriction?

   b. What are the psychological effects of crowding?

4. The effectiveness of certain "social engineering" approaches to the structuring of groups, for example, combining people with complementary needs, congruent attitudes, etc. should be evaluated.

E - HAZARD PROTECTION

PRIORITY

1. Development of a self-contained emergency breathing apparatus for use inside the capsule as protection against atmospheric contaminants.

2. Research and development concerning in-flight detection of atmospheric contaminants.

3. Development of a miniaturized hand-operated, ejection fire extinguisher (e.g., liquid CO_2, N_2, or fabric mesh-covered pellet which, when propelled against a burning surface, would adhere and release fire extinguishing gaseous material).

4. The development of a prompt fire warning system.

5. Development of a sealant for capsule perforation.

6. The development of methods enabling the prompt detection of solar flares and means of transmitting this information from ground-based stations to spacecraft.

7. For the low earth orbit case,

   (a) determine the effect of low dose rates of $\frac{1}{4}$ rad/day. Are there demonstrable measurable effects? At what energies? — I

   (b) determine the effect of dose protraction at two different low dose rates $\frac{1}{4}$ rad/day to 1 rad/day. Are there demonstrable measurable effects? At what energies? — I

8. For highly elliptical orbits, the establishment and determination of differences in proton and electron response at the expected dose rates. The skin is likely to be the most responsive in this region. What is the depth dose pattern? — I

9. For synchronous orbit, the determination of the response of blood cells to low energy electrons at ~ 3 rad/day. — I

HAZARD PROTECTION (Continued)

	PRIORITY
10. For lunar missions, proton effects in an acute exposure pretty well known or will be from on-going research. Solar flares could be the limiting factor in the LM and/or on surface of the moon.	I
11. Determine where best to measure radiation absorbed dose to detect blood changes.	I

F - CLINICAL MEDICAL SUPPORT AND SAFETY MONITORING

PRIORITY

1. Constant surveillance for more sensitive and more predictive methods to be incorporated into crew selection procedures.

2. Development of infusion, transfusion, and surgical techniques for in-flight use.

G - INERTIAL FORCES

		PRIORITY
1.	Define comfort (various levels of predisposition) and tolerance zones (levels of actual symptoms) to motion sickness using as variables, (1) variations in constant rpm, (2) rate of change in rpm, and, (3) levels of centripetal force. No new R & D requirements.	I-0
2.	Define comfort and tolerance zones for standing and walking under the conditions in 1 (1). No new R & D requirements.	I-0
3.	Define comfort and tolerance zones for Coriolis illusions under conditions in 1 (1). No new R & D requirements.	II-0
4.	Define configurations of living spaces and color coding of same to minimize disturbances (side effects) and maximize proper orientation to spacecraft in terms of direction of rotation and visual up-down. R & D: Ground-based experiments will provide tentative schemes which require validation aloft.	I-0
5.	Determine countermeasures to be taken to prevent or reduce side effects in unexpected situations involving unusual flight modes or illness of astronaut.	II-0
6.	Determine countermeasures to be taken to prevent or reduce side effects incidental to re-entry, EVA or landing on a planet. R & D involves simulation of conditions in terrestrial laboratories and further experimentation aloft.	

SECTION III

SECTION III

INFORMATION REQUIRED OF NASA PHYSICAL SCIENCES
FOR SPACE FLIGHT MEDICAL INVESTIGATION AND SUPPORT

PRIORITY

From the medical and crew support point of view, manned space flight requires measurements of the external space environment as well as internal spacecraft environments extrapolatable to manned space flight vehicles. These measurements are to be obtained for the following cases: I

1. Candidate Low Earth Orbits
2. Candidate Lunar and Planetary Courses
3. Synchronous Orbit
4. Lunar and Planetary Surfaces

Needed for medical investigative in-flight crew support purposes are measurements of:

1. Electromagnetic spectrum to include:
   a. Ionizing radiation (dose, dose rates, quality factors, solar flare data, shielding factors)
   b. Magnetic fields
   c. Visible light, IR and UV
2. Micrometeoroid environment
3. Atmosphere, temperature, surface characteristics, and evidence of life on lunar and planetary targets

A

QUESTIONS TO BE RESOLVED BY SPACE FLIGHT MEDICAL INVESTIGATION (MEDICAL EXPERIMENTS PROGRAM)

Hematology IA

	PRIORITY
11. Are plasma immunoglobulin types and quantities altered by space environment - weightlessness? Answers could be obtained by pre- and post-flight studies.	I-O I-S
12. Does lymphocyte transformation occur normally in space flight? (Pre and post-flight lymphocyte cultures.)	I-O I-S

e. Chromosomes and Cell Cultures

13. Are chromosome numbers and types the same before and after space flight?	II-O I-S
14. Are lymphocyte transformation capabilities the same before and after space flight? Does cell division and replication occur normally in weightlessness?	I-O I-S

KEEP IN - under immune

KEEP IN