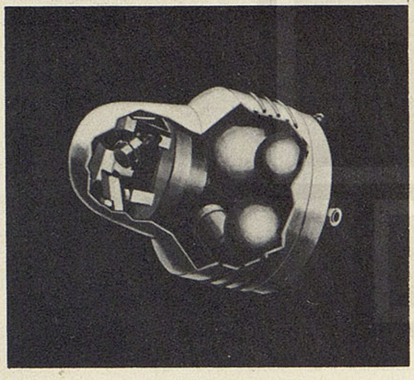
PROGRAM REVIEW DOCUMENT

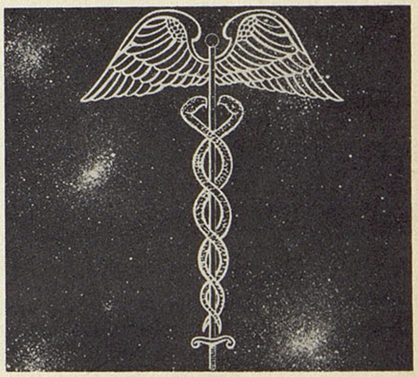
LIFE SCIENCES

BIOSCIENCE



HUMAN FACTORS SYSTEMS

SPACE MEDICINE



MAY 23, 1967

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HEADQUARTERS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROGRAM REVIEW

LIFE SCIENCES

MAY 23, 1967

PRESENTED JOINTLY BY:

- BIOSCIENCE PROGRAMS
  OFFICE OF SPACE SCIENCE AND APPLICATIONS
- BIOTECHNOLOGY AND HUMAN RESEARCH DIVISION
  OFFICE OF ADVANCED RESEARCH AND TECHNOLOGY
- SPACE MEDICINE
  OFFICE OF MANNED SPACE FLIGHT

PUBLISHED BY:

- PROGRAM AND SPECIAL REPORTS
  EXECUTIVE SECRETARIAT

Foreword

NASA Program Reviews are a part of the continuing process of review and evaluation of NASA programs and activities by the Administrator and General Management. These Reviews are scheduled so that each program area is presented at least once a year. Reviews are presented by the responsible Program and Staff Offices. They are designed to present a candid appraisal of substantive program content, management, organization and major trends and problems of General Management concern and interest. An examination is made of program-project objectives and the state of accomplishment.

Presentation material generated for the Reviews comprises an authoritative source of detailed information concerning NASA programs. THIS REPORT IS FOR INTERNAL USE ONLY.

It should be noted that resources information contained in this document represents firm approvals of General Management only for current year plans. Future year projections which are included represent Program Office plans which are subject to General Management approval, and perhaps modification, at such time as appropriations become available to NASA from Congress for the year concerned.

This report is provided for the information of key technical and management personnel of the NASA organization. The privileged nature of the information should be carefully observed.

Robert C. Seamans Jr.

Robert C. Seamans, Jr.
Deputy Administrator

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INTRODUCTION

By Dr. Orr E. Reynolds

The objective of the life sciences programs outlined in Figure 1 are unchanged since the figure was prepared last year.

The organization shown in Figure 2 of our life sciences activity consists primarily of three components, each attached to the principle program offices in NASA.

The concept generating this organization is that life sciences is a cluster of disciplines that relates to various elements of the space program and the life sciences activities are divided in the way in which they can best interact with our program management organization.

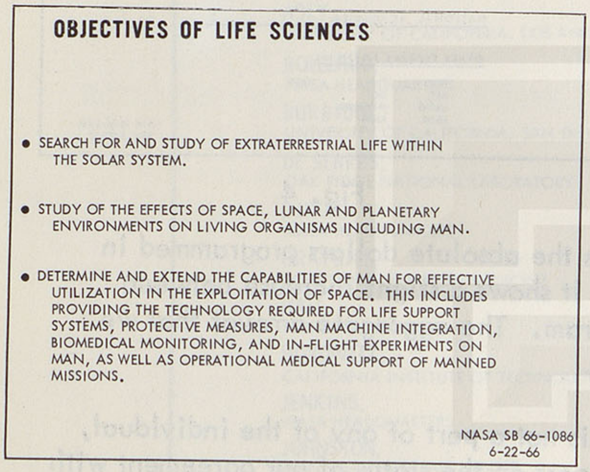

Fig. 1

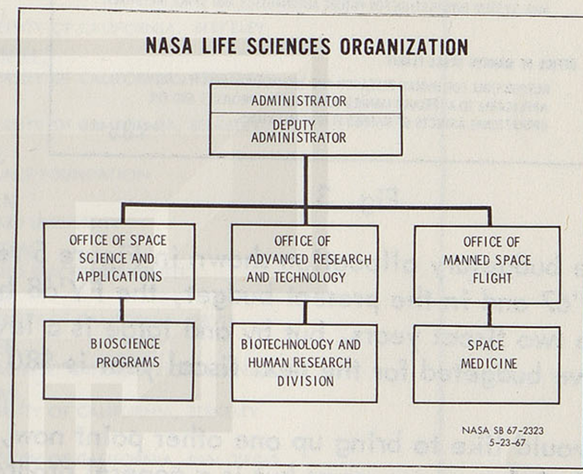

Fig. 2

The Office of Biotechnology and Human Research in the Office of Advanced Research and Technology is responsible for human and animal research, both basic and applied, and the advanced technology related to life support systems and manned system integration.

The Space Medicine Division is responsible for the research and technology applicable to manned space flight projects and the operational aspects of manned missions.

In June 1964 Dr. Seamans established the Life Sciences Director's group to perform the necessary coordination between the life sciences programs, and it is in the role of acting chairman of this group that I am introducing this review.

The following presentations will cover programs in each of the three areas, covering the subject of interrelationships of the life sciences activities to the broader activities of the program offices.

The division of responsibilitites of the three life sciences divisions are shown in Figure 3. Again these are unchanged in the last two or three years. Essentially the bioscience program in the Office of Space Science and Applications is responsible for fundamental biological search in exobiology, environmental biology and behavioral biology, and the development of flight experiments in these programs.

Figure 4 shows the institutional support of Life Sciences activities. The field support constitutes 11 centers including the Jet Propulsion Laboratory and the launch facilities. There are 79 universities involved in these programs working on grants and contracts with life sciences organizational elements, fifty branches of industry, thirty-two nonprofit and other types of research institutes, and many interactions with other federal agencies.

RESPONSIBILITIES

OFFICE OF SPACE SCIENCE & APPLICATIONS-

RESPONSIBLE FOR FUNDAMENTAL BIOLOGICAL RESEARCH INCLUDING THE SEARCH FOR EXTRATERRESTRIAL LIFE (EXOBIOLOGY), ENVIRONMENTAL BIOLOGY AND BEHAVIORAL BIOLOGY; DEVELOPMENT OF FLIGHT EXPERIMENTS RELATED TO THE ABOVE PROGRAMS FOR AUTOMATED AND MANNED FLIGHTS.

OFFICE OF ADVANCED RESEARCH & TECHNOLOGY-

RESPONSIBLE FOR HUMAN AND ANIMAL RESEARCH (BASIC AND APPLIED) ADVANCED TECHNOLOGY OF PROTECTIVE LIFE SUPPORTING SYSTEMS AND MAN SYSTEM INTEGRATION FOR FUTURE AERONAUTICS AND SPACE MISSIONS.

OFFICE OF MANNED SPACE FLIGHT-

RESPONSIBLE FOR HUMAN RESEARCH AND TECHNOLOGY SPECIFICALLY APPLICABLE TO APPROVED MANNED SPACE FLIGHT PROJECTS AND THE OPERATIONAL ASPECTS OF MANNED FLIGHT MISSIONS.

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Fig. 3

LIFE SCIENCES ORGANIZATION AND SUPPORTING INSTITUTIONS

NASA HEADQUARTERS
BIOSCIENCE PROGRAMS, OSSA
BIOTECHNOLOGY AND HUMAN RESEARCH, OART
SPACE MEDICINE, OMSF

NASA CENTERS (ALL)	11
UNIVERSITIES	79
INDUSTRY	50
NON-PROFIT RESEARCH INSTITUTES	32
NATIONAL ACADEMIES	2

OTHER FEDERAL AGENCIES

DOD	FAA	NSF
AEC	DOT	
USPHS	INTERIOR	
USDA	ESSA	

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REV. 5-23-67

Fig. 4

The budgetary allocation shown in Figure 5 represents the absolute dollars programmed in FY'67 and in the present budget, the FY'68 budget. It shows a slight increase between the two fiscal years, but by and large is a level program. The aggregate amount that we have budgeted for the next fiscal year is $80 million.

I would like to bring up one other point now, which is not a part of any of the individual, Life Sciences programs but is a general program to report on the status of our agreement with the Soviet Union on the "Foundations of Space Biology and Medicine."

Figure 6 lists the membership of the Joint Editorial Board established in the agreement between NASA and the Soviet Academy of Sciences. Mr. Webb convened the first meeting of our U. S. Board and we have since been informed of the Soviet Board membership. We have had a number of interchanges by mail and informal visits with the Soviets and have arrived at what we think is an agreement on the details of the chapters and their contents in this work. This has been a longer process than was scheduled. We have already modified our schedule as a result.

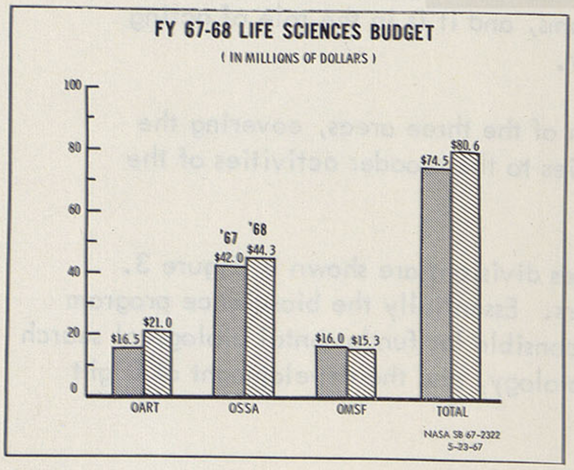

Fig. 5

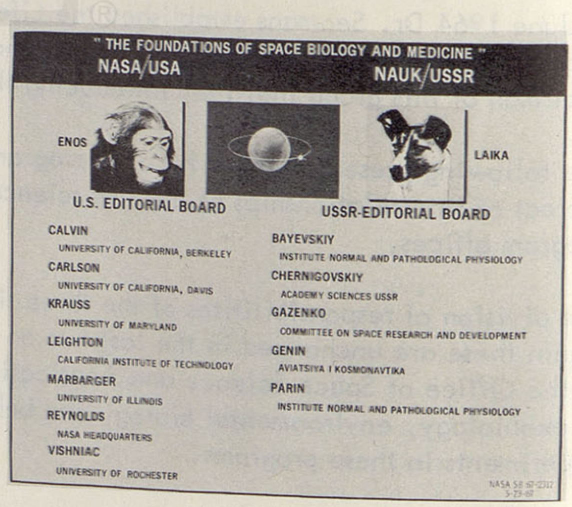

Fig. 6

Figure 7 represents the individuals in the United States who have agreed to be responsible for the chapter of inputs from the U.S. As the figure show, we have an outstanding selection of scientists who will prepare this material.

I might add briefly that it also is intended that the U. S. production for the joint work will not be allowed to disappear from sight by virtue of it being merged with the Soviet material, but these individual chapter contributions will be put out in the form of a U. S. monograph in each area.

AMERICAN COMPILERS FOR THE FOUNDATIONS OF SPACE BIOLOGY AND MEDICINE

ADEY, UNIVERSITY OF CALIFORNIA, LOS ANGELES	PACE, UNIVERSITY OF CALIFORNIA, BERKELEY
BOLLERUD, NASA HEADQUARTERS	PIMENTEL, UNIVERSITY OF CALIFORNIA, BERKELEY
BURBIDGE, UNIVERSITY OF CALIFORNIA, SAN DIEGO	REA, UNIVERSITY OF CALIFORNIA, BERKELEY
DE SERRES, OAK RIDGE NATIONAL LABORATORY	ROTH, LOVELACE FOUNDATION
DIXON, NASA HEADQUARTERS	SAGAN, HARVARD UNIVERSITY
GRAYBIEL, SCHOOL OF AVIATION MEDICINE	SLAYTON, MANNED SPACECRAFT CENTER
HALL, NASA HEADQUARTERS	SMITH, UNIVERSITY OF CALIFORNIA, DAVIS
HOROWITZ, CALIFORNIA INSTITUTE OF TECHNOLOGY	TEUBER, MASSACHUSETTS INSTITUTE OF TECHNOLOGY
JENKINS, NASA HEADQUARTERS	TOBIAS, UNIVERSITY OF CALIFORNIA, BERKELEY
JOHNSTON, MANNED SPACECRAFT CENTER	UREY, UNIVERSITY OF CALIFORNIA, SAN DIEGO
LAWTON, GENERAL ELECTRIC COMPANY	VAN ALLEN, STATE UNIVERSITY OF IOWA
	WELLS, NORTH AMERICAN AVIATION

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Fig. 7

Figure 8 shows the schedule that we now have, having had certain delays in scheduled deliveries by the Soviets on the outline.

We have completed the first two of these actions. The exchange of glossaries, which was suggested by the Soviets, and the exchange of our compiler list. The Soviets have not complied with either of these dates as yet. We look forward to this as a schedule for the rest of the activity, completing the editorial and writing activities on 1 March 1969.

SCHEDULE FOR THE FOUNDATIONS OF SPACE BIOLOGY AND MEDICINE

• EXCHANGE OF GLOSSARIES	15 NOVEMBER 1966 ✓
• EXCHANGE OF COMPILER LISTS	1 APRIL 1967 ✓
• RECEIPT OF COMPILERS' MATERIAL BY NATIONAL BOARDS	1 DECEMBER 1967
• TRANSMISSION OF COMPILATIONS BETWEEN BOARDS AND TO WORLD DATA CENTER	1 MARCH 1968
• MEETING OF BOARD TO SELECT AUTHORS	30 JUNE 1968
• SUBMISSION OF FINISHED MANUSCRIPTS	1 JANUARY 1969
• EDITORIAL AND WRITING CONCLUSIONS COMPLETED	1 MARCH 1969

✓ ACTION COMPLETED

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5-23-67

Fig. 8

BIOSCIENCE PROGRAMS

OBJECTIVES, MANAGEMENT AND SPACE BIOLOGY

By: Dr. Dale W. Jenkins

I will discuss the areas of management, resources, and space biology. (Figure 1) Dr. Richard Young will talk on planetary biology and Mr. Lawrence Hall will deal with spacecraft sterilization and quarantine.

The objectives of our program in bioscience shown in Figure 2 are to determine the effects of the space environment on living Earth organisms, search for and study of extraterrestrial life, and to carry out research in support of and protection for man in extended manned missions.

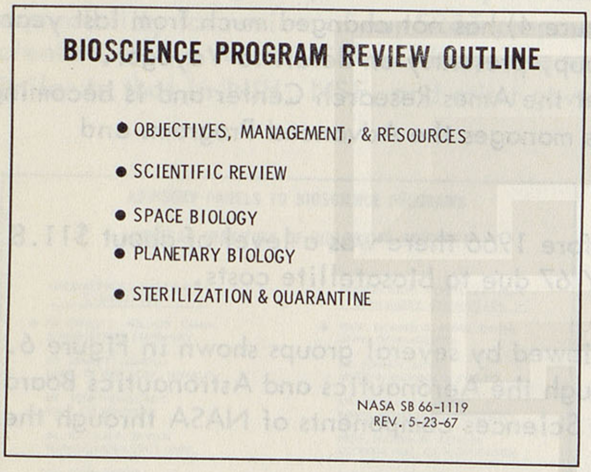

Fig. 1

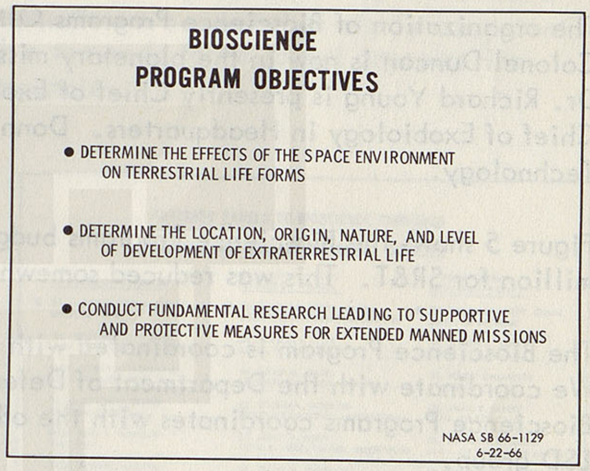

Fig. 2

The places where we carry out this research are shown in Figure 3. All of the R&D is carried out on Earth and involves chemical evolution, origin of life, developing instrumentation for the search for life, analyses for sample return, and studying the biological effects of environment on life. Study of effects of weightlessness is being done in Earth orbit in the biosatellite program. We are considering a follow-on biosatellite program, biological experiments in the Apollo Applications Program, and in the manned space station.

We are very interested in Apollo lunar sample return and samples from the follow-on Apollo applications, especially Voyager missions in the search for extraterrestrial life on the planets.

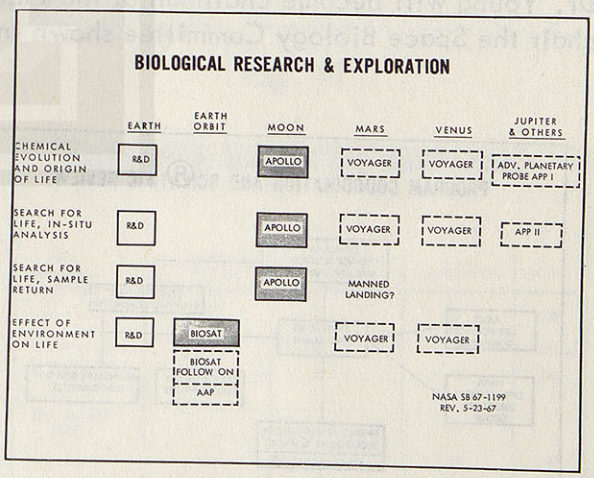

Fig. 3

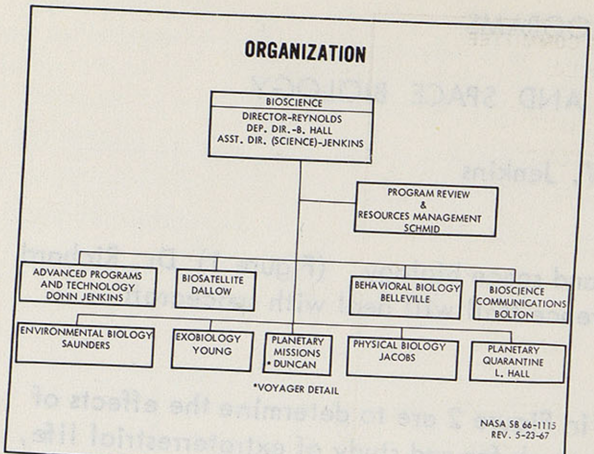

Fig. 4

BIOSCIENCE PROGRAMS BUDGET
(IN MILLIONS OF DOLLARS)

	FY 66	FY 67	FY 68
SUPPORTING RESEARCH & TECHNOLOGY	$10.1	$10.2	$11.8
BIOSATELLITE PROGRAM	23.3	30.0	30.0
PLANETARY QUARANTINE	1.0	1.3	2.5
APOLLO LUNAR SAMPLE ANALYSIS	1.1	1.2	2.5
AAP - SR&T	--	--	1.6
AAP - BIO A	1.7	--	3.0
TOTAL	$37.2	$42.7	$51.4

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5-23-67

Fig. 5

The organization of Bioscience Programs Office (Figure 4) has not changed much from last year. Colonel Duncan is now in the planetary missions group, presently on detail to Voyager. Dr. Richard Young is presently Chief of Exobilogy at the Ames Research Center and is becoming Chief of Exobiology in Headquarters. Donn Jenkins manages the Advanced Programs and Technology.

Figure 5 shows the Bioscience Programs budget. Before 1966 there was a level of about $11.8 million for SR&T. This was reduced somewhat in FY 67 due to biosatellite costs.

The Bioscience Program is coordinated with and reviewed by several groups shown in Figure 6. We coordinate with the Department of Defense through the Aeronautics and Astronautics Board. Bioscience Programs coordinates with the other Life Sciences components of NASA through the LSD group.

A new Planetary Mission Board acts in an advisory capacity. Under the Space Science Steering Committee we have the Space Biology Subcommittee and Planetary Biology Subcommittee. Dr. Young will become chairman of the Planetary Biology Subcommittee (Figure 7) in July and I chair the Space Biology Committee shown in Figure 8.

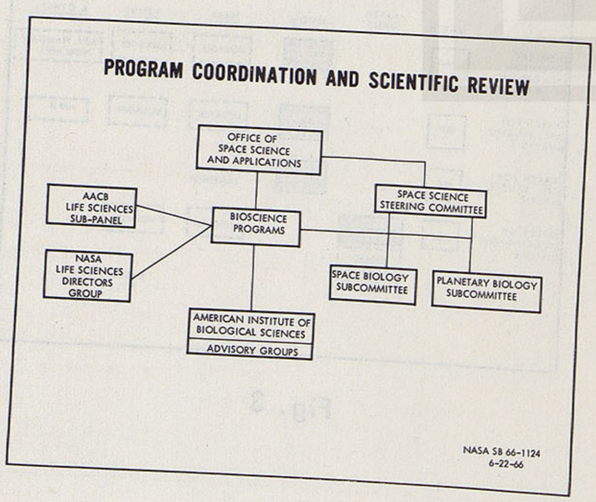

Fig. 6

SPACE SCIENCE STEERING COMMITTEE

PLANETARY BIOLOGY SUBCOMMITTEE

CHAIRMAN -------- DR. ORR E. REYNOLDS, NASA HEADQUARTERS

VICE CHAIRMAN ------ COL. GEORGE H. DUNCAN, NASA HEADQUARTERS

SECRETARY -------- MRS. VIRGINIA M. BOLTON, NASA HEADQUARTERS

MEMBERS

DR. DONALD M. ALLISON, NASA HEADQUARTERS
DR. KIMBALL C. ATWOOD, UNIV. OF ILLINOIS
MR. MELVIN CALVIN, UNIV. OF CALIF., BERKELEY
DR. ELLIOTT C. LEVINTHAL, STANFORD UNIV.
DR. HAROLD MOROWITZ, YALE UNIV.
DR. COLIN S. PITTENDRIGH, PRINCETON UNIV.
DR. CARL SAGAN, HARVARD UNIV.
DR. GERALD SOFFEN, JET PROPULSION LABORATORY
MR. WILLIAM G. STROUD, GODDARD SPACE FLIGHT CENTER
DR. WALF VISHNIAC, UNIV. OF ROCHESTER
DR. ABEL WOLMAN, THE JOHNS HOPKINS UNIV.
DR. RICHARD S. YOUNG, AMES RESEARCH CENTER

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6-22-66

Fig. 7

SPACE SCIENCE STEERING COMMITTEE

SPACE BIOLOGY SUBCOMMITTEE

CHAIRMAN - - - - - - - - - DR. DALE W. JENKINS, NASA HEADQUARTERS

VICE CHAIRMAN - - - - - - - DR. RICHARD E. BELLEVILLE, NASA HEADQUARTERS

SECRETARY - - - - - - - - - DR. JOSEPH F. SAUNDERS, NASA HEADQUARTERS

MEMBERS

DR. JOHN BILLINGHAM, AMES RESEARCH CENTER
DR. LOREN D. CARLSON, UNIV. OF KENTUCKY
DR. JOHN D. FRENCH, UNIV. OF CALIF., LOS ANGELES
DR. SOLON GORDON, ARGONNE NATIONAL LABORATORY
DR. HAROLD O. KRUGER, JET PROPULSION LABORATORY
DR. ALLAN H. BROWN, UNIV. OF PENNSYLVANIA
DR. SIDNEY GALLER, SMITHSONIAN INSTITUTION
DR. JOHN W. HASTINGS, UNIV. OF ILLINOIS
DR. GERALD MCDONNEL, UNIV. OF CALIF., LOS ANGELES
DR. NELLO PACE, UNIV. OF CALIF., BERKELEY
COL. A. G. SWAN, BROOKS AIR FORCE BASE
DR. HANS-LUKAS TEUBER, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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6-22-66

Fig. 8

We have something unique in NASA, advisory panels shown in Figures 9 and 10, which have responsibility for review of our SR&T proposals. The panels are composed of highly competent scientists in the various fields. These are set up with a tenured, formal panel organization similar to that in NIH, NSF, and other government agencies.

ADVISORY PANELS TO BIOSCIENCE PROGRAMS
AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES

THEORETICAL BIOLOGY COMMITTEE

- DR. ERNEST C. POLLARD, CHMN., PENNSYLVANIA STATE UNIV.
- DR. JAMES F. DANIELLI, UNIV. OF NEW YORK, BUFFALO
- DR. JOSEPH ENGLEBERG, UNIV. OF KENTUCKY
- DR. WILLIAM D. TAYLOR, PENNSYLVANIA STATE UNIV.
- DR. JOHN GREGG, DUKE UNIV.
- DR. HAROLD J. MOROWITZ, YALE UNIV.

LIAISON
DR. JOHN R. TOTTER, ATOMIC ENERGY COMMISSION

SPACECRAFT STERILIZATION ADVISORY COMMITTEE

- PROF. RICHARD G. BOND, CHMN., UNIV. OF MINNESOTA
- DR. JOHN H. BREWER, BECTON, DICKINSON AND CO.
- MR. MARK A. CHATIGNY, NAVAL BIOLOGICAL LABORATORY
- PROF. THOMAS W. KETHLEY, GEORGIA INST. OF TECHNOLOGY
- PROF. IRVING J. PFLUG, MICHIGAN STATE UNIV.
- DR. JOHN A. ULRICH, MAYO CLINIC
- DR. WILLIAM G. WALTER, MONTANA STATE UNIV.

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6-22-66

Fig. 9

ADVISORY PANELS TO BIOSCIENCE PROGRAMS
AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES

EXOBIOLOGY PANEL

- DR. J. ROGER PORTER, CHMN., UNIV. OF IOWA
- DR. PRESTON E. CLOUD, JR., UNIV. OF CALIF., LOS ANGELES
- PROF. ROBERT C. ELDERFIELD, UNIV. OF MICHIGAN
- DR. CARLETON B. MOORE, ARIZONA STATE UNIV.
- PROF. KARL K. TUREKIAN, YALE UNIV.
- PROF. PERRY W. WILSON, UNIV. OF WISCONSIN
- DR. J. R. VALLENTYNE, CORNELL UNIV.

ENVIRONMENTAL BIOLOGY PANEL

- DR. AUSTIN M. BRUES, CHMN., ARGONNE NATIONAL LABORATORY
- DR. CHARLES D. COX, UNIV. OF MASSACHUSETTS
- DR. DAVID M. GATES, MISSOURI BOTANICAL GARDEN
- DR. SOLON A. GORDON, ARGONNE NATIONAL LABORATORY
- DR. JAMES D. HARDY, JOHN B. PIERCE FOUND. LABORATORY
- DR. FRANK H. JOHNSON, PRINCETON UNIV.
- DR. PETER MAZUR, OAK RIDGE NATIONAL LABORATORY
- DR. C. LADD PROSSER, UNIV. OF ILLINOIS
- DR. C. HERBERT WARD, RICE UNIV.

BEHAVIORAL BIOLOGY PANEL

- DR. WILLIAM D. NEFF, CHMN., UNIV. OF INDIANA
- DR. JOSEPH V. BRADY, UNIV. OF MARYLAND
- DR. ROBERT GALAMBOS, YALE UNIV.
- DR. JAMES P. HENRY, UNIV. OF SO. CALIF.
- DR. THEODORE L. JAHN., UNIV. OF CALIF., LOS ANGELES
- DR. DONALD LINDSLEY, UNIV. OF CALIF., LOS ANGELES

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6-22-66

Fig. 10

These panels have been in operation about a year and a half. They have reviewed a total of 267 proposals shown in Figure 11, of which 203 are new proposals. Out of these, they have listed 87 as being of high scientific merit (ratings from 1.0 to 2.5).

Due to budgetary restrictions, we have been able to fund only 11 proposals, and the program chiefs wish to fund 48 additional proposal with the highest scientific merit and program relevance.

SR&T PROPOSAL REVIEW BY AIBS ADVISORY PANELS

NO. PROPOSALS	BEHAVIORAL BIOLOGY	ENVIRONMENTAL BIOLOGY	EXOBIOLOGY	TOTAL
NEW	68	78	57	203
RENEWAL	22	20	22	64
TOTAL	90	98	79	267
AVE. RATINGS (NEW)				
1.0 - 2.5	27	34	26	87
2.5 - 5.0	37	37	30	104

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Fig. 11

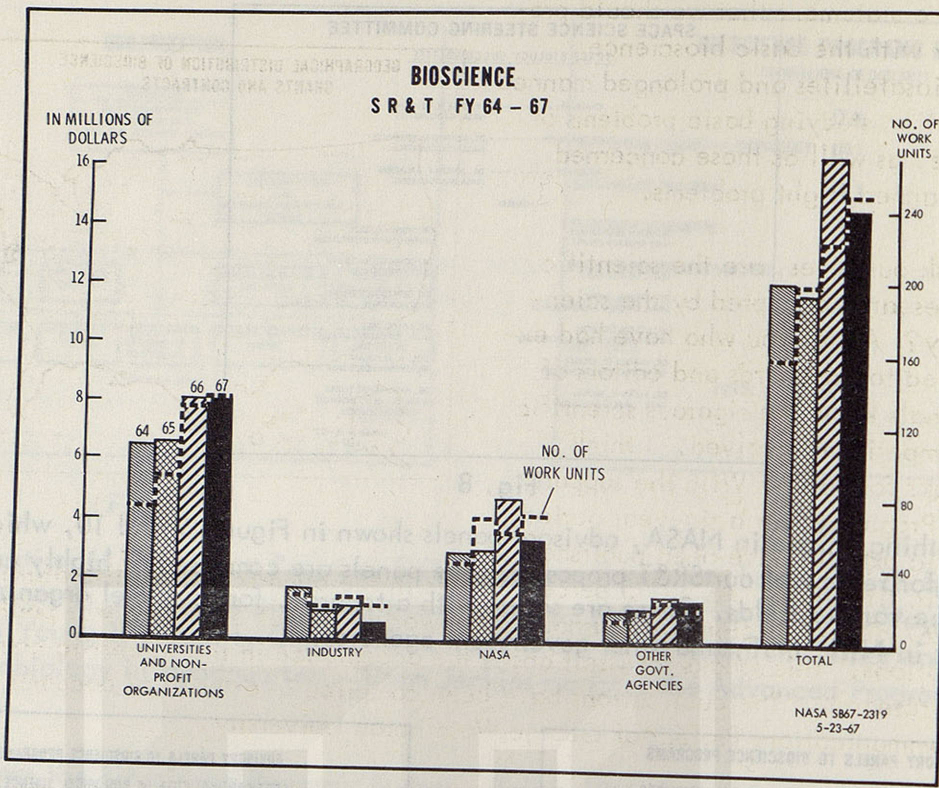

Fig. 12

A summary of the Bioscience Program SR&T support is shown in Figure 12. This year we have approximately $14 million requested. Last year there was about $16 million. This includes not only our 11.8 SR&T but also the SR&T aspects of the AAP and sterilization programs which come under those line items. We supported about 225 different work units or research tasks in this last year. In the first year (1962) there were only about 160. In this fiscal year we have 250 work units. With only a small increase in budget, this means that the average cost per grant or contract is decreasing. With so many areas to cover we can't fund in as large amounts as we desire. Universities are carrying out about half of the research program. About a quarter of the research is in NASA centers, and the rest in industry and non-profit research institutes, and in other government agencies.

The distribution of our research grants and contracts over the United States is shown in Figure 13. The large number in California is due to about half of these being carried out in the Ames Research Center and JPL.

We can ask at this point after five or six years of operation, is this scientific program accepted by the scientific community? Are we in accord with the recommendations of the outside scientists? I think this is well illustrated by the PSAC report which states there is central agreement with the National Academy of Sciences, Space Sciences Board, that the most challenging scientific goal (Figure 14) is the search for extraterrestrial life. This was No. 1 of three major goals stated in the PSAC report.

They also made a statement that we should proceed vigorously with the basic bioscience programs and biosatellites and prolonged manned flight investigation studying basic problems of scientific value, as well as those concerned with applied manned flight problems.

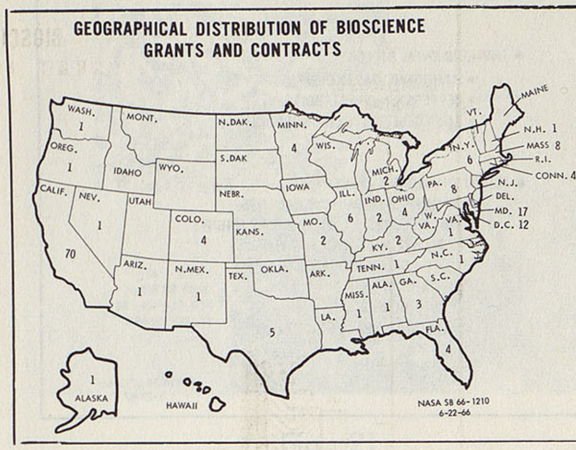

Fig. 13

We can also ask ourselves, are the scientific results of our research accepted by the scientific community? All of you who have had experience with editorial boards and editors of scientific journals know the rigorous scientific review and competition involved. I think Figure 15 speaks for itself. With the support of Bioscience Programs over a six-year period, 1,894 scientific articles have been published in the scientific literature. About 95 percent of this in the open scientific literature published in a total of 267 different scientific journals in the world. About 5 percent was published in NASA publications. This speaks for itself about the acceptance in the scientific community of our scientific research. The publications have been compiled in a series of documents by the Bioscience Communications Project of George Washington University.

PSAC REPORT-1967

IN ESSENTIAL AGREEMENT WITH THE NATIONAL ACADEMY OF SCIENCE A MOST CHALLENGING SCIENTIFIC GOAL IS: "DOES LIFE ABIDE IN PLACES OTHER THAN THE EARTH, AND IF SO, WHAT IS ITS NATURE, HOW DID IT EVOLVE AND WHAT ARE ITS PROBABLE FORMS ELSEWHERE?"

"NASA SHOULD PROCEED VIGOROUSLY WITH BASIC BIOSCIENCE PROGRAMS IN BIOSATELLITES AND IN PROLONGED MANNED FLIGHTS WITH VEHICLES SUITED TO CARE OF ANIMALS AND SIMPLE LIVING FORMS. IN ADDITION TO ITS FUNDAMENTAL VALUE, THIS INFORMATION COULD BE IMPORTANT TO OUR UNDERSTANDING AND SOLUTION OF PROBLEMS OF MANNED FLIGHT."

NASA SB 67-2449
5-23-67

Fig. 14

SCIENTIFIC PUBLICATIONS- BIOSCIENCE PROGRAMS

	UNIVERSITIES & INDUSTRY	NASA CENTERS & HQ.	TOTAL
1960-61 -	29	4	33
1962 -	56	20	76
1963 -	147	42	189
1964 -	269	86	355
1965 -	408	150	558
1966 -	382	160	542
1967 -	141 +	?	141 +
	1,432	462	1,894

1,894 SCIENTIFIC PUBLICATIONS PUBLISHED IN 267 DIFFERENT SCIENTIFIC JOURNALS

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5-23-67

Fig. 15

SPACE BIOLOGY

I would like to discuss our Space Biology program (Figure 16) and give some examples of the type of work being carried out, and then review our flight missions.

In the study of environmental extremes, we go to various exotic habitats to find organisms. In dry valleys of the Antarctic living organisms were collected, both at the surface and in the permafrost ice, by members of the JPL staff to carry out studies in the laboratory. Enviornmental measurements were made.

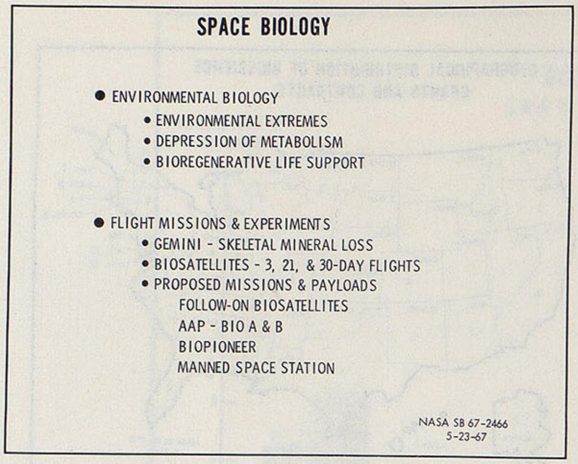

Fig. 16

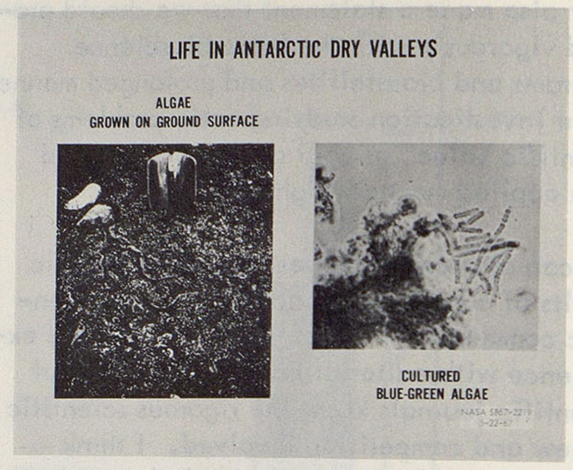

Fig. 17

Fig. 18

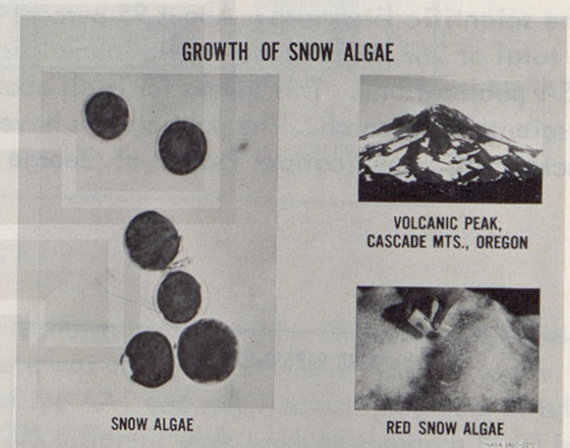

Fig. 19

Algae that grow on the surface of soil in the Antarctic in dry valleys are shown in Figure 17. Bacteria and molds shown in Figure 18 have been obtained from the surface. Even at nearly two feet down in the permafrost ice, bacteria were isolated and grown.

We are also studying desert organisms and those from mountain tops and snow tundra. Snow algae are shown in Figure 19. They occur in snow on high mountains. These red algae are being cultivated in the laboratory.

In addition to studying the growth of organisms at unusual temperatures and in various atmospheres and chemicals, we are also interested in study of the effects of physical factors. For example, in the Earth's magnetic field, which is about one half gauss (50,000 gamma), we get what we consider normal growth. But if we put these organisms in a mu metal container and cut the magnetic field down to about 30 gamma, we get increased growth (shown in Figure 20). We can't explain it, but it has been observed.

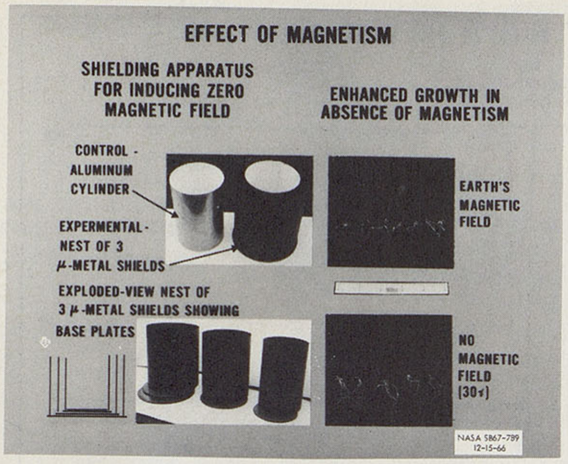

Fig. 20

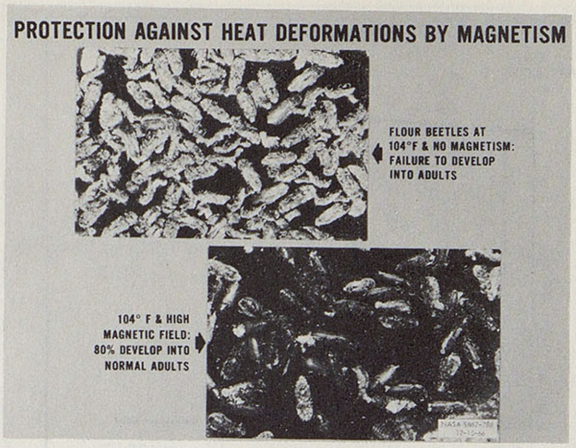

Fig. 21

Last year I mentioned that we have shown that magnetism also protects against X-radiation. It has been found by one of the grantees that flour beetles at 104°F with a normal magnetic field did not develop from larvae to adults, as shown in Figure 21. But with a high magnetic field of several thousand gauss, 80 percent developed into normal adults and reproduced.

The Russians reported a few years ago, after they had flown several experiments with Tradescantia microspores, that weightlessness apparently caused spherical chromosomes to develop, which was curious since it had never been observed before. In our baseline studies on the biosatellite experiments to determine the effect of space flight factors such as acceleration and vibration, we were able to produce (Figure 22) these same spherical fragments of chromosomes by vibration. The Russians also found this in their ground based studies and ascribed it to vibration. This shows the importance or necessity of carrying out very detailed and accurate base line studies before flying space biological experiments.

In the area of bioregenerative life support systems using the bacterial-electrolysis system I mentioned last year that it took about 20 to 22 liters of hydrogenomonas bacteria combined with the electrolysis process to support one astronaut. Recent studies now have shown that it takes about 14 liters by careful control of the acidity and other factors, both in batch fermenters and in continuous culture (Figure 23).

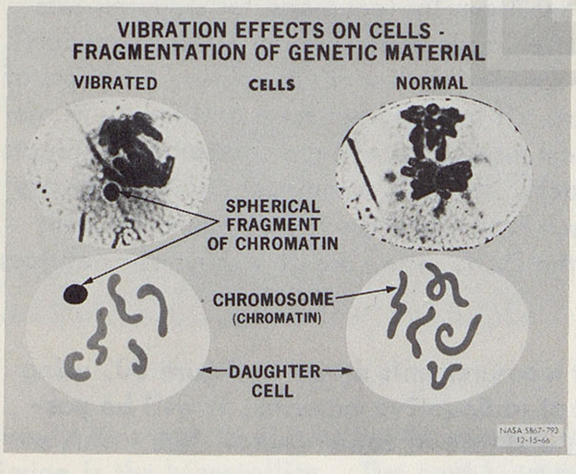

Fig. 22

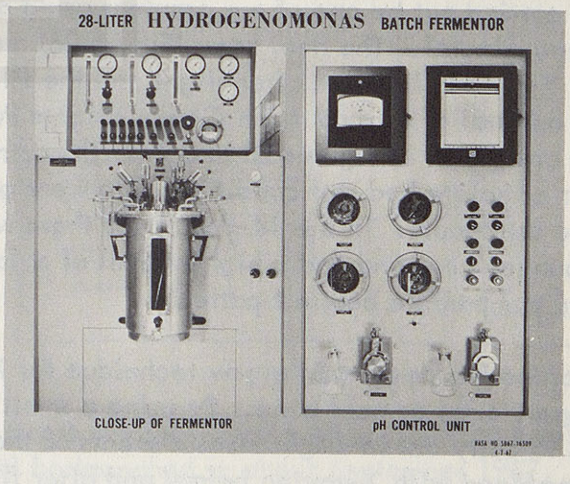

Fig. 23

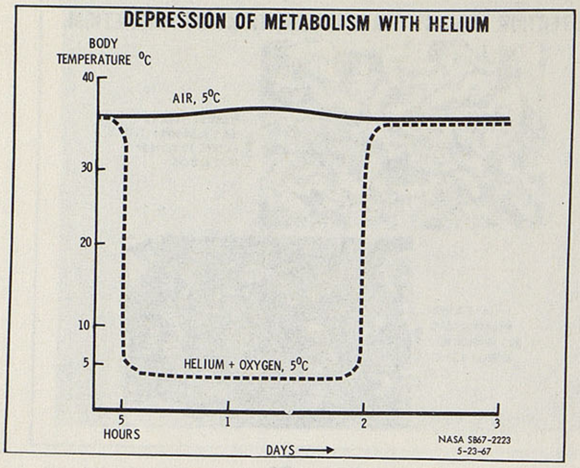

Fig. 24

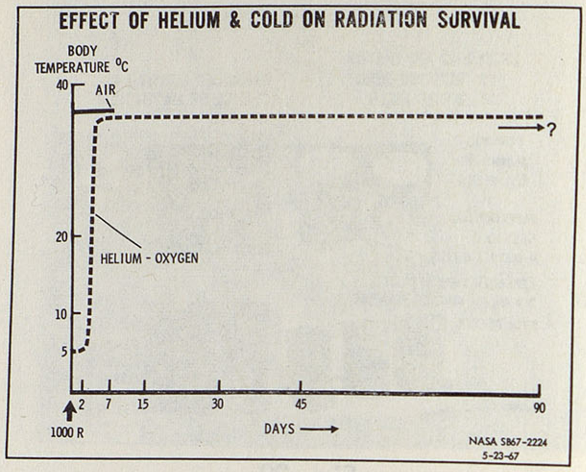

Fig. 25

There has been much progress in this area. The developmental and production aspects of this program have been turned over to OART for scale-up and pilot plant development.

We are interested in decreasing metabolism for possible use in case of emergency in long term manned space flight. An extremely interesting finding by one of our grantees is that if you expose certain animals such as hamsters to 20 percent oxygen and 80 percent nitrogen, at five degrees C there is practically no change. But if you substitute helium in place of the nitrogen (Figure 24), the animal goes into a state of hypothermia or hibernation, the temperature drops to 5°C and it will remain at this temperature for two or three days. By increasing to room temperature, we bring the animals out of this hibernation and back to normal.

A potential scientific breakthrough has resulted from this with regard to radiation protection. If the hamster is exposed when it is in normal air to 1,000 roentgen of radiation as shown in Figure 25, the animals die in five to seven days. If the animals are exposed during hibernation in an atmosphere of helium in place of nitrogen at 5°C and then warmed up after a couple of days, over 50 percent of them live 90 days or more. This cannot yet be extrapolated to humans since this experiment hasn't been tried yet.

In cooperation with the Space Medicine Division and with the Manned Spacecraft Center, studies were carried out by one of our grantees using an Xray densitometry technique for studying loss of bone mineral. The heel bone (Figure 26) and the little finger bone (Figure 27) of astronauts were Xrayed before and after flight and the films were scanned with a densitometer. The loss of bone mineral of astronauts on Gemini flights IV, V, and VII for the heel bone and for the finger bone are shown in Figures 28 and 29. The astronauts lost more mineral than comparable subjects under complete bed rest conditions who were given exactly the same amount of calcium per day as the astronauts. In the 14-day flight there was less mineral loss. These men exercised with the bungee cord and had a higher level of calcium in the food. They did now show as much loss as the comparable bed rest patients.

A grantee has developed a new technique for in-flight measurements shown in Figure 30, using a finger, arm, or heel bone. By using a small amount of radioactive material, it will be possible to carry out in-flight measurements of the amount and rate of bone mineral loss. This can be combined with X-raying before and after flight missions.

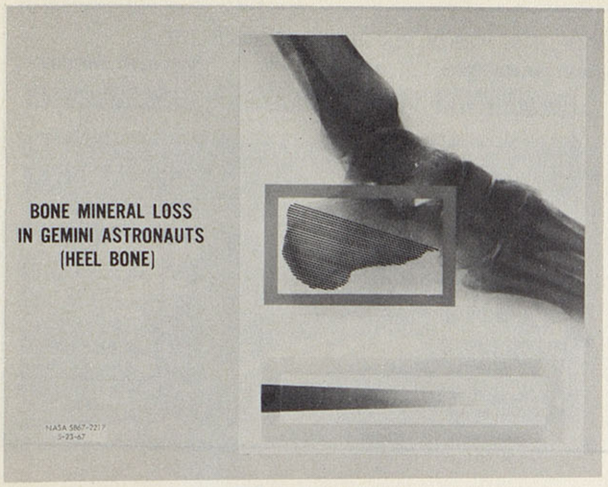

Fig. 26

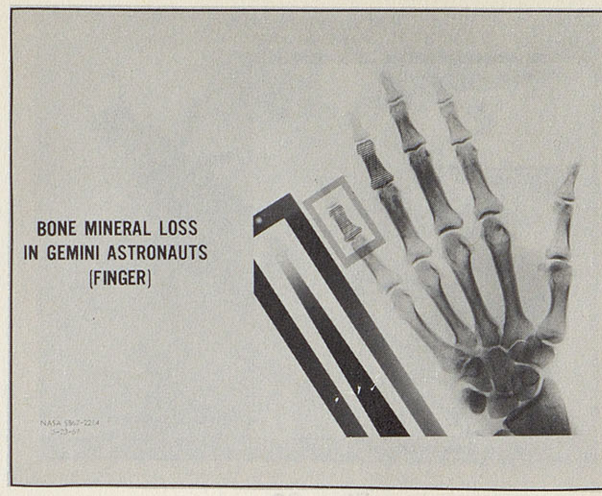

Fig. 27

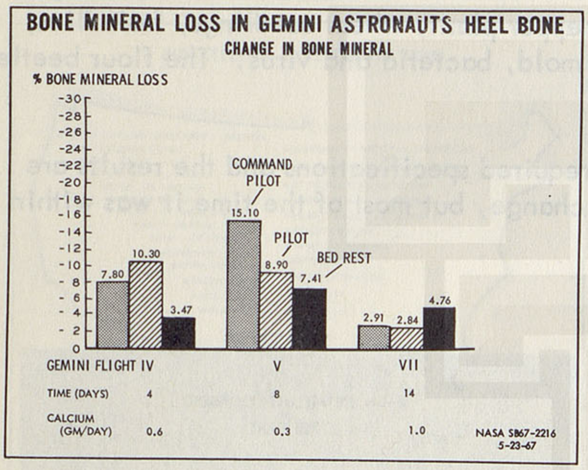

Fig. 28

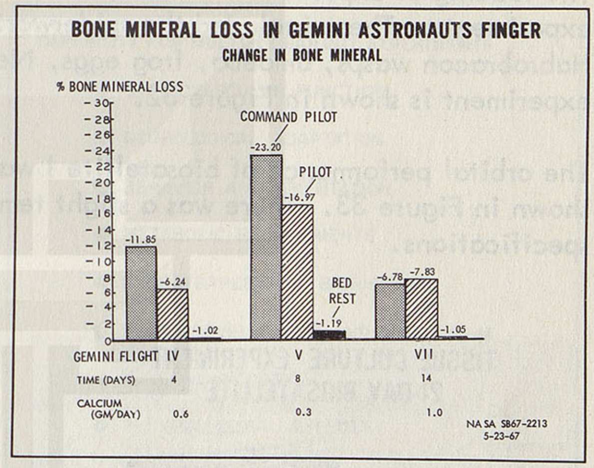

Fig. 29

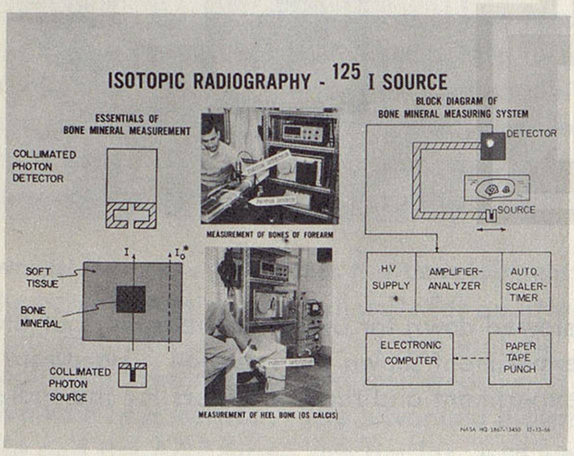

Fig. 30

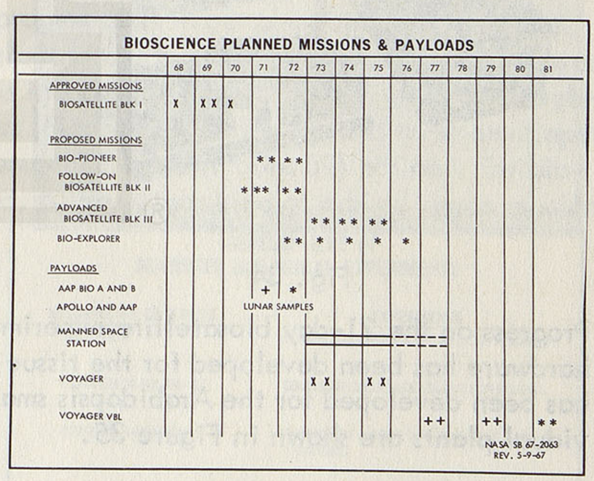

Fig. 31

I would like now to discuss the Bioscience Programs flight missions (Figure 31). The first orbital mission is the biosatellite. The next biosatellite will be launched in about September 1967.

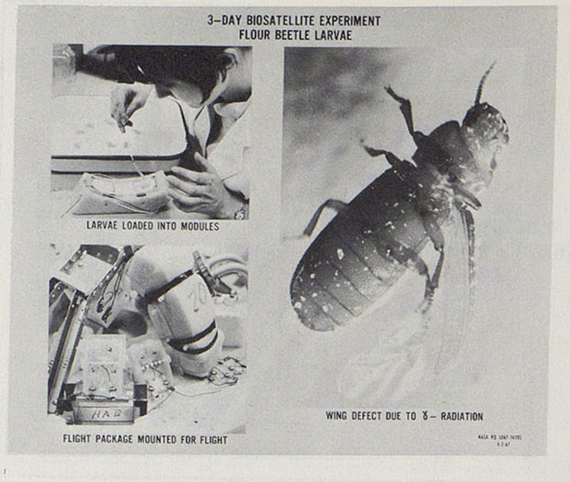

Fig. 32

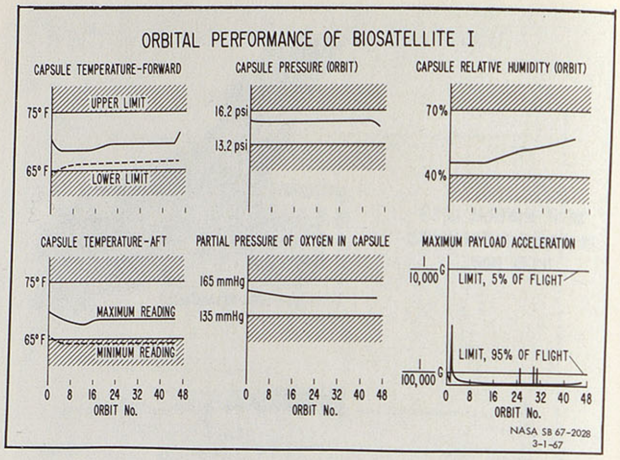

Fig. 33

The loading of experiments was done a few hours before launch. There were thirteen biological experiments. These included the spiderwort plant, pepper plant, wheat seedlings, fruit flies, Habrobracon wasps, amoeba, frog eggs, Neurospora mold, bacteria and virus. The flour beetle experiment is shown in Figure 32.

The orbital performance of biosatellite I was within required specifications and the results are shown in Figure 33. There was a slight temperature change, but most of the time it was within specifications.

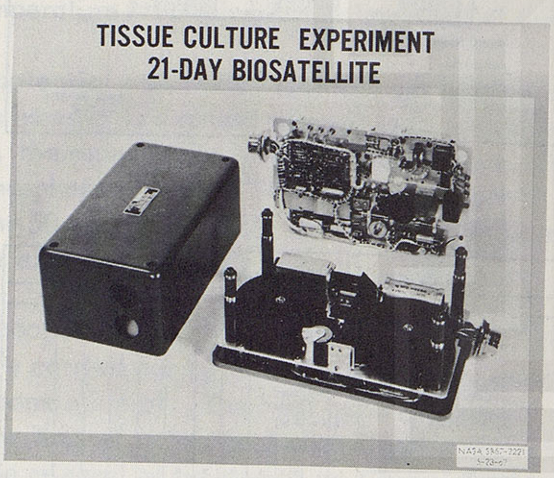

Fig. 34

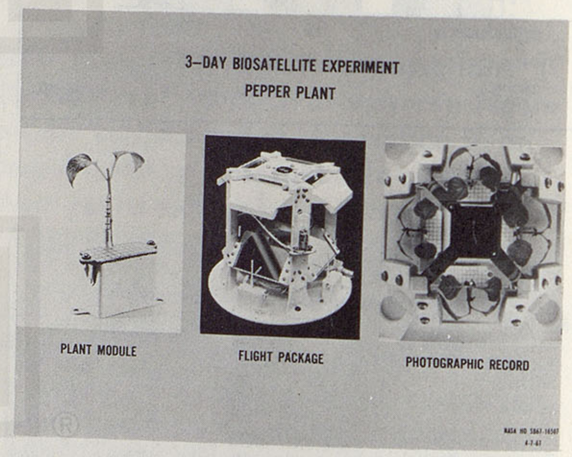

Fig. 35

Progress on the 21-day biosatellite experiments has slowed down for budgetary reasons, but the hardware has been developed for the tissue culture experiment shown in Figure 34. Hardware has been developed for the Arabidopsis small plant experiment and the containers for the individual plants are shown in Figure 35.

The primate experiment for the 30-day Biosatellite is progressing well. This flight will follow the 3-day flight. The primate couch which has been further developed in cooperation with the Air Force, shown in Figure 36, stores heparin and other materials for the cardiovascular experiment. Figure 37 shows the final model of the automated urine analyzer which we discussed last year.

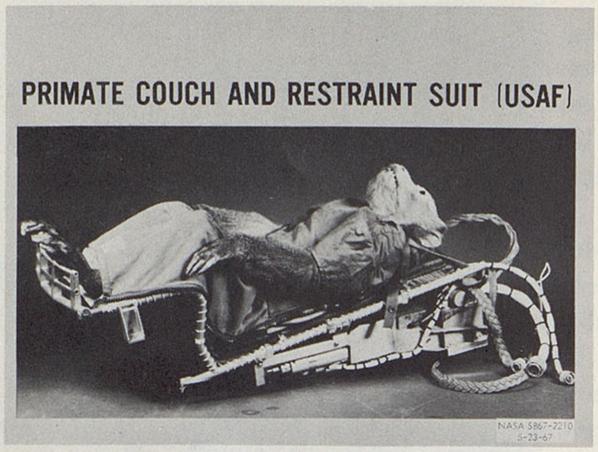

Fig. 36

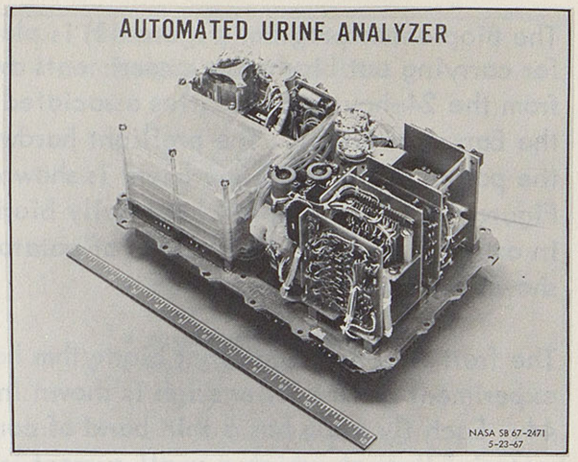

Fig. 37

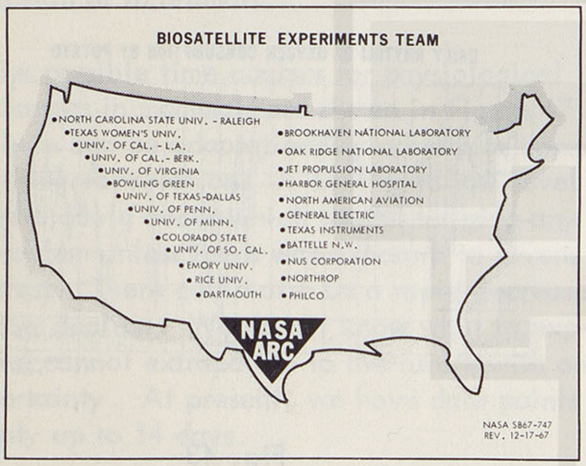

Fig. 38

CAPABILITY FOR MULTIPLE BIOLOGY EXPERIMENTS

- CARDIOVASCULAR FUNCTION
- NEUROLOGICAL ADAPTATION
- BEHAVIOR AND ORIENTATION
- METABOLIC REQUIREMENTS
- EXTRATERRESTRIAL BIORHYTHMS
- PLANT DEVELOPMENT AND GEOTROPISM
- GENERAL BIOLOGY
- RADIOBIOLOGICAL EFFECTS

NASA SB67-746
12-1-66

Fig. 39

One of the real accomplishments in the Biosatellite program was to get a group of outstanding scientists from universities to cooperate fully in developing the technological aspects of hardware development. The experimenters worked with various industrial groups and with NASA management from the Ames Research Center and Headquarters (Figure 38). These groups have developed a real capability for carrying out experiments in a number of areas (Figure 39) not only for biosatellites but also for AAP, for advanced biosatellites, or any other kind of orbital space mission.

I would like now to discuss the development of advanced biological experiments for additional flight programs (Figure 40). These include biopioneer, the biosatellite follow-on, and the advanced biosatellite. The advanced Biosatellite and the AAP Bio-A are similar, and we are now studying tradeoffs to determine which program would be the best to carry out the proposed primate experiments.

DEVELOPMENT OF ADVANCED BIOLOGICAL EXPERIMENTS

MISSIONS OR PAYLOADS	EXPERIMENTS
BIOPIONEER	BIORHYTHMS OUTSIDE OF EARTH ENVIRONMENT
BIOSATELLITE FOLLOW-ON	CONTINUATION OF BIOSATELLITE EXPERIMENTS
ADVANCED BIOSATELLITE	PHYSIOLOGY & BEHAVIOR OF PRIMATES AND RODENTS
AAP BIO A	PHYSIOLOGY & BEHAVIOR OF PRIMATES AND RODENTS
AAP BIO B	ANIMAL, PLANT, & CELLULAR BIOLOGY
MANNED SPACE STATION	ADVANCED & LONG DURATION BIOLOGICAL EXPERIMENTS

NASA SB 67-2468
5-23-67

Fig. 40

The Biopioneer program (Figure 41) is planned for carrying out biorhythm experiments away from the 24-hour periodicities associated with the Earth's rotation. The preflight hardware for the potato biorhythm experiment is shown in Figure 42. An example of the daily biorhythms in oxygen uptake of small cores of potatoes is shown in Figure 43.

The fruit fly or vinegar gnat biorhythm hatching experiment of Dr. Pittendrigh is shown in Figure 44. Each fly pupa has a thin band of conducting material through which a small current is passed.

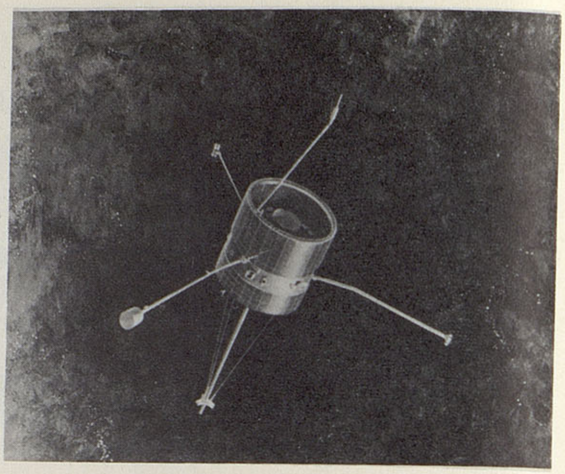

Fig. 41

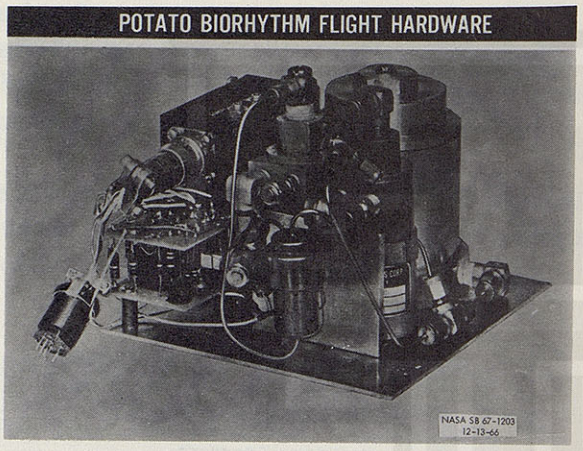

Fig. 42

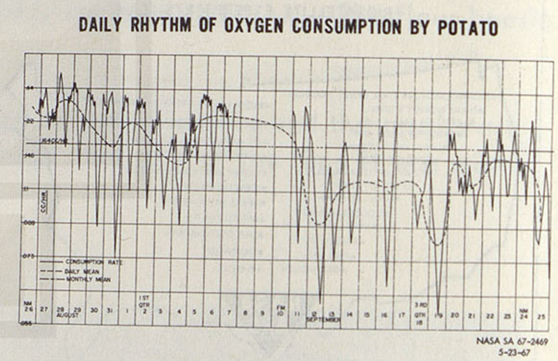

Fig. 43

When it hatches this is interrupted and is automatically counted. A fruit fly is shown in Figure 45 emerging from one of the pupae.

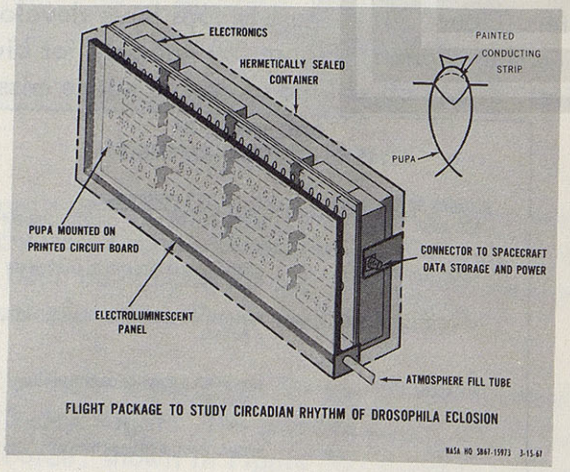

Fig. 44

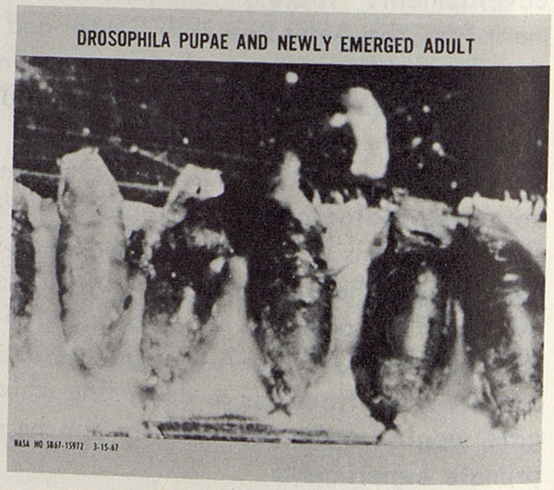

Fig. 45

The physiological and behavioral changes which have been reported in man during weightlessness are summarized in Figure 46. These include loss of bone mineral, muscle mass, blood volume, red blood cell mass, reduced blood plasma, change in albumin, orthostatic hypotension, elevated heart rate, disturbed sleep-wakefulness, and disorientation. These have not been observed or reported in all of the astronauts. In fact, some specific ones have been reported only in certain cosmonauts or astronauts. We don't know too much about what is happening because flight experiments with valid base line studies including carefully controlled experiments, have not yet been studied in flight in man or in animals.

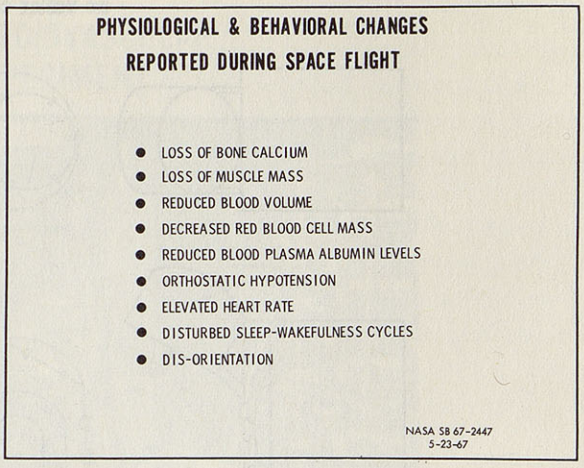

Fig. 46

The possible time courses for physiological changes in mammals are shown in Figure 47. There can be adaptation with return to normal, or over-adaptation. A continued low level state could occur which would not give any problem unless there was exposure to severe stress. There could also be a rapid decrease or slow decline. We do not know what to expect and cannot extrapolate to the future with any certainty. At present, we have data points only up to 14 days.

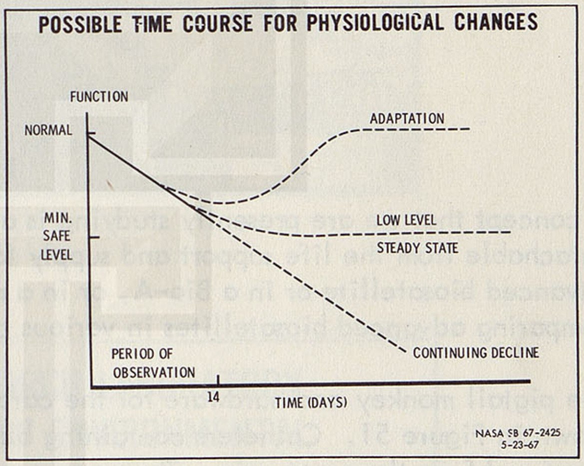

Fig. 47

When we have medical problems in humans, we usually go to laboratory animals to determine causes and cures. There are about 38 million laboratory animals used a year, most of which are for study of human problems. We think that such a capability is necessary to be able to study the effects of the space environment, especially weightlessness, under space conditions, with careful controlled animal experiments. The reason for using primates (Figure 48) is that in these studies it is necessary to use surgically implanted catheters, sensors, and implanted electrodes. These experiments are impossible to do in humans under space flight conditions. Some experiments can be done in humans but not accurately, since there are no base line data in the weightlessness environment.

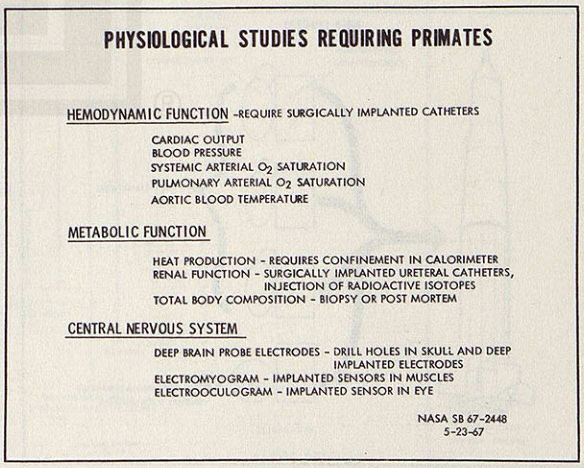

Fig. 48

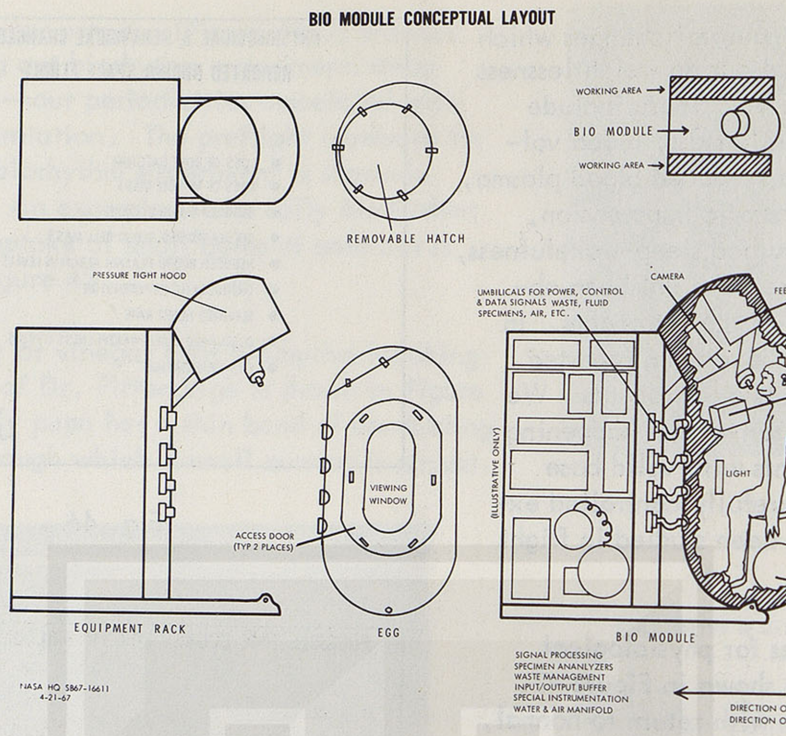

Fig. 49

A concept that we are presently studying is a primate in a module (shown in Figure 49) which is detachable from the life support and supply facilities. This module could be used either in the advanced biosatellite or in a Bio-A, or in a manned space station (Figure 50). We are presently comparing advanced biosatellites in various configurations with the AAP program.

The pigtail monkey and hardware for the cardiovascular experiment of Dr. Nello Pace are shown in Figure 51. Catheters containing blood are shown which come from the aorta near the heart and from the great vein. The components of blood cardiac output, and other measurements, are very carefully analyzed in the data readout equipment shown in Figure 52.

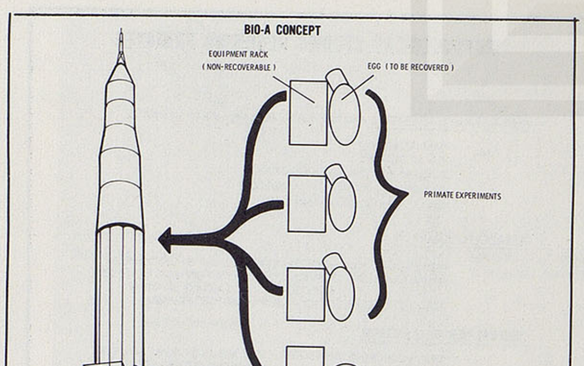

Fig. 50

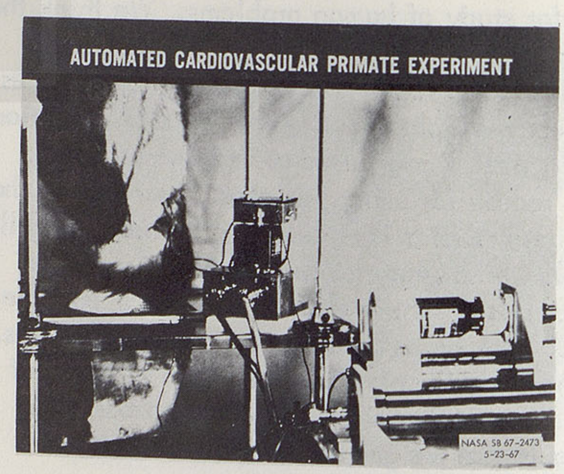

Fig. 51

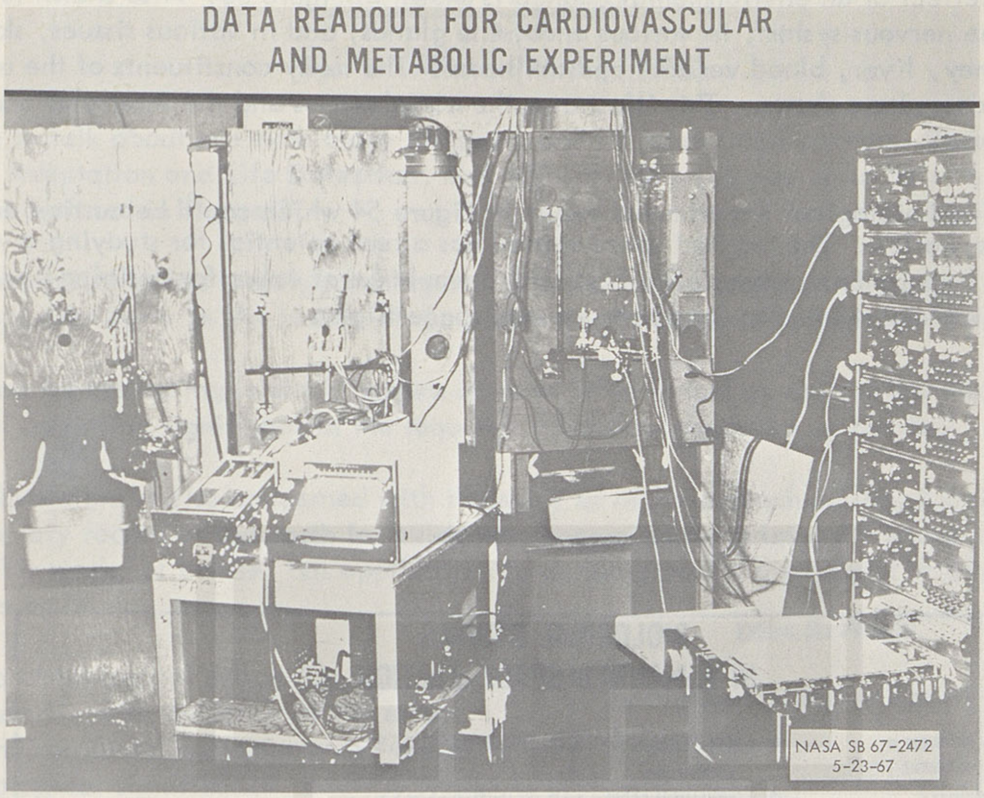
DATA READOUT FOR CARDIOVASCULAR
AND METABOLIC EXPERIMENT
NASA SB 67-2472
5-23-67

Fig. 52

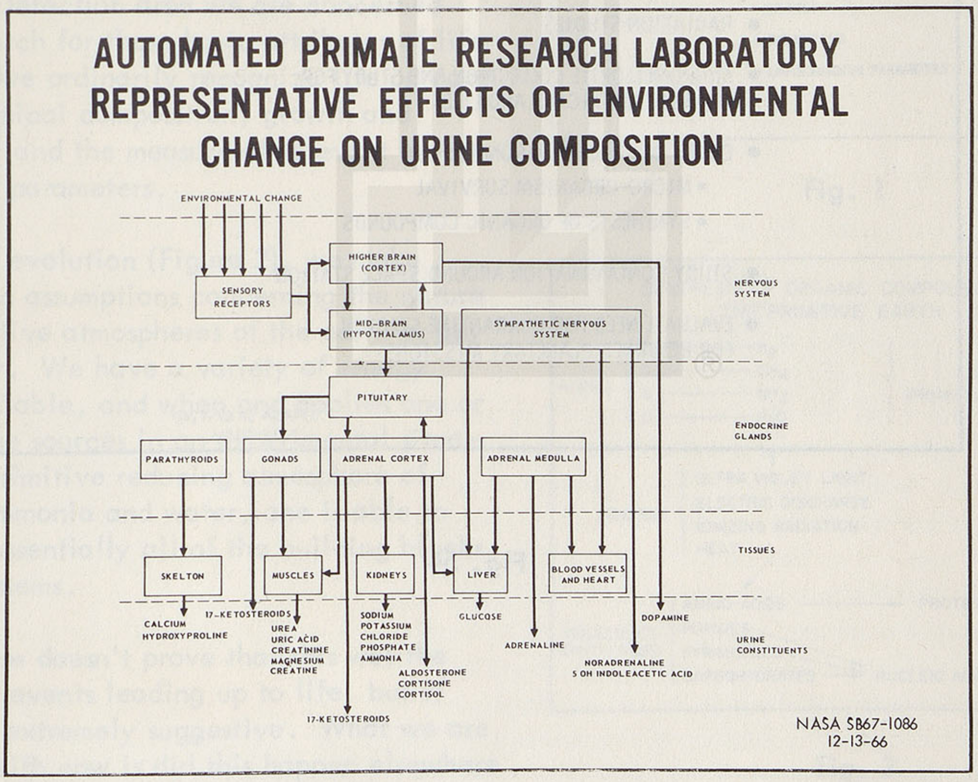
AUTOMATED PRIMATE RESEARCH LABORATORY
REPRESENTATIVE EFFECTS OF ENVIRONMENTAL
CHANGE ON URINE COMPOSITION
ENVIRONMENTAL CHANGE
SENSORY RECEPTORS
HIGHER BRAIN (CORTEX)
MID-BRAIN (HYPOTHALAMUS)
SYMPATHETIC NERVOUS SYSTEM
NERVOUS SYSTEM
PITUITARY
ENDOCRINE GLANDS
PARATHYROIDS
GONADS
ADRENAL CORTEX
ADRENAL MEDULLA
SKELTON
MUSCLES
KIDNEYS
LIVER
BLOOD VESSELS AND HEART
TISSUES
CALCIUM
HYDROXYPROLINE
17-KETOSTEROIDS
UREA
URIC ACID
CREATININE
MAGNESIUM
CREATINE
SODIUM
POTASSIUM
CHLORIDE
PHOSPHATE
AMMONIA
ALDOSTERONE
CORTISONE
CORTISOL
17-KETOSTEROIDS
GLUCOSE
ADRENALINE
NORADRENALINE
5 OH INDOLEACETIC ACID
DOPAMINE
URINE CONSTITUENTS
NASA SB67-1086
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Fig. 53

The complex effect of an environmental change is shown in Figure 53. Also shown is what happens in the nervous system, in various endocrine glands, and in various tissues, skeleton, muscles, kidney, liver, blood vessels, and the heart. The many constituents of the urine which should be measured are shown. This illustrates the complexities and the interrelationships of a complex mammal.

We have defined biological experiments shown in Figure 54 which could be carried out in a manned space station. The manned space station has a real potential for studying a variety of biological experiments, especially those which would be of value for defining and solving biomedical problems related to long term manned space flight.

BIOLOGICAL STUDIES
IN A MANNED SPACE STATION

- LONG TERM EFFECTS OF WEIGHTLESSNESS
- COMBINED EFFECTS OF WEIGHTLESSNESS
- EFFECTS OF VARIABLE AND PARTIAL G
- BIORHYTHM STUDIES
- RADIATION STUDIES
- MICROMETEORITE COLLECTION AND STUDY FOR ORGANIC CHEMICALS AND LIFE
- EFFECT OF SPACE ENVIRONMENT ON
  - MICRO-ORGANISM SURVIVAL
  - SYNTHESIS OF ORGANIC COMPOUNDS
- STUDY CONTAMINATION AROUND SPACE STATION
- EVALUATE NEED FOR QUARANTINE STATION FOR RETURNED PLANETARY MISSIONS

NASA SB 67-1240
12/13/66

Fig. 54

PLANETARY BIOLOGY

By: Dr. Richard Young (ARC)

I am going to talk about the exobiology program, and its three major aspects, Chemical Evolution, Biological Adaptation and Life Detection, and more or less bring you up to date in the three major areas outlined in Figure 1.

Chemical evolution refers largely to abiogenesis, which is the synthesis of organic matter as we think it happened early in the history of the planet earth, before the origin of life.

The question we are asking is did it happen on some other planet as well as the planet earth, and is chemical evolution significant in the sequence of events which led up to life?

Chemical Evolution is also concerned with the study of organic geochemistry; looking back into the sedimentary record of the earth for evidence concerning the origin of life and its early history. This work, of course, has application in our program for analysis of returned lunar and planetary samples.

In the area of biological adaptation we are concerned primarily with the study of the effect of those environmental extremes which are of special biological significance, and the types of environments to be expected on other planets on which life may have evolved.

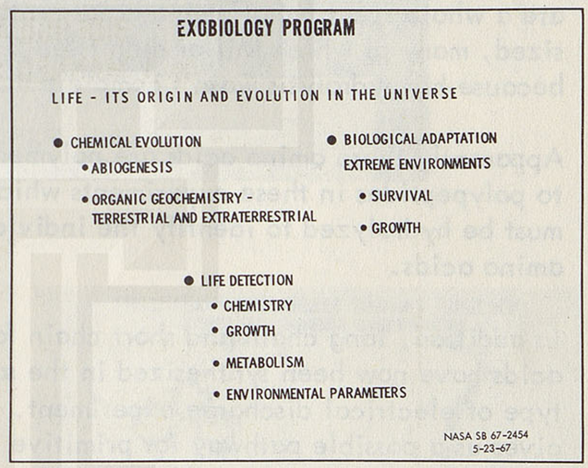

Fig. 1

In the Life Detection area we are concerned with the search for those basic attributes of life with which we ordinarily recognize life on earth, such as chemical composition, growth and metabolism, and the measure of relevant environmental parameters.

In chemical evolution (Figure 2), we make certain basic assumptions concerning the nature of the primitive atmospheres of the earth or any other planet. We have a variety of energy sources available, and when one applies one or more of these sources in an experimental situation, to a primitive reducing atmosphere of methane, ammonia and water, one is able to synthesize essentially all of the building blocks of living systems.

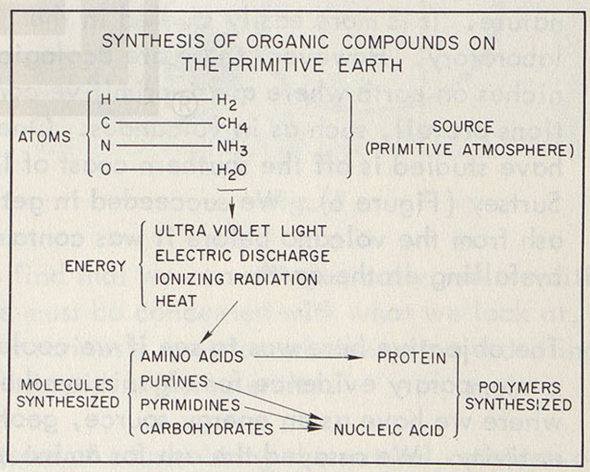

Fig. 2

This of course doesn't prove that this was the sequence of events leading up to life, but it is certainly extremely suggestive. What we are concerned with now is did this happen elsewhere in the universe?

Recently we have been able to extend some of these earlier observations from that kind of an experiment, in which we take a primitive atmosphere and apply energy.

There are still a lot of problems, of course. There are a lot of gaps to be filled in to complete the story. Figures 3,4, and 5 illustrate that we have now extended the range of organic compounds that we know must have been synthesized very early in the history of the earth, a "natural experiment", if you will.

We know that in a typical Miller-Urey experiment, where a spark is discharged in an array of gases, Miller reported that a few amino acids were synthesized. As it turns out there are a whole spectrum of amino acids synthesized, many of which Miller didn't see simply because his hydrolysis wasn't complete.

Apparently these amino acids are polymerized to polypeptides in these experiments which must be hydrolyzed to identify the individual amino acids.

In addition, long chain and short chain fatty acids have now been synthesized in the same type of electrical discharge experiment. This gives us a possible pathway for primitive lipid synthesis.

Abiogenesis is extremely difficult to study in nature. It is more easily studied in the laboratory. However, there are ecological niches on earth where quasi-primitive conditions prevail, such as in volcanoes. One we have studied is off the southern coast of Iceland, Surtsey (Figure 6). We succeeded in getting ash from the volcano before it was contaminated by falling on the earth.

The objective here was to see if we could find contemporary evidence for organic synthesis where we have as an energy source, geothermal activity. We assayed the ash for amino acids, and found them, giving further evidence to our ideas about chemical evolution.

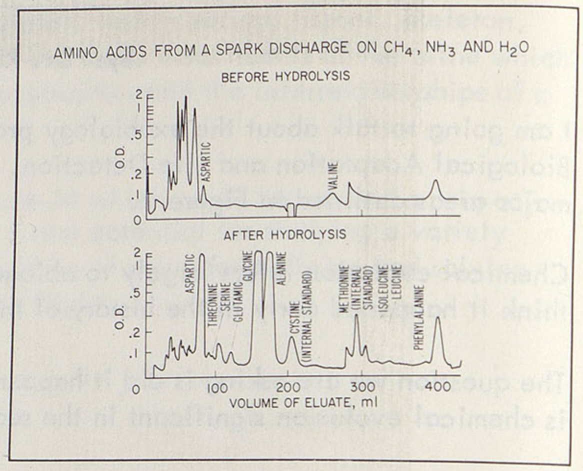

Fig. 3

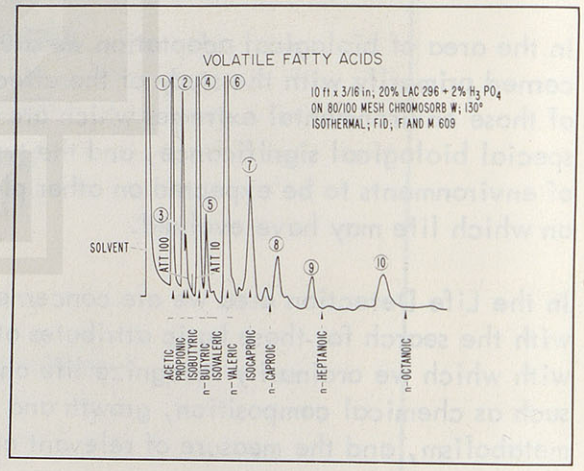

Fig. 4

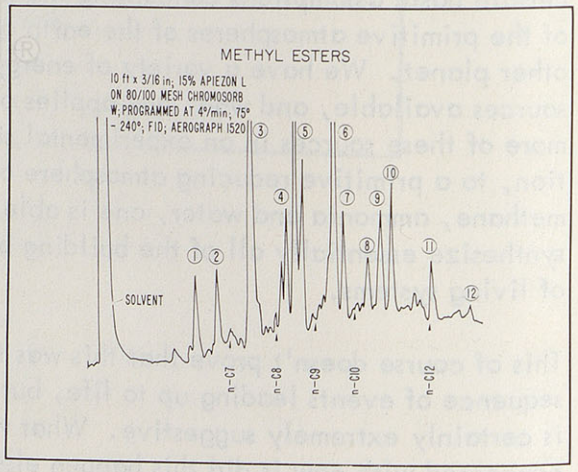

Fig. 5

Fig. 6

This experiment needs confirmation, of course. It is subject to questions of contamination. There is sea water around here which contains biologically produced organic molecules and which may be being blown up at the same time. But it is an encouraging thought that we can find amino acids under these conditions.

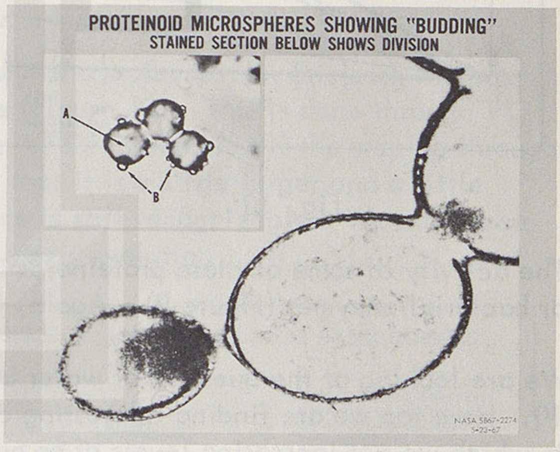

Fig. 7

Sidney Fox takes amino acids as they may have been synthesized under these conditions, and then polymerizes these amino acids by heating them dry and finds that when the resulting polymer is resuspended in water he ends up with interesting structures Figure 7 which are certainly suggestive from the point of view of biology. They are of great interest to us because we find that we can abiogenically make entities with many of the properties of living cells. Also, we must be concerned with what we look at, say, on the planet Mars under a microscope. We must seriously question whether we are dealing with an abiogenic experiment or whether we are dealing with a living entity.

We are doing some work with synthetic proteins, proteins of course being the natural catalysts of living systems. Synthetic proteins, as made by Sidney Fox, for example, do show a low level catalytic activity as represented by Figure 8, when compared to the individual amino acid components unpolymerized.

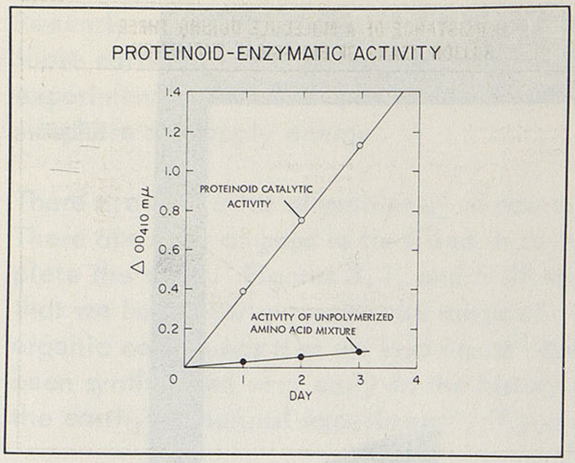

Fig. 8

COMPARISON OF CATALYTIC ACTIVITY

PREPARATION	p-NITROPHENYLPHOSPHATE HYDROLYZED	REFERENCE
CRUDE EXTRACTS FROM MILK	217 μ MOLES/DAY/mg. PROTEIN	MORTON; B.J. 55, 795 (1953)
B. subtilis	0.1 μ MOLE/DAY/10^7 CELLS OR 50 μ MOLES/DAY/mg. DRIED CELL	WESTLEY; NASA REPORT (1964)
FRACTIONATED PROTEINOID MW 2,500-4,000	3 μ MOLES/DAY/mg. PREPARATION	

Fig. 9

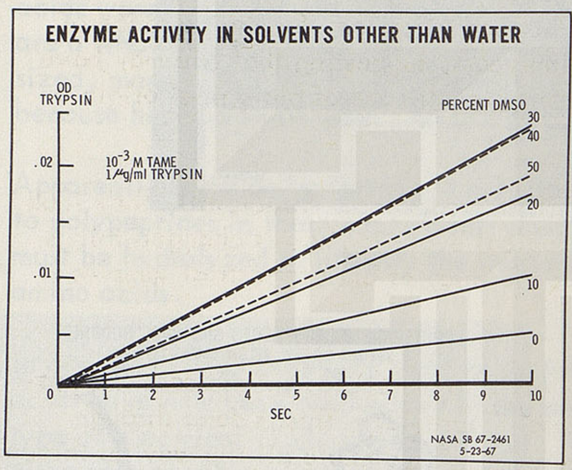

Fig. 10

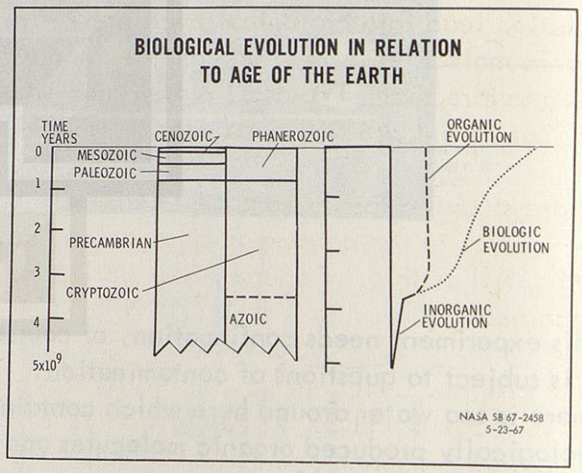

Fig. 11

The activity of some of these proteinoids is high, although not as high a level as natural enzymes or bacterial enzymes (Figure 9). Again, it is extremely suggestive.

We are looking at the question of water being a required solvent for biological activity Figure 10. Here too we are finding interesting data with an organic solvent, DMSO, (dimethysulfoxide), in which we get increasing levels of enzymatic activity as we increase the concentration of this organic solvent up to about 30%, which in turn is decreasing the concentration of water. Thus, we may not have to restrict ourselves to water as a potential solvent for living systems.

Looking at the geological record, (Figure 11) we are concerned primarily with the period of time way back between two to four billion years ago. We know by studying rocks of about two and a half to three billion years ago, that organisms were already present (Figure 12).

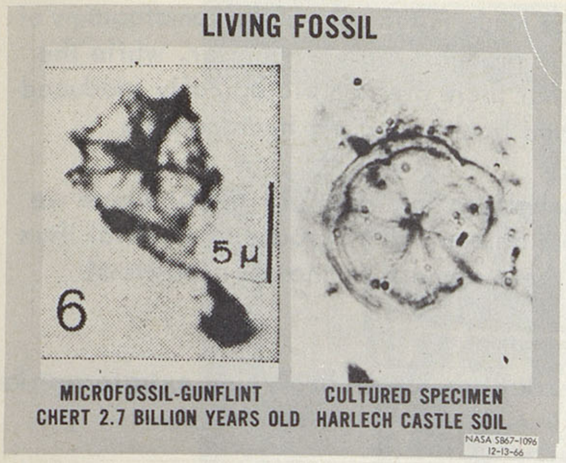

Fig. 12

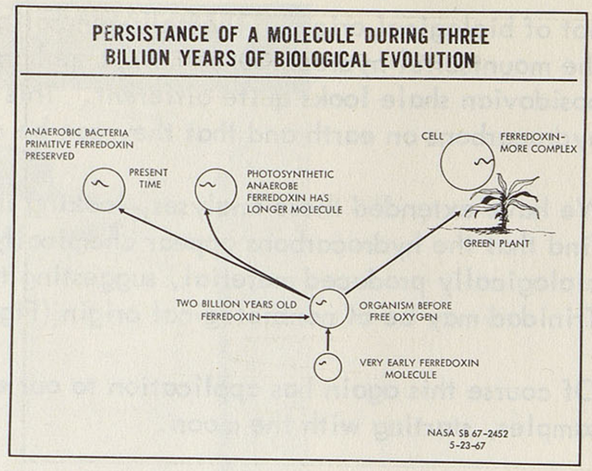

Fig. 13

However, we don't know exactly what happened in this early time period. When did chemical evolution lead into biological evolution? We now have good evidence, for the presence of organic molecules as long ago as three and a half billion years, suggesting that life may have arisen before that. We don't really know whether these molecules are of biological origin or not, but I think we will have data on this point soon.

We are studying fossils from the GunFlint chert, 2.7 billion years ago. Structurally they look very similar to the contemporary organism, so that biological evolution hasn't changed things much. All of this, of course, has application as far as the study of extraterrestrial samples is concerned.

There are now techniques available for tracing the history of a molecule, in this case the protein ferredoxin probably a two billion year old molecule (Figure 13). This is done through amino acid sequence analysis. We can trace the history of this molecule all the way up through modern plants. Although the molecule has changed, in that it is a little larger and a little longer and there are more amino acids in it, the sequence is still recognizable. We can trace the history of this molecule through two or three billion years evolution.

We are also looking at the chemistry of these ancient sediments, particularly from one very special point of view (Figure 14).

If you look at an organic molecule that is several billion years old, you must raise the question, is it of biological origin or is it some natural experiment? We think we have a handle on this question. It is done by analyzing terrestrial shales that are of known biological origin, and comparing these to the products of a methane discharge experiment which are certainly not of biological origin, and to organic matter in solid chunks of granite which the geologists have felt for years is probably

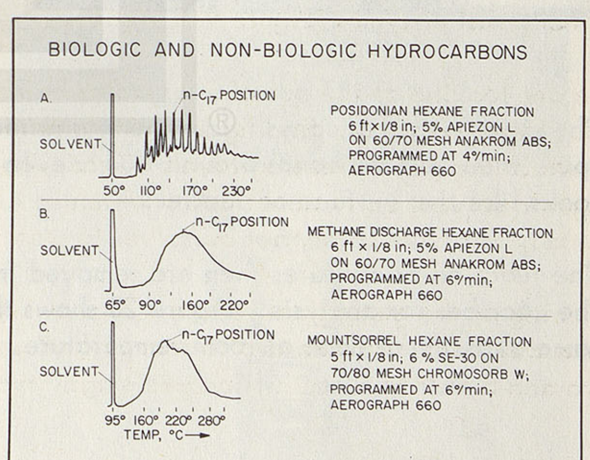

Fig. 14

not of biological origin. The only generalization to be made is that the gas chromatograms of the mountserrel hydrocarbons and the methane discharge products are very similar, while the posidovian shale looks quite different. This suggests that there are non biologically produced hydrocarbons on earth and that they can be distinguished from biological hydrocarbons.

We have extended these analyses, looking into the asphalts in Trinidad (Figure 15) where we find that the hydrocarbons appear chemically more like abiogenically produced material than biologically produced material, suggesting that even these asphalts in the oil deposits of Trinidad may be of nonbiological origin (Figure 16).

Of course this again has application to our extraterrestrial program in analyzing extraterrestrial samples, starting with the moon.

We are interested in the potential of Jupiter from this point of view. As shown in Figure 17, Jupiter still has primitive atmosphere. Some experimental work has been done in chambers like the one shown in Figure 18 where we can introduce a Jovian atmosphere, through a hollow electrode impacting on a liquid nitrogen cold finger inside the chamber. The gases are sparked electrically as they are impacted on the cold finger. Figure 19 shows an enlargement of what would be seen through the window on the chamber. The obvious feature is that we get all sorts of colored compounds being deposited on the cold finger during the experiment.

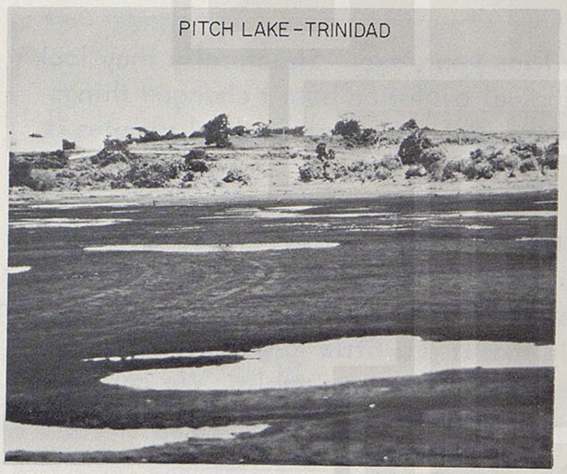

Fig. 15

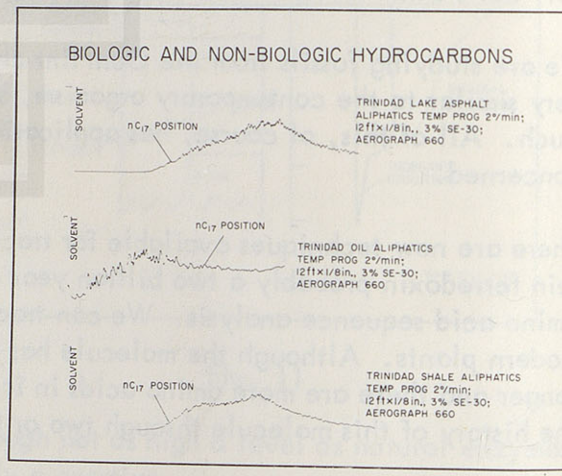

Fig. 16

The first thing that forms is a rather large red spot, then colored bands around it. It even looks like the surface of Jupiter.

The reaction of mixtures then are removed from the chamber for analysis. Figure 20 shows the same experiment done at room temperature.

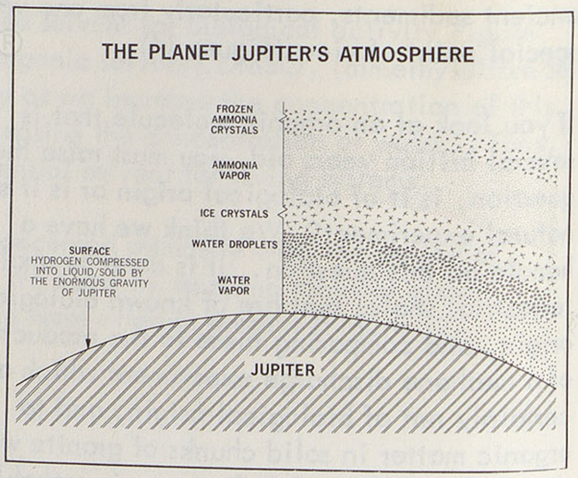

Fig. 17

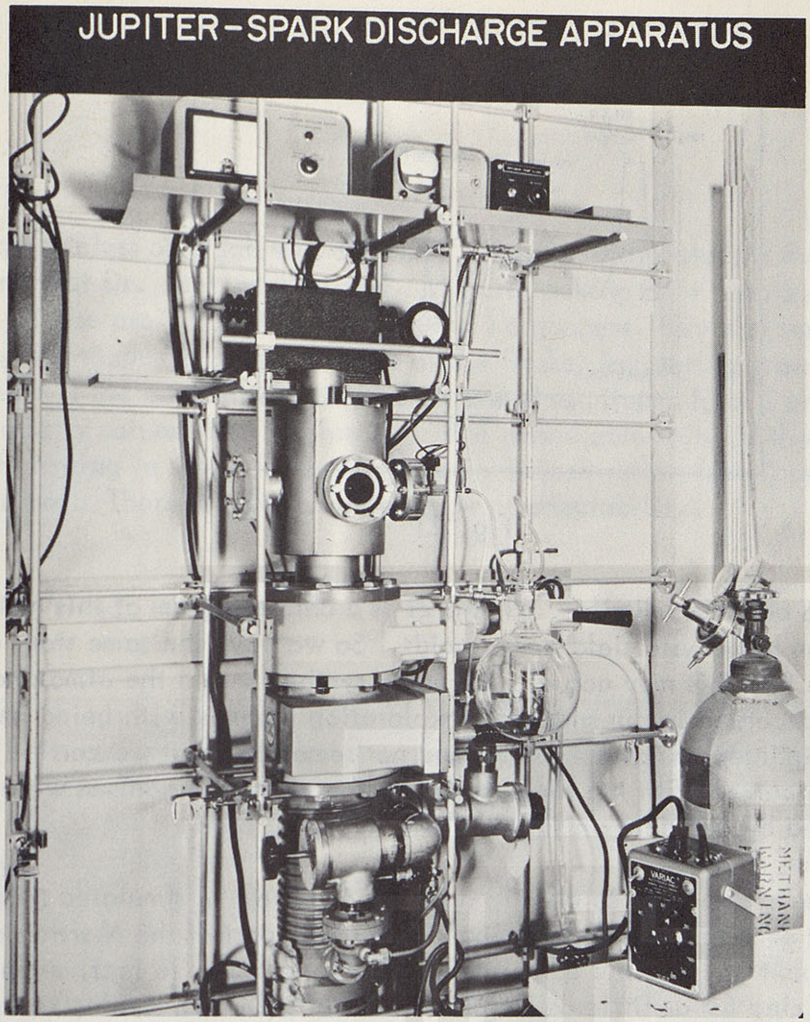

Fig. 18

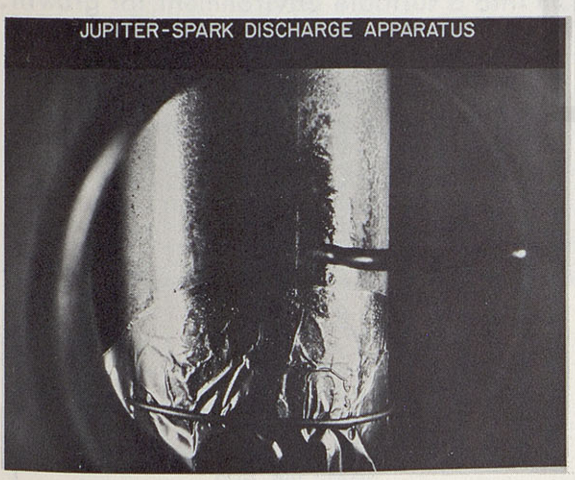

Fig. 19

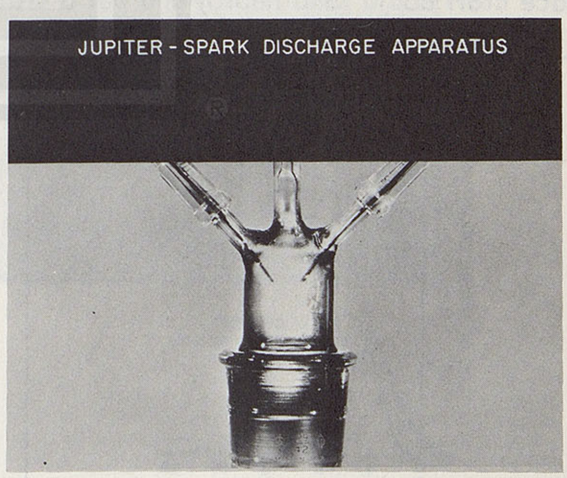

Fig. 20

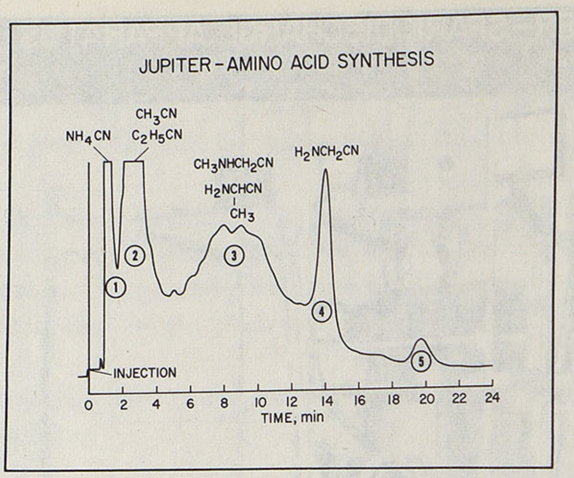

Fig. 21

The end products are to be amino nitriles. Figure 21 is a chromatogram of this material, showing amino nitriles, which on hydrolysis yield amino acids. So we have the same story again, suggesting that compounds like this may actually be being synthesized in the atmosphere of Jupiter today. We are very concerned in our planetary exploration program with being certain that whatever we detect is indigenous to that planet and not something that we carried along from Earth. Thus we are concerned with the survivability and growth of organisms we are familiar with if they were landed by accident on such a planet as, say, Mars.

Many organisms have been shown to be able to adapt to and grow in simulated Martian environments. Although many of them are killed during the freezing part of the Martian night, they take off and grow the next day without much difficulty (Figure 22). In fact, even if the temperature gets above freezing for as little as 15 minutes out of a 24 hour cycle, some bacteria are capable of growing in a simulated Martian environment (Figure 23).

We simulate Martian atmospheric composition, the temperature, pressure, in some cases radiation fluxes, varying only the availability of water. We make the assumption there could be water available in some micro-environment, and if so, we have to consider the possibility that a space craft could land nearby and put a viable organism into a suitable environment for growth.

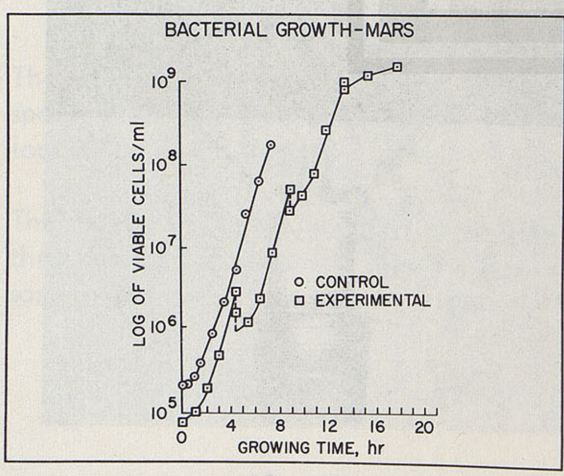

Fig. 22

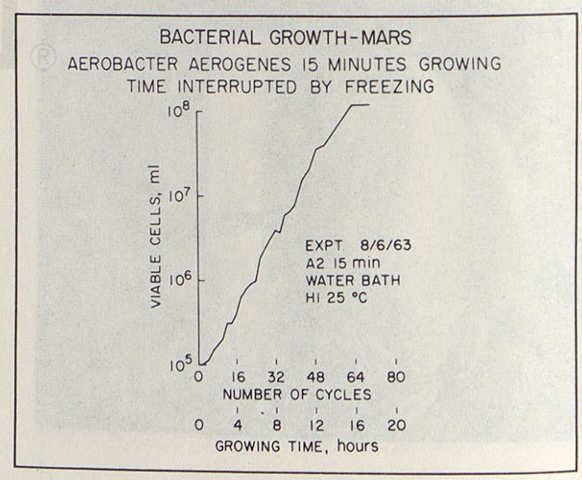

Fig. 23

Looking at another class of organisms, this work is obviously related to the Environmental Biology program that Dr. Jenkins discussed. We are looking at it from a very specific point of view. These are halophilic (salt loving) organisms. You can see green (shown in Figure 24 by the shades of grays) in some of the flasks, indicating growing algae. The variable here is the concentration of salt in these solutions, from 1 percent up to 30 percent, (essentially saturated salt solution). The remarkable thing is that the same cells are capable of growing in salt solutions ranging in concentration from 3 percent right on to 22 or 25 percent. There is a remarkable range of adaptability.

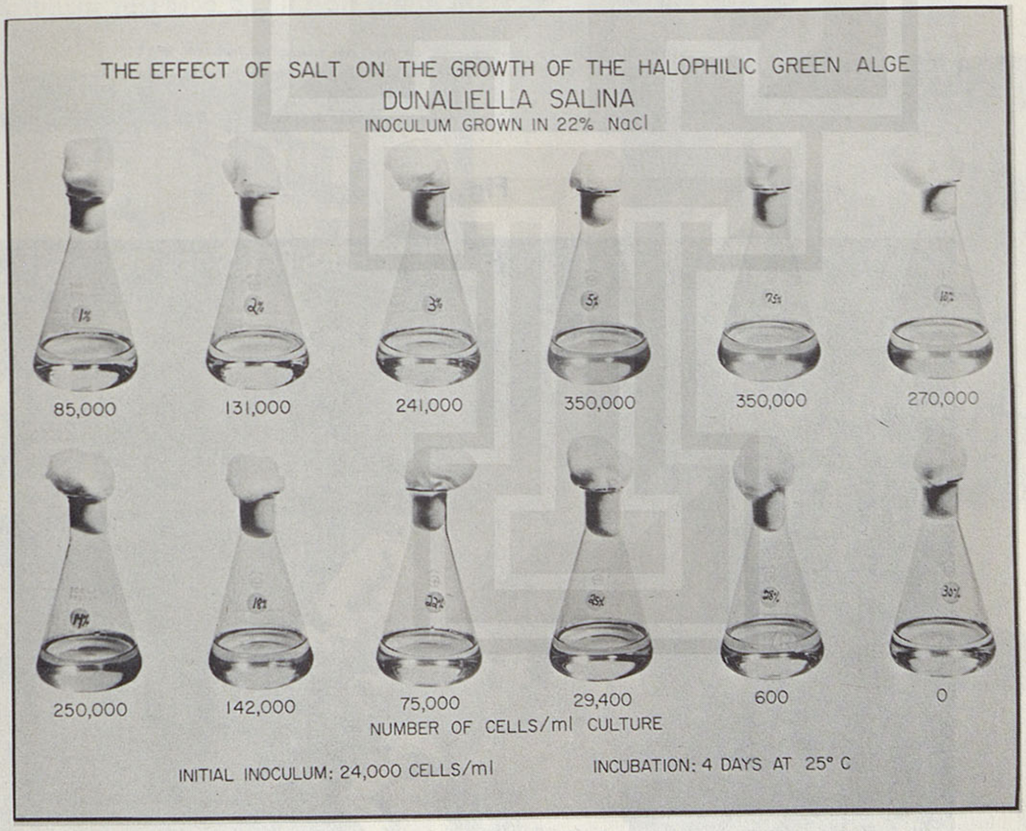

Fig. 24

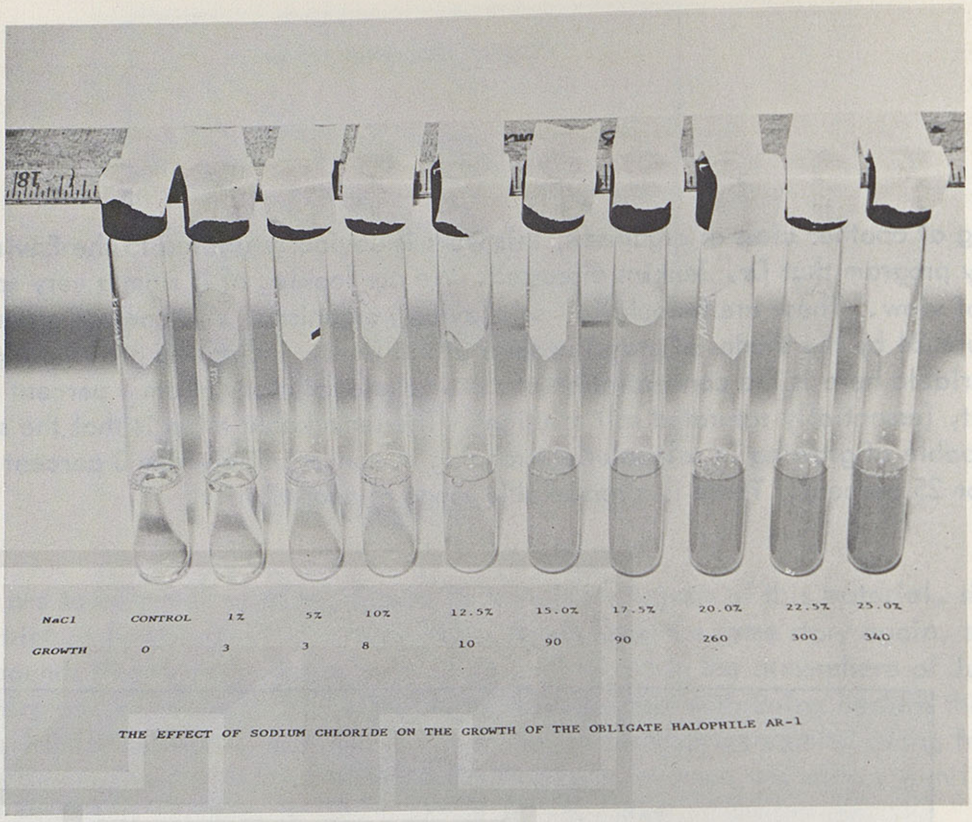
NaCl CONTROL 1% 5% 10% 12.5% 15.0% 17.5% 20.0% 22.5% 25.0%
GROWTH 0 3 3 8 10 90 90 260 300 340
THE EFFECT OF SODIUM CHLORIDE ON THE GROWTH OF THE OBLIGATE HALOPHILE AR-1

Fig. 25


BACTERIA IN SALT CRYSTALS

Fig. 26

Figure 25 shows growing halophilic bacteria, which not only can tolerate this kind of salt range but require it. They need an almost saturated salt solution for optimum growth. From the point of water availability, this is really remarkable. These organisms are really competing with the crystal salts for their water.

As illustrated in Figure 26, where we actually allow some of these crystals to dry out, we still have viable organisms, the red color (shown here as the white areas) in the crystals growing in and on these crystals of salt.

Some interesting calculations have been done on the energy requirements for organisms like this to pull water away from the salt crystals. It turns out they are roughly comparable to an organism pulling water out of the atmosphere of Mars.

We are using simulators of the types shown in Figures 27& 28 to do some of this kind of experimentation. The one at Ames Research Center is our latest model, so to speak, in which we can simulate solar radiation fluxes on the surface of the planet. Samples can be put in through the air lock, and removed, and it is sterilizable.

We can actually test life detection technology in simulators like this.

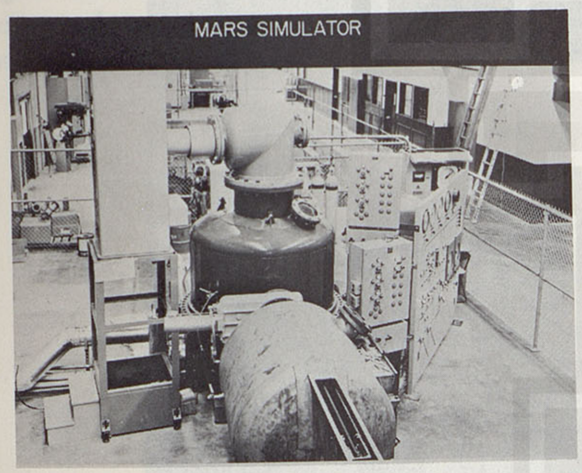

Fig. 27

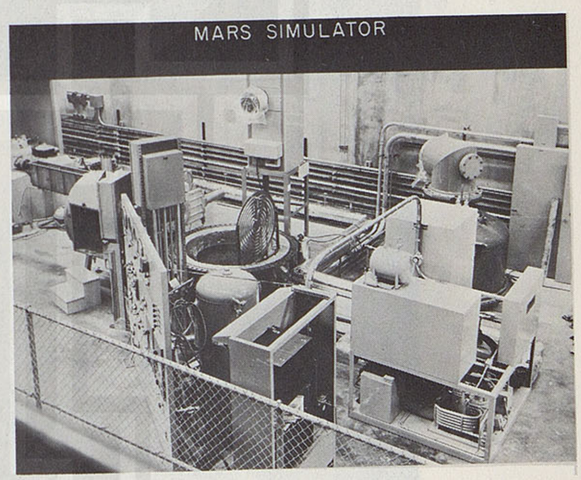

Fig. 28

We are working on techniques with which we actually hope to look for living organisms on Mars. Figure 29 shows a chamber that is similar to Dr. Vishniac's "Wolf Trap." It is a modification of the "Wolf Trap" concept where we have a liquid nutrient medium in the chamber, but we have soil introduced not directly into the medium, where it provides background noise for any optical readout, but on a shelf adjacent to the medium connected by means of a scintered glass filter.

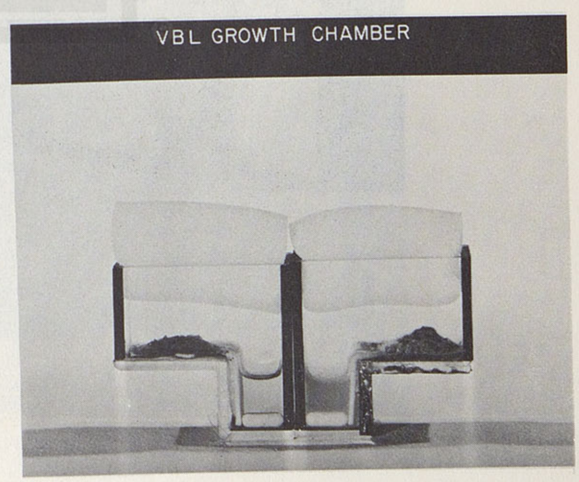

Fig. 29

The soil then is wet by capillary action. The organisms will migrate back down and innoculate the medium without any direct innoculation of soil. Growth can be seen in a matter of hours by measuring changes in the turbidity of the medium.

The ultimate life detection experiment is more sophisticated and complex; one in which we can interface as many scientists as possible, using and integrated and automated device capable of doing a broad array of experiments and analyses on the same sample in a sequential fashion.

We can design an apparatus (See Figure 30) capable of doing automated chemical analyses on gas, liquid or solid samples, and look for evidence of metabolic activity and growth. We can include visual devices and actually look for recognizable structures. We can then have some degree of assurance that what we are looking at is the result of biological activity.

It is this sort of thing we think is probably going to ultimately resolve the problem of life on Mars or any other planet.

Fig. 30

There are a number of sybsystems (Figure 31) that are required for our attempted Voyager landing system for life detection. I won't go into detail here, except to say that, they are being looked at, both in-house and on contract.

CRITICAL VBL SUBSYSTEMS

GAS SYSTEMS

- GAS CHROMATOGRAPHY
  - DETECTORS*
  - ELECTRONICS* (AMPLIFIERS AND DATA HANDLING)
  - SAMPLING SYSTEMS
    - PYROLYSIS*
    - INJECTION*
- OTHER DETECTION SYSTEMS
  - WATER VAPOR

LIQUID SYSTEMS

- SOIL EXTRACTION*
- CHEMICAL REACTORS
- METERING AND VALVING*
- REAGENT STORAGE*
- AGITATION*

SOLID SYSTEMS

- ACQUISITION
- PROCESSING
- MEASUREMENT (WEIGHT OR VOLUME)
- TRANSFER
- PARTICULATE SUSPENSIONS
  - FILTRATION*
  - AGITATION*
  - DETECTORS

*STUDY UNDER CURRENT OUTSIDE CONTRACTS

NASA SB 67-2459
5-23-67

Fig. 31

Figure 32 is a miniaturized mass spectrometer which we think is an essential part of the Voyager laboratory. This will ultimately do the sorts of chemical analyses that a laboratory instrument weighing thousands of pounds can do. This sort of technology has gone a long way.

Fig. 32

In summary, as outlined in Figure 33, we are concerned with terrestrial samples for all of the reasons that I stated earlier, identification of organic compounds related to living systems, the position of these compounds in the evolutionary scale, and whatever relevance this has for extraterrestrial sample analysis.

OBJECTIVES - EXTRATERRESTRIAL SAMPLE ANALYSIS

IDENTIFICATION OF ORGANIC COMPOUNDS FROM EXTRATERRESTRIAL SOURCES

DETERMINATION OF THE POSITION OF THESE COMPOUNDS IN THE EVOLUTIONARY SCALE DEVELOPED FROM THE GEOLOGIC RECORD

DISCOVERY OF THE PRESENCE OR ABSENCE OF CURRENT OR PAST EXTRATERRESTRIAL LIFE THROUGH CHEMICAL EVIDENCE

Fig. 33

SPACECRAFT STERILIZATION

By Dr. Lawrence B. Hall

The scientific community originally thought of the contamination of the planet almost entirely in terms of landing a contaminated capsule on a planet. Since then we have found other factors that enter into this problem, and other possibilities of contamination. However, most of our research has been directed to the sterilization of the landing capsule, with a minimum of stress placed upon that capsule by the sterilization process.

As shown in Figure 1, in 1962 we thought in terms of a heat cycle at 135 degrees C for approximately 28 hours. In 1966 we modified it slightly for engineering considerations to 125°C, and extended its length accordingly.

Further studies during the last two years now permit us a 1967 hypothesis that may result in a heat cycle which, by integration of lethality of the heat-up and the cool-down time, may result in a shorter heat cycle.

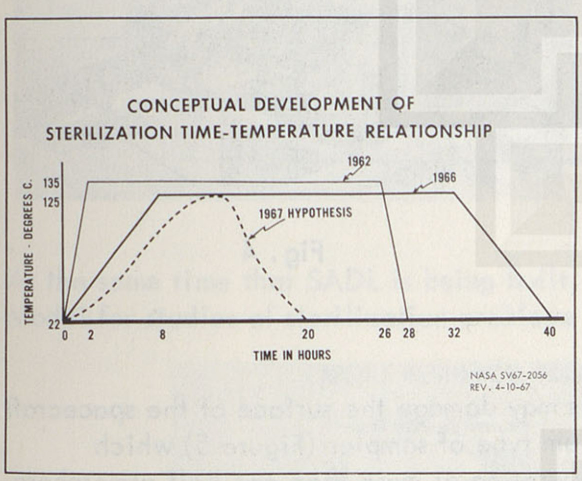

Fig. 1

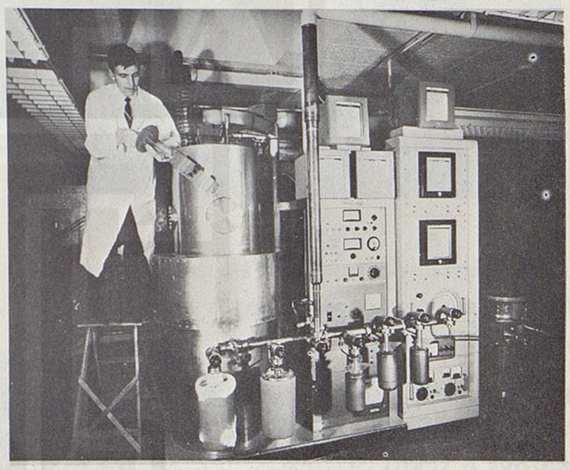

Fig. 2

The idea still remains, particularly in the layman's mind, that deep space environment will kill all the organisms on the spacecraft despite the fact that many in-flight and terrestial experiments have shown that this is not so. In hope of obtaining final and irrefutable answers to this question JPL is using what they call a "mole sink" (Figure 2) in which they study terrestrial organisms and the death of terrestrial organisms under simulated environmental conditions.

In a cryogenic tank at a very low temperature and with most of the other factors encountered in outer space they place organisms on metal strips, leave them in the tank for periods up to six months, and then determine what the die-off has been.

So far results are inconclusive, but so are the results of many of the other experiments in this field.

The bio-assay of spacecraft has been going on for the last year and a half, particularly at Cape Kennedy where the Public Health Service and our own office have been exploring the possible techniques of management of this type of effort, an effort which presents many unusual complications.

In Figure 3 is shown the equipment for sampling of the contamination of the air, next to the spacecraft, one technique for surface sampling that can be used only on those surfaces of the spacecraft that will not be damaged by swabbing, and as shown in Figure 4, another sampling method in which metal coupons are used. In some cases, metal stainless steel coupons, one inch by one inch, are placed on the spacecraft, in advance, really during its early assembly. These are sterile when put in place. A few are removed every few days and are analyzed. By this technique we have been able to get a representation of the kinds and amounts of contamination that have been on our spacecraft launched in the last year.

The National Communicable Disease Center of the Public Health Service is operating the laboratory at Cape Kennedy for NASA.

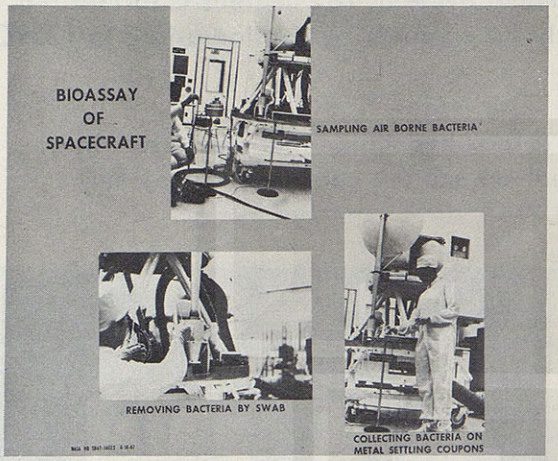

Fig. 3

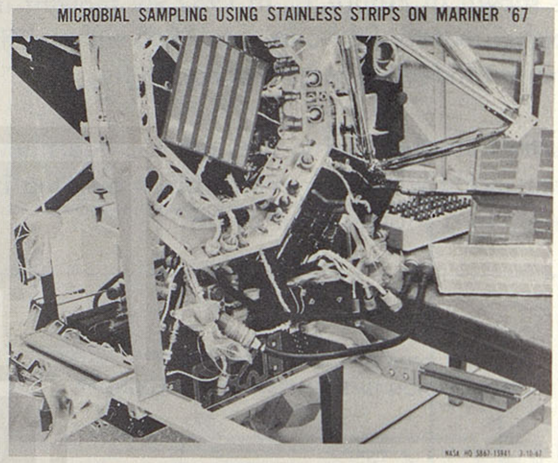

Fig. 4

Unfortunately, some of the surface sampling techniques may damage the surface of the spacecraft. The Sandia Corporation has recently developed a vacuum type of sampler (Figure 5) which employs a small orifice at the end of a nylon tube. Operating at more than one half atmosphere of vacuum the air enters the orifice at very nearly the speed of sound. The orifice is run over a surface to be sampled; the air stream picks up the contamination that is on the surface and carries it to a membrane downstream. The filter is placed on culture media, incubated, and the viable organisms grow and are counted. Efficiency of the device appears to be better than 95 percent and may be a considerable advance in the state of this particular art.

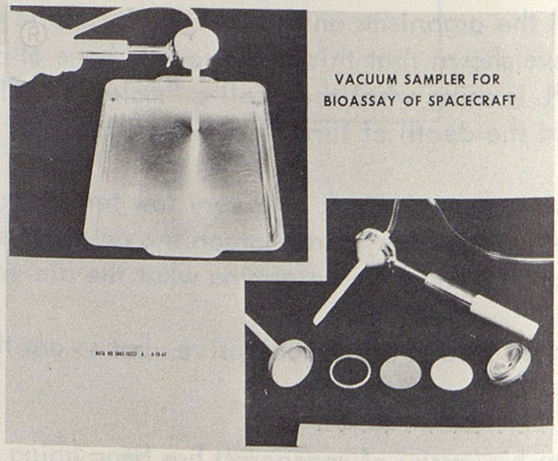

Fig. 5

The sterilization assembly development laboratory (Figure 6), at JPL, known as SADL is designed primarily to develop and find out what the engineering problems are in the assembly of a major spacecraft under bio-clean conditions. It has many different features, including a laminar down flow high bay area, in which a 14 foot spacecraft can be assembled. This will not be big enough for the Voyager '73 mission, but it may suffice for assembly of the other missions.

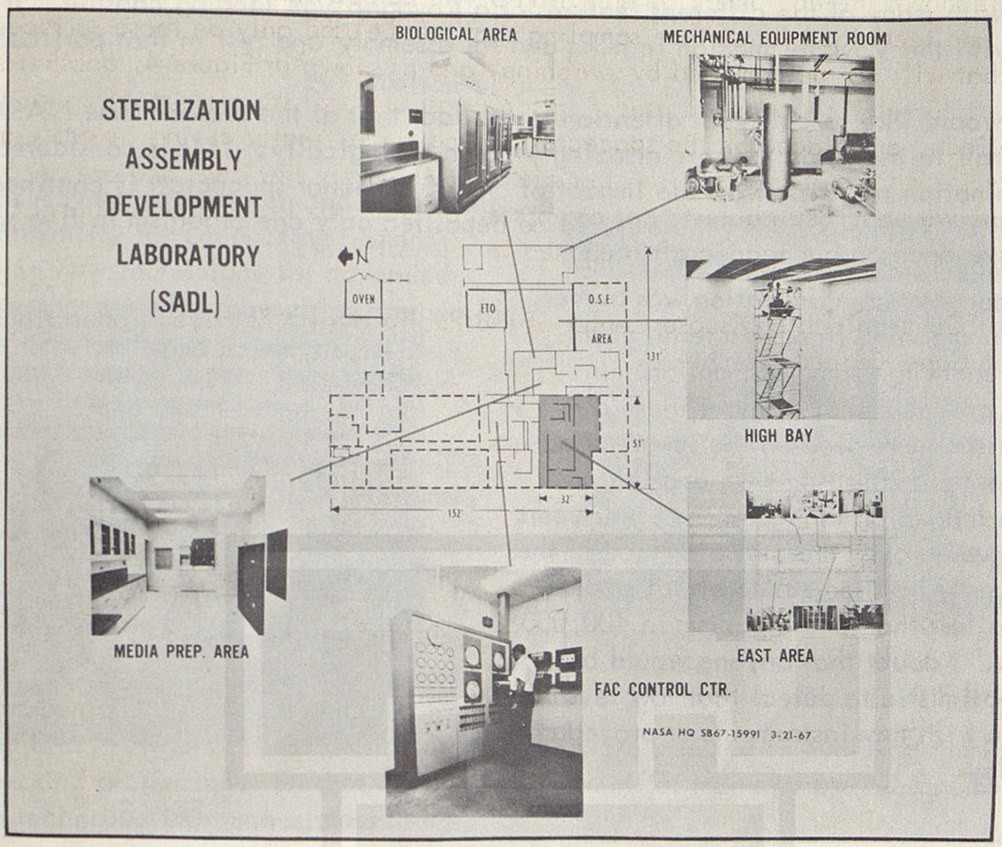

Fig. 6

At the same time that SADL is being built, JPL is developing a Capsule Mechanical Training Model for studies of sterilization problems (Figure 7). The model is a rather large size, 14 feet

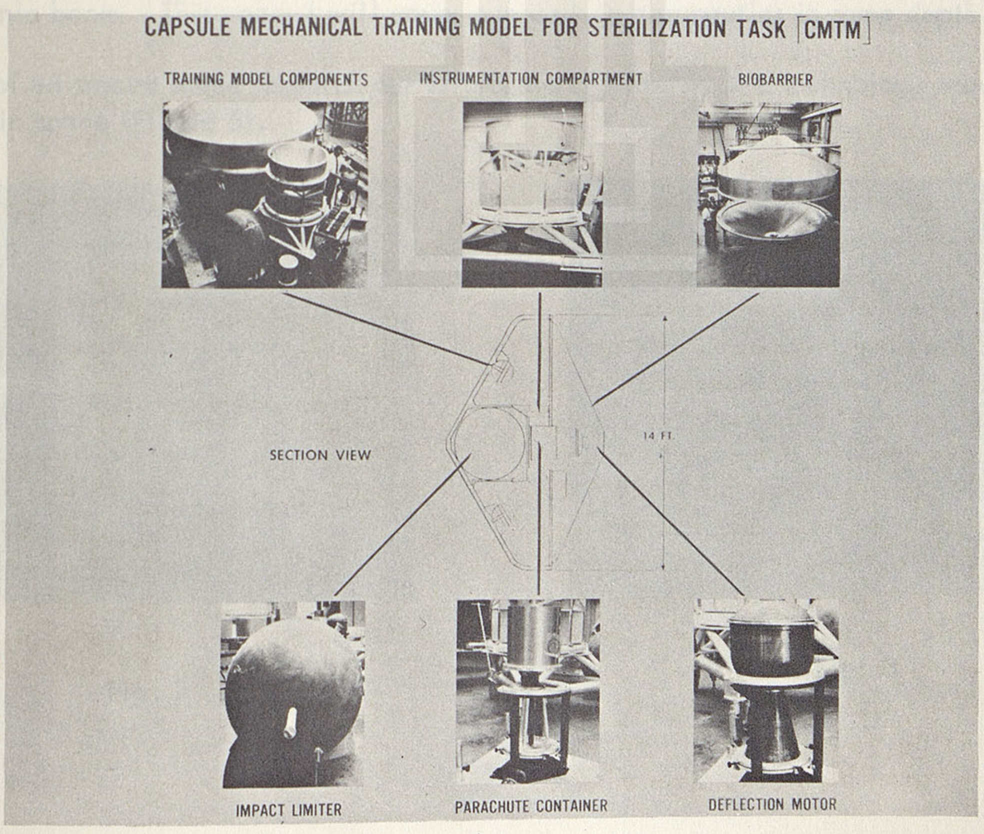

Fig. 7

in diameter, with many of the different features of a Voyager type landing capsule. It is built specifically with the Voyager mission in mind and for assembly and test in that particular facility.

In closing, I would like to call your attention to the fact that at the present time NASA has been flying spacecraft to the moon that are amazingly clean biologically. If it is considered that all of the contamination resulting from the impact of one of our lunar spacecraft is confined to one square Kilometer (Figure 8), then there would be deposited only one organism in five square meters as a result of the impact of Surveyor I. For Ranger, of course, the contamination was higher, so we find one organism in only a tenth of a square meter under the same assumption. In addition it is probable that many of these deposited organisms have died on the lunar surface. If the total contamination that we and the Russians have landed on the moon in recent years were spread evenly over the entire surface of the moon, (as suggested by some theoretical studies) we would find less than one organism in 400,000 square meters. I doubt that anyone would be sufficiently optimistic to detect that low level of contamination with any instruments or procedures available today.

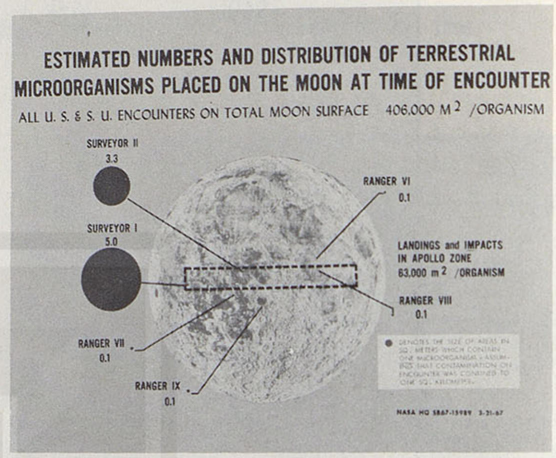

Fig. 8

HUMAN FACTORS SYSTEMS

By: Walton L. Jones, M. D.

The Office of Advanced Research and Technology has the responsibility for conducting research and developing new technology for advanced aircraft and space vehicles that will assure world leadership in aeronautics and space. As illustrated in Figure 1, this work is accomplished under Dr. Mac C. Adams by eight separate but inter-related divisions. The Human Factors Systems program is one of these eight divisions. It provides the technology for the effective utilization of man in aeronautical and space flight in conjunction with the work of these other seven divisions in OART (Figure 2). Man's technological requirements of physiology must be determined by animal and human research on the ground and in flight. These design requirements are utilized in evolving the technology of life support and protection. Studies of the best trade-off of man and machine combination generate the technology for man-system integration.

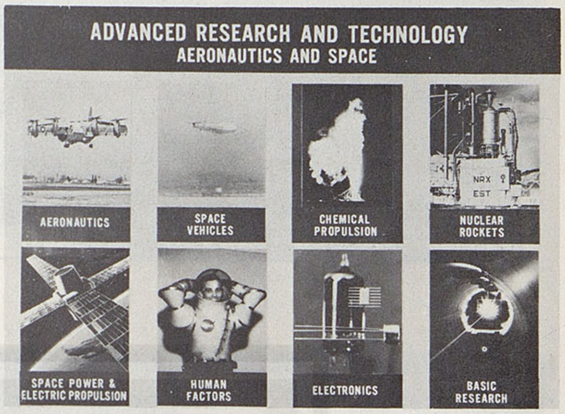

Fig. 1

In aeronautics, the future aircraft shown in Figure 3 are indicative of the scope of NASA's aeronautics research program including the Human Factors aspects. (Figure 4) The Human Factors program in OART is the focal point for all NASA life sciences work in this field. This is a vital and growing part of our program. Included is the psychoacoustic aspects of aircraft noise and sonic boom. This year, I will cover our work in aeronautics in some depth.

In the case of advanced space research our efforts are typified by the technology required for useful work in space (Figure 5).

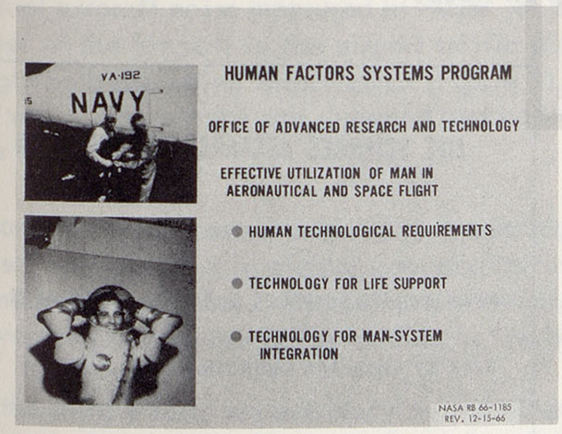

Fig. 2

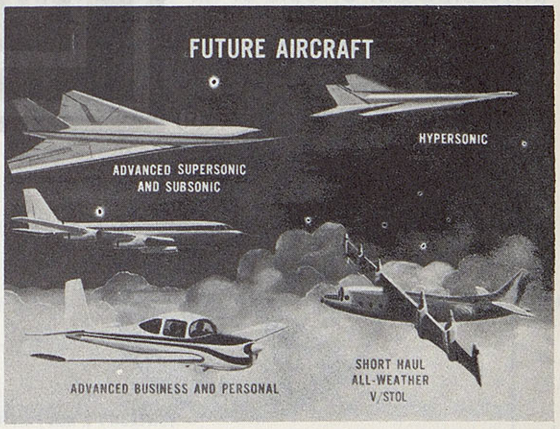

Fig. 3

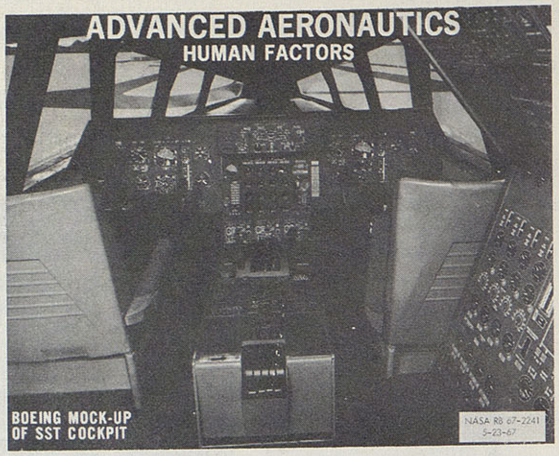

Fig. 4

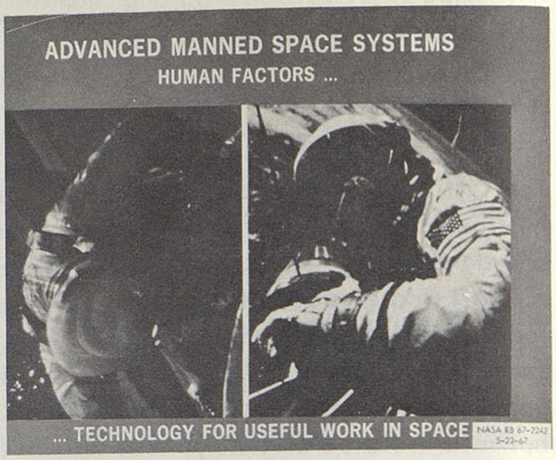

Fig. 5

In achieving these goals, we utilize the team concept of University-Government-Industry. We rely rather heavily on other government agencies for a helping hand--primarily DOD, and AEC, as shown in Figure 6. More recently, in the newly emphasized areas of pollution, we are collaborating with the Federal Water Pollution Control Administration of the Department of the Interior and have discussions underway with others. As shown here, NASA in-house research utilizes 10% of our R&D resources, Government 8%, Universities 14%, and Industry 68%. Our budget, shown on the bottom of Figure 6 reflects considerable growth from 14.9 million in '66 to 21.0 million in '68. Our efforts are coordinated with other NASA Life Sciences programs by OART's review of all SRT work units (Figure 7). The FY 68 units are being received now. Through the Life Sciences Sub-Panel of the AACB, the NASA-DOD coordination of over 4000 Life Sciences work units is actively underway. The NASA-FAA current work units are being coordinated by Dr. Siegel, of FAA, and myself.

I would like, now, to discuss with you, our increasing effort in the important area of advanced aeronautics. This is summarized in Figure 8. It covers work in all of our areas of effort--noise, human research, life support, and man-machine integration. Our noise research covers three areas--the measurement of community reaction to subsonic noise, the measurement of physiological effects of noise and sonic boom effects on sleep.

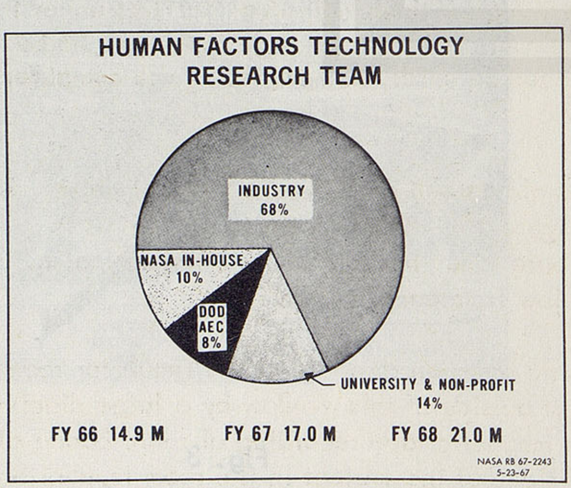

Fig. 6

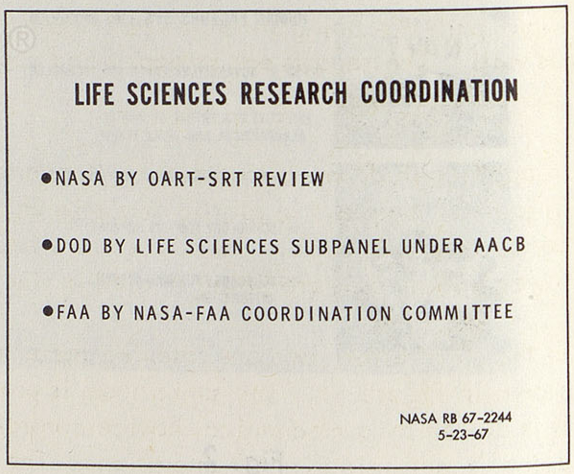

Fig. 7

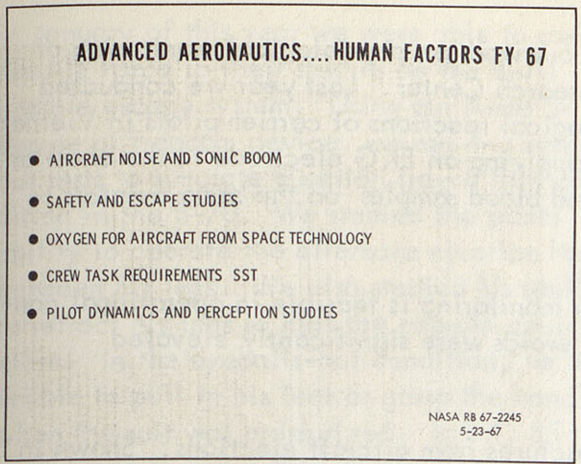

Fig. 8

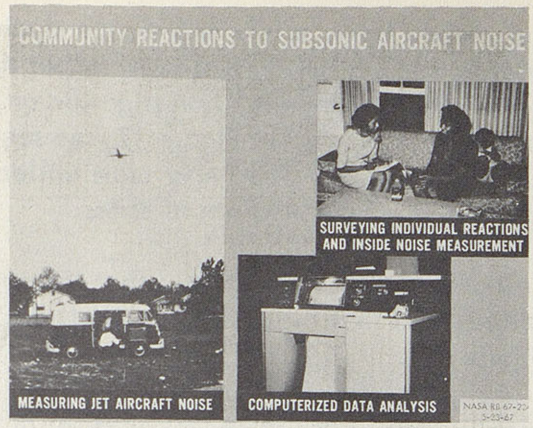

Fig. 9

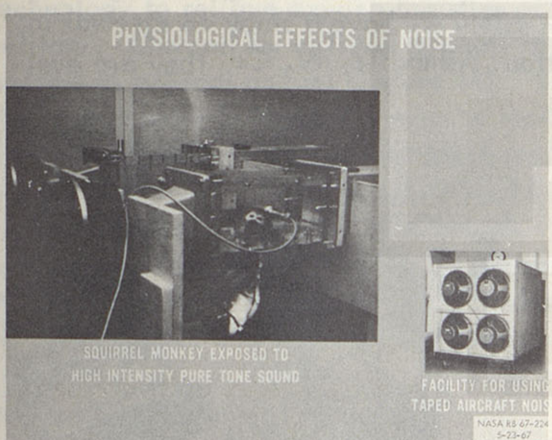

Fig. 10

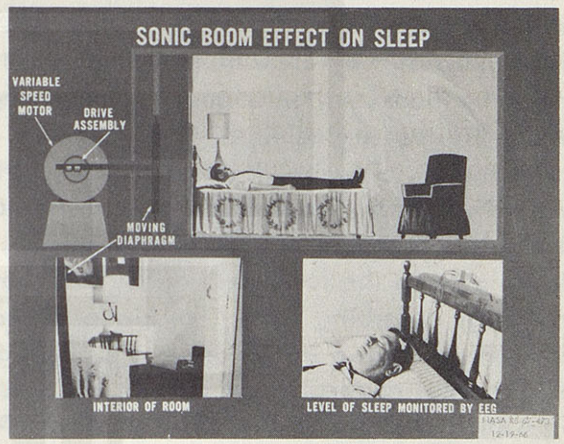

Fig. 11

We are utilizing TRACOR, Incorporated, of Austin, Texas, to conduct the needed field studies for community reaction ot subsonic aircraft noise. They are relating individual responses to the actual aircraft noise measured at major jet airports in the U.S. They are measuring the noise level of the aircraft in the airport traffic pattern at the same time individual families under the flight path are being interviewed (Figure 9). Noise measurements are made inside the house as well. The reports are screened and coded, punched on cards, and placed in the computer for the analyses.

In another study we are measuring the damage threshold caused by different types of noise, in squirrel monkeys in plastic acoustic chambers (Figure 10). The University of Illinois is conducting this work. The animals are exposed to pure tone, helicopter, and impact noise. The lower frequencies are being studied in the Langley low frequency facility.

In the third effort, we are studying the effect of sonic boom on sleep using the simulator room shown in Figure 11. The sonic boom is produced just outside of this window by a large diaphragm. It is driven by a mechanical device controlled by a magnetic tape recording of sonic booms of actual supersonic aircraft operations. The level of sleep of the subject in the room is monitored by electroencephalograph. The changes in level of sleep shown on the EEG will be correlated with the physical characteristics of the sonic boom signatures.

Our second item, safety and escape studies, incudes our work on physiological monitoring of aviators in high performance aircraft at the Flight Research Center. Last year we conducted the second NASA-Navy investigation on the physiological reactions of carrier pilots in Vietnam combat operations. In Figure 12, we see Dr. Lewis applying an EKG electrode to the chest of a Marine aviator. The Navy team collected urine and blood samples on the same aviators to obtain a hormonal measure of stress.

Preliminary analysis indicates that the cardiovascular monitoring is feasible in operational conditions, and that the serum phospholipids and urine steroids were significantly elevated (Figure 13).

Another item under safety is our study of vertebral fractures from aircraft ejections. Shown in upper left of Figure 14 is a fresh human vertebra mounted in the special-purpose testing machine to determine the dynamic stress/strain relationships in the spine. The picture below is a cross section of a fractured vertebra from an aircraft ejection. The chart on the right of Figure 14 indicates the rate of deflection upon stiffness. Also in safety we have a study on survival in civilian aircraft by Stencel Aero Engineering Corporation, Asheville, N. C. They are evaluating methods and techniques for improving the probability of survival in civilian aircraft emergencies. For speeds below 100 M.P.H. and with shallow flight path angles, internal safety concepts are feasible for saving life, as depicted in the lower left of Figure 15 by an energy absorbing seat. For higher speeds, however, as shown in the upper right of Figure 15, external concept requirements are needed. An example would be the lowering of the entire aircraft by parachute, or at least the inhabitated portion. Mr. Stencel has already demonstrated full scale such a scheme for helicopters for the Army.

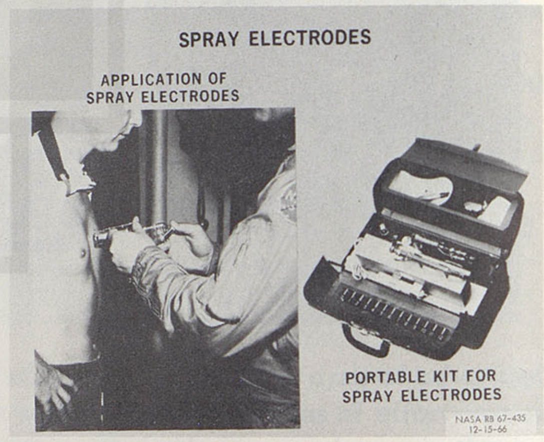

Fig. 12

PHYSIOLOGICAL REACTIONS OF CARRIER AVIATORS TO COMBAT

SECOND NASA-NAVY VIETNAM TEAM STUDY

PRELIMINARY ANALYSIS OF DATA INDICATES:

- MONITORING ATTACK CARRIER AVIATORS ON LARGE SCALE DURING COMBAT OPERATIONS IS FEASIBLE PRODUCES USEFUL SCIENTIFIC AND OPERATIONAL DATA.
- NASA TEAM CARDIORESPIRATORY DATA PROVIDED AN INDEX OF PHYSICAL AND NON-PHYSICAL STRESS RELATED TO PREVIOUS TEST PILOT RESPONSE DATA BANK.
- NAVY TEAM DETERMINATION OF SERUM PHOSPHOLIPIDS WERE SIGNIFICANTLY ELEVATED IN COMBAT AS WERE URINE STEROIDS.

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Fig. 13

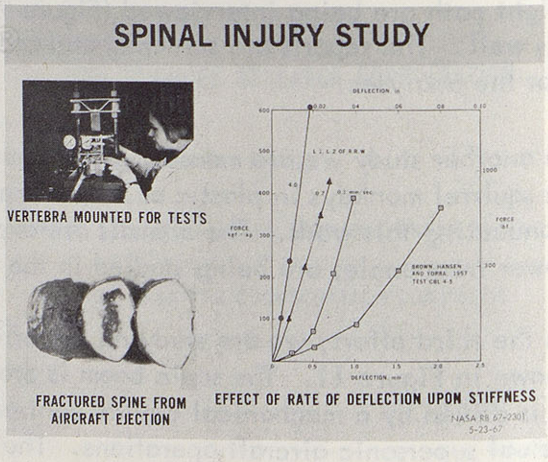

Fig. 14

In January of this year we were able to assist the Air Force in their studies on the B-70 capsule escape system. Using our Ames 5-degree of freedom device, we ran 4-g eyeballs-out tests to simulate ejection from a spin condition in the B-70. We studied the pilots ability to operate the alternate ejection handle between his legs. We also studied his ability to retract his legs so that the capsule could close. In the eyeballs-out condition, he was unable to pull in his feet or grasp the handle when the suit was pressurized. In all, 55 runs were made in seven days to complete the tests.

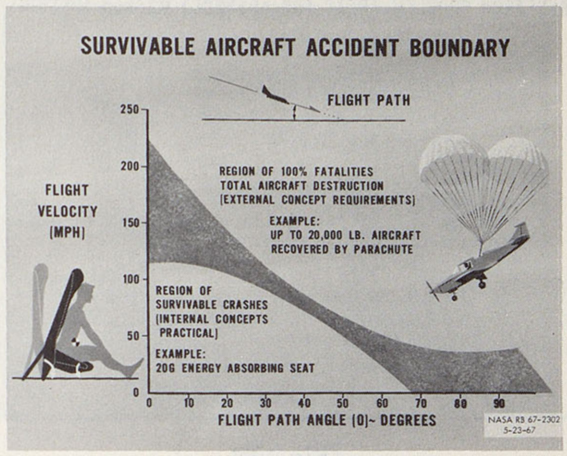

Fig. 15

In life support we are attempting to apply space technology to relieve oxygen logistics of the military. Oxygen for military aircraft has become as critical as fuel (Figure 16). Since they use cryogenic oxygen it must be made on the field or ship. This requires space and elaborate facilities, such as illustrated in Figure 17. Utilizing space electrolysis techniques, and aircraft power, The Ames Research Center is studying the electrolysis of water to provide oxygen while the plane flies. Carbon dioxide will be removed by a space electrochemical technique.

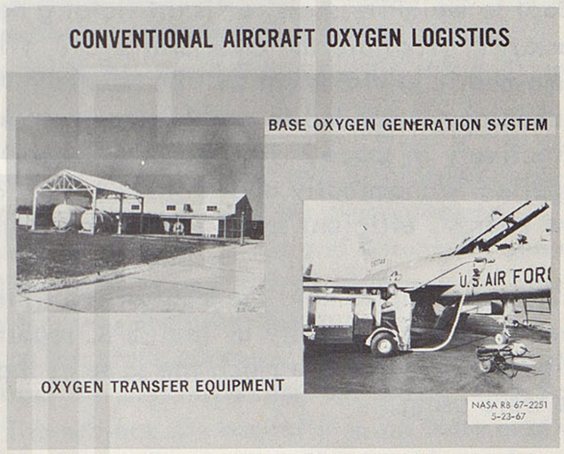

Fig. 16

The next item is the crew task requirements study of the super sonic transport. The crew factors are being studied for the Ames Reseach Center by Serendipity Associates. Information regarding the SST flight deck layouts and proposed SST operations were obtained from Boeing.

We will also study concepts of possible improvements of passenger provisions giving greater comfort, convenience, and protection at an economical weight. This completes my briefing of our aeronautical program in human factors.

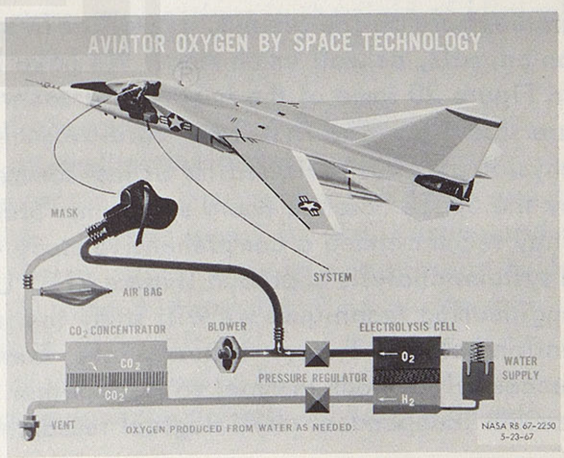

Fig. 17

Turning now to research for advanced manned space systems, you may recall last year we grouped our human factors work into pertinent problem areas as shown in Figure 18. These covered the physiological effects of the space environment, human engineering, and extra-vehicular technology, protective systems such

RESEARCH PROBLEM AREAS FOR ADVANCED MANNED MISSIONS

- PHYSIOLOGICAL EFFECTS
- HUMAN ENGINEERING
- EXTRA VEHICULAR TECHNOLOGY
- PROTECTIVE SYSTEMS
- LIFE SUPPORT

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Fig. 18

PSAC 1967

- IS AN ARTIFICIAL GRAVITY NECESSARY, AND IF SO, BY WHAT MEANS SHOULD IT BE SECURED?
- WHAT ATMOSPHERE SHOULD BE PROVIDED, AND WHAT DILUENT GASES SHOULD BE USED IN A MIXED GAS SYSTEM?
- WHAT ARE THE REQUIREMENTS FOR "COMFORTABLE LIVING," PARTICULARLY IN RELATION TO FEEDING AND HYGIENE?
- WHAT ARE THE OPTIMAL PROCEDURES FOR MAN'S UTILIZATION IN SPACE AS AN OBSERVER, AS A MECHANIC, AND AS A DECISIONMAKER?

...SPECIAL ATTENTION...LIFE-SUPPORT SYSTEMS, PSYCHOLOGICAL STUDIES...
...SPACE SUIT DESIGN.... WORK LOAD

NASA RB 67-2297
5-23-67

Fig. 19

as space suits, and life support for long duration flight. Our research, then, was programmed to answer such questions as: How will man adapt to weightlessness, or is artificial g necessary? What are the characteristics? What atmospheric environment will be needed? What technology is needed to enable man to work effectively in space? How can life support be supplied economically and reliably? How can low energy, efficient space suits be constructed?

It is interesting to note the similiarity of the questions posed recently by the PSAC report (Figure 19). They are much the same as those we were using.

We certainly are in agreement that the question of man's adaptation to weightlessness is a crucial one. The resolution of this question will require considerable research effort in studies here on the ground, as well as in space, on animals, as well as on man. We have listed in Figure 20 some of the important areas we are studying. The first item "cardiovascular physiology" was reviewed for us last summer by the Space Science Board's "Summer Study." They recommended a comprehensive study using a systems analysis approach (Figure 21). Using engineering techniques we will study the interaction between the sub-systems, using known successful methods in order to tie together the various independent physiological research data.

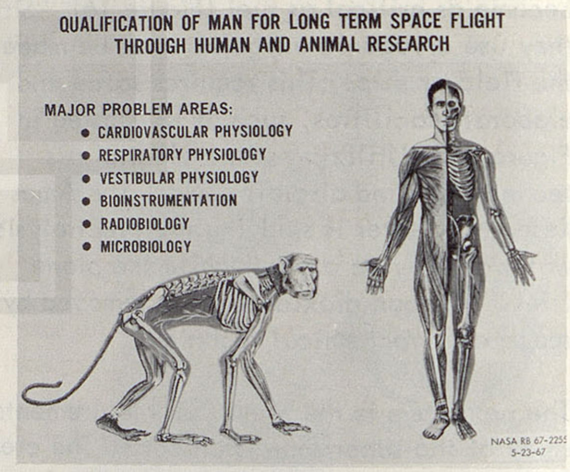

Fig. 20

PHYSIOLOGICAL SYSTEM ANALYSIS

- AN ENGINEERING STUDY OF INTERACTIONS BETWEEN BIOLOGICAL SUBSYSTEMS.
- BIOLOGICAL APPLICATION OF EXISTING METHODS SUCCESSFULLY USED IN ELECTRICAL ENGINEERING, CONTROL, AEROSPACE SYSTEMS.
- AN ATTEMPT TO TIE TOGETHER INDEPENDENT PHYSIOLOGICAL RESEARCH DATA.
- A STUDY OF BASIC PHYSIOLOGICAL CONTROL MECHANISMS - HOMEOSTASIS.

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Fig. 21

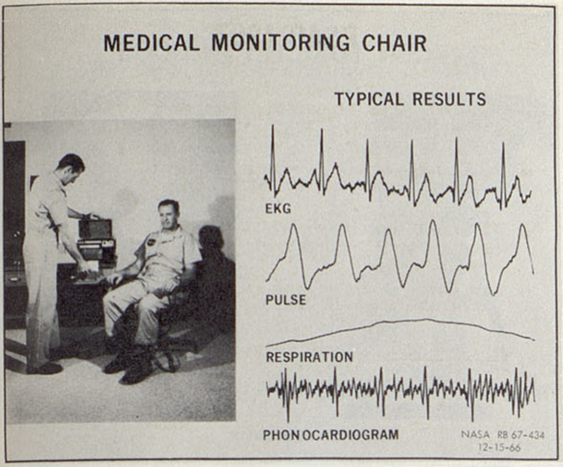

Fig. 22

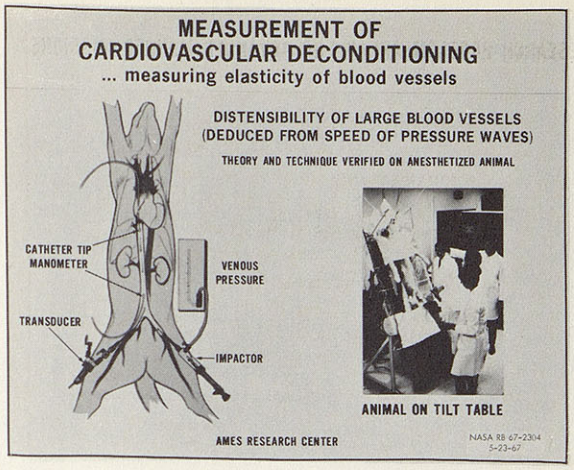

Fig. 23

Such a scheme then, will enable us to study the basic physiological control mechanisms. We would use conventional engineering methods in this effort. The advantages of this approach are that it permits a divide and conquer approach to complex physiological studies, the identification of primary control variables; it allows a prediction of system response in advanced environments; the identification of missing physiological links, and we can obtain information on system variables not experimentally available.

In order to do this research, we have an active program in advanced methods of bioinstrumentation. One method being studied for the Electronics Research Center uses ultrasonics to measure blood flow. This is being done by Dr. Franklin of Scripps Clinic and Research Foundation of Lajolla, California. Another example of this work is the Medical Monitoring Chair developed for ERC by the Philco Corporation. It obtains an electrocardiogram, pulse rate, respiration rate, and a phonocardiogram. The back of the chair contains the phonocardiograph sensor. The pulse and respiration rates are derived from the electrocardiogram which is obtained from sensors on the armrests as shown in Figure 22. The subject sits normally in an instrumented chair. The data is available real time from a chart recorder. As a spin-off from this work, the Ford Motor Company has placed a version of the recording equipment in the trunk of an automobile. Sensors fastened to the steering wheel provide stress measurements during automobile driving. The physiological responses can be studied under normal and hazardous traffic conditions. This measurement technique should have many applications in the field of clinical medicine.

The Ames Research Center is developing implantable instrumentation for our cardiovascular studies. The Ames instrumentation lab is developing an implantable pressure sensor for use in animals to make direct cardiac measurements. The unit will utilize a magnetic latch switch to turn the equipment on and off for power conservation. Also at Ames, Dr. Eric Ogden and Dr. Max Anliker are studying the elasticity of blood vessels using the speed of a pressure pulse wave as it is propagated through the vessels. Figure 23 shows a schematic of the system test conditions, and in the lower right a picture of an animal on the tilt table. A measure of the elasticity could be significant in measuring the state of deconditioning from weightlessness. Later, we feel this test can be accomplished on the surface of the animal, as well as on man himself.

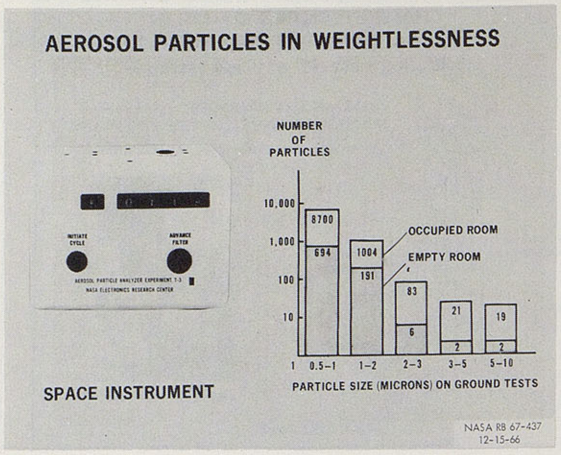

Fig. 24

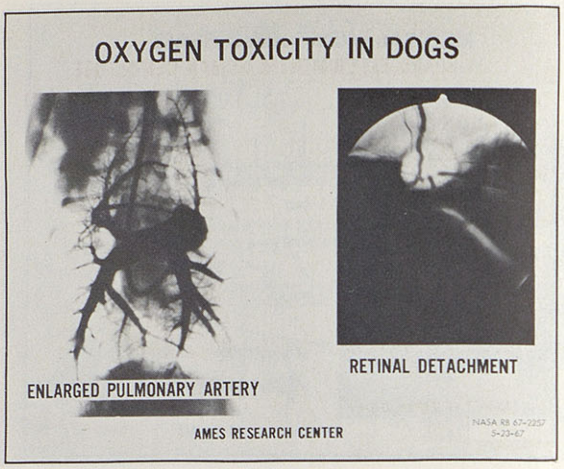

Fig. 25

The next study is respiratory physiology. To assist in planning our research upon which to base the selection of optimal atmospheres and pressures for astronauts on very long missions, the Space Science Board, at our request, conducted another Summer Study last year. It was on respiratory physiology.

One of the effects of weightlessness which they identified as potentially serious was the increased possibility of aspiration of particulate matter. In zero gravity conditions, dust particles do not settle out. This could lead to deposits in the respiratory tract which could have important implications in the production of pulmonary disease. An instrument has been developed for the Electronics Research Center by Block Engineering, Incorporated, to measure the number and size of such particles in a spacecraft. The particles are counted automatically and recorded in the windows shown in Figure 24. It is scheduled for an Apollo flight. Because of its size and convenience, this instrument may find many applications in air pollution studies.

In studying the mechanisms of oxygen toxicity at Ames, Mr. Brooksby has demonstrated various types of damage in beagle dogs. He showed an extreme lung and kidney sensitivity as well as eye damage. Shown in Figure 25 is the enlarged pulmonary artery caused by the vascular obstruction in the lung from the toxic reaction to oxygen and the resulting hypertension. Also shown is a detachment of the retina. Figure 26 summarizes in the third and fourth columns the various histological and ultrastructural changes we have observed from oxygen toxicity at various pressures in the different species studied. Note at the bottom of Figure 26 that one monkey at Ames was exposed to 5 psi O_2, as in Apollo, with no recognizible lesions in 77 days.

HISTOLOGICAL AND ULTRASTRUCTURAL CHANGES AFTER EXPOSURE TO 100% OXYGEN

	PO_2 mmHg	DURATION OF EXPOSURE DAYS	MAJOR HISTOLOGICAL CHANGES	ULTRASTRUCTURAL CHANGES
RAT	197	14 - 64	NONE	SOME OBSERVED BY OTHER WORKERS IN LIVER AND KIDNEY
	600	7 - 30	PULMONARY EDEMA, SEPTAL THICKENING	KIDNEY, LIVER AND LUNG CHANGES
	760	3 - 30	EMPHYSEMA	MASSIVE PULMONARY CHANGES
RABBIT	197 & 258	14 - 20	NONE	-
	300	7 - 30	PULMONARY EDEMA, ATELECTASIS	-
	450	3 - 10	MASSIVE PULMONARY EDEMA, ATELECTASIS, KIDNEY CHANGES	-
	600 - 760	3 - 4	ANIMALS DIE FROM PULMONARY EDEMA	-
DOG	300	4 - 10	PULMONARY EDEMA	-
	450	4 - 33	PULMONARY EDEMA, MASSIVE KIDNEY DAMAGE, RETINAL DAMAGE	-
	600 - 760	3 - 4	ANIMALS DIE FROM PULMONARY EDEMA	-
MONKEY	258	77	NONE	-

AMES RESEARCH CENTER

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Fig. 26

For human tests in weightlessness an on-board centrifuge is being studied as a possible AAP experiment by Langley, as shown in Figure 27. It would be located in the LEM section as in the S4B workshop. Cardiovascular and vestibular research would be accomplised on this device.

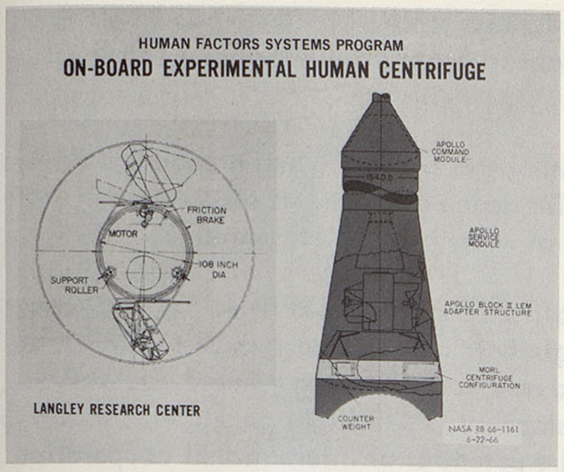


Fig. 27

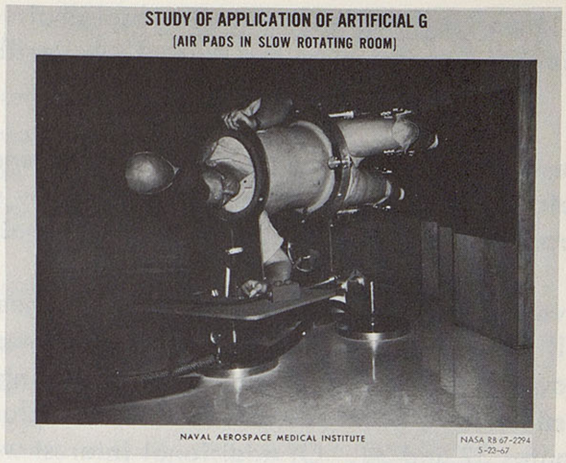


Fig. 28

General Dynamics has just been awarded the contract for this study.

Turning now to vestibular studies on humans, Dr. Graybiel of Pensacola is continuing his studies on men rotating as they might in a spacecraft with artifical G (Figure 28). The subject is supported horizontally and moves about in the rotating room on air pads. He is thrown against the outside wall by the centrifugal force, and with the foot friction can move about with ease. Using this technique, Dr. Graybiel studied the transitioning of four subjects to rotation of 4 rpm for 4 days compared to the same four subjects in a vertical attitude. The transition was excellent. Six rpm studies are being planned.

Dr. Graybiel is also the prime investigator on our AAP long duration primate experiment to delineate actual changes to weightlessness of 6 months to one year duration. Dr. Graybiel has been defining this experiment for several years in conjunction with the University of Illinois and the NIH Yerkes Primate Center at Emory University. Last September, a Planning Approval Document was signed authorizing two contractors to conduct Phase B studies. Shown in Figure 29 is Northrup's initial concept and Lockheed's is shown in Figure 30. This experiment should assist materially in the decision on the requirement for artificial G, as well as provide needed experience on life support systems and components.

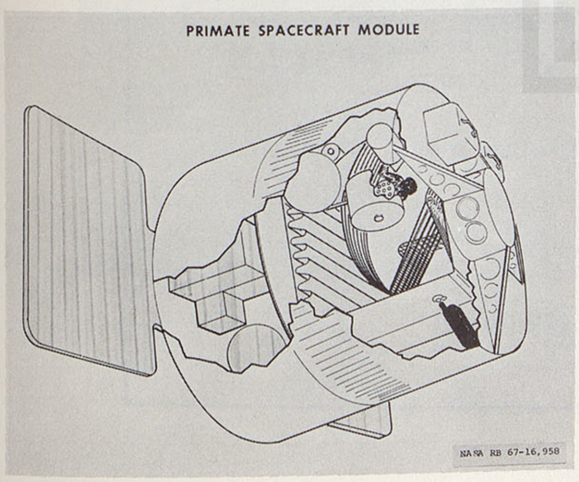


Fig. 29

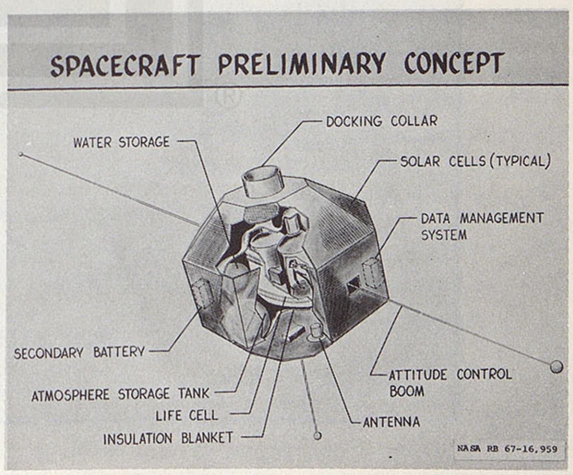


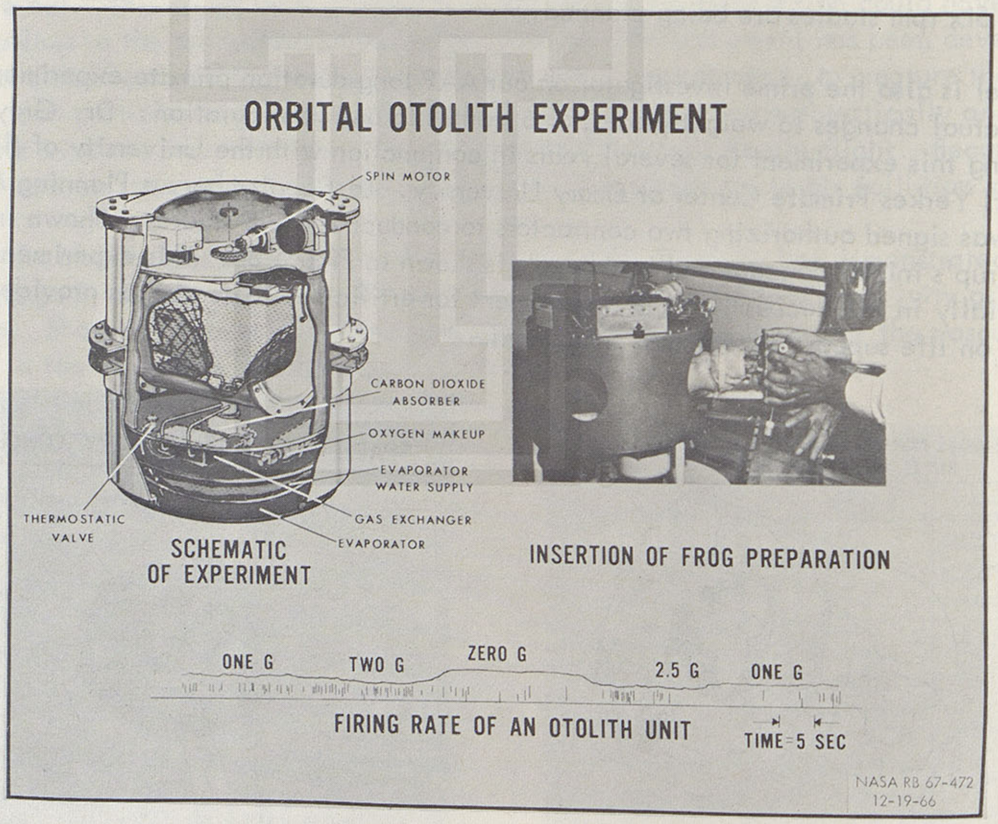
Fig. 30

In January of this year, Dr. Graybiel chaired the third Joint NASA-National Academy of Sciences Symposium on the Role of the Vestibular Organs in Space Exploration.

These meetings have become very well attended by authorities from here and abroad, to discuss their research on this little understood body system. The space program has served a very useful purpose in stimulating this research--the main benefit of which will be for mankind.

A vestibular flight experiment from Ames has been qualified for an Apollo flight. Dr. Gualteriotti will measure the adaptation to weightlessness of a single hair cell in a portion of the inner ear known as the otolith (Figure 31). It is being reviewed now as an AAP experiment, as well as possibly for a Scout launch. It could be placed in a standard OV-3 flight package as shown in Figures 32 and 33. Of additional interest would be the potential of international cooperation for future experiments. Dr. Gualteriotti is Italian and the Italians have the San Marco launch site.

For the future we are conducting a study through Douglas on a concept of a manned orbital animal research facility as shown in Figure 34. It would utilize the spent S-IVB stage and would be essentially comparable to an earth bound animal laboratory. Using such a facility, second order flight experiments of a more complex and sophisticated nature could be conducted in weightlessness with man in attendance.



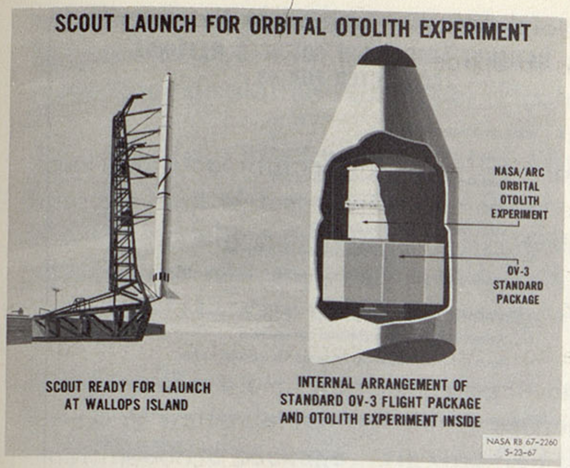


Fig. 32

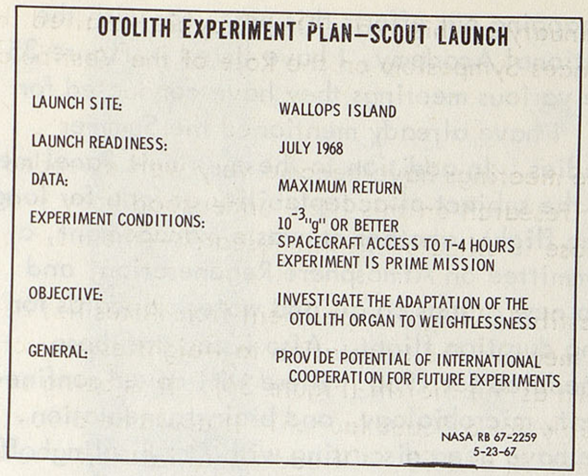


Fig. 33

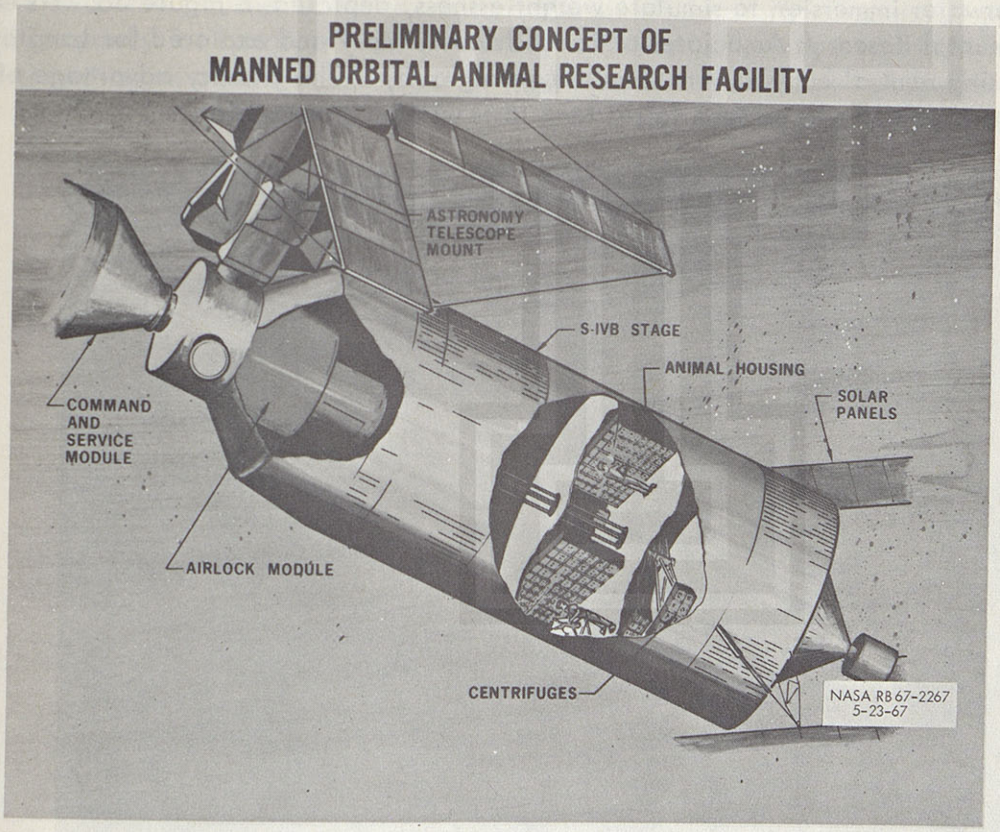


Fig. 34

Recapping our efforts this past year with the National Academy, I have listed in Figure 35 the various meetings they have conducted for us. I have already mentioned the Summer Studies. In addition to these, a new Panel met on the subject of acceptability of food for long term flight, another on waste management, a committee on Atmosphere Regeneration, and two new groups on air and water standards for long duration flight. Also listed are those scheduled for 1968. These will cover confinement, microbiology, and bioinstrumentation. We have been discussing with Dr. Bisplinghoff the possibility of some meetings with the Academy of Engineering next year. They will be on life support and extravehicular technology.

NATIONAL ACADEMY OF SCIENCES MEETINGS CONDUCTED FOR RB.

A. MEETINGS CONDUCTED IN FY 67.
1. SUMMER STUDY ON CARDIOVASCULAR PHYSIOLOGY
2. SUMMER STUDY ON PULMONARY PHYSIOLOGY
3. PANEL ON ACCEPTABILITY AND PALATABILITY OF FOOD
4. PANEL ON WASTE MANAGEMENT
5. COMMITTEE ON ATMOSPHERE REGENERATION METHODS
6. COMMITTEE ON AIR AND WATER STANDARDS FOR MANNED FLIGHT

B. SCHEDULED MEETINGS FOR FY 68
1. SUMMER STUDY ON ISOLATION AND CONFINEMENT
2. PANEL ON MICROBIOLOGICAL PROBLEMS FOR MANNED FLIGHT
3. PANEL ON BIOINSTRUMENTATION

National Academy of Engineering: discussions on possible meetings on life support and EVA.

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5-23-67

Fig. 35

Our next major area of effort is on Human Engineering in Space Systems. A condition important to these studies is the ability to simulate zero gravity. The Langley Research Center pioneered the use of underwater immersion to simulate weightlessness, depicted in Figure 36. As early as 1964, Environmental Research Associates of Randallstown, Maryland explored for Langley the feasibility of using neutral buoyancy to simulate zero gravity. The primary advantage of this technique is the capability to perform fairly long tests without interruption.

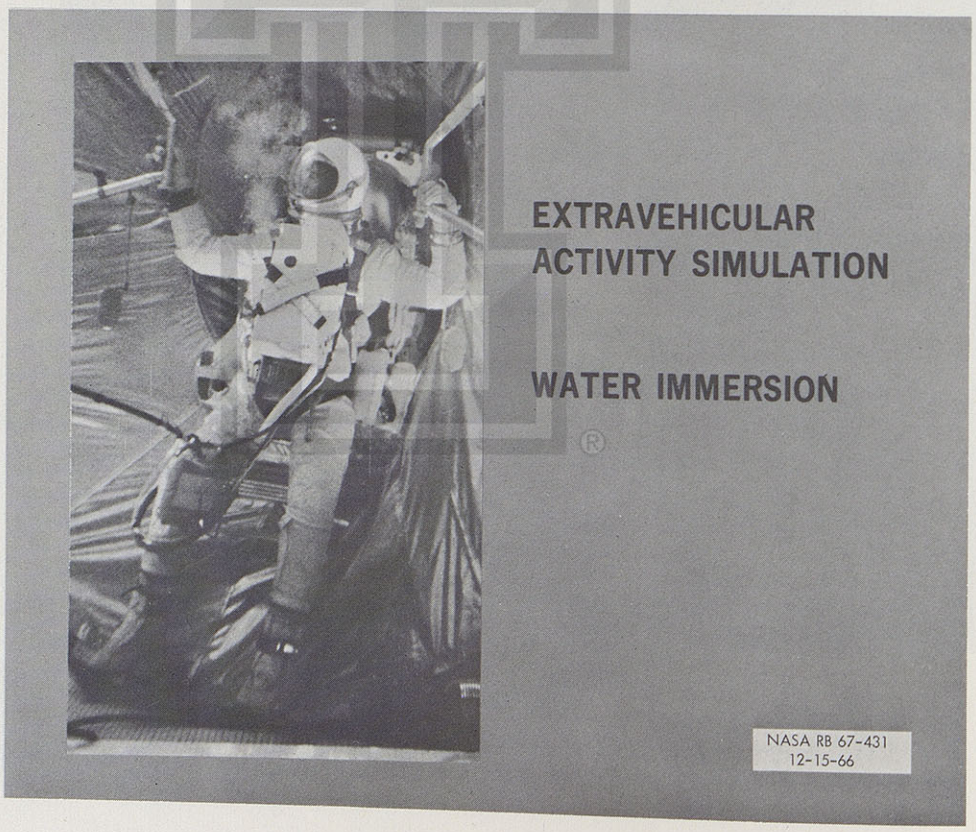

Fig. 36

Mr. Otto Trout of Langley recently received a performance award for his development of these underwater simulation techniques (Figure 37).

These facilities and techniques were utilized by the astronauts of the last Gemini flights. Mock-ups of the docking adapter of the Agena, the Gemini nose section, and the EVA work equipment in GT-12 were used by Astronaut Aldrin.

In Figure 38 we see Aldrin working at neutral buoyancy while detaching and inspecting a micrometeorite package. He modified the planned procedures as he became more familiar with the activities.

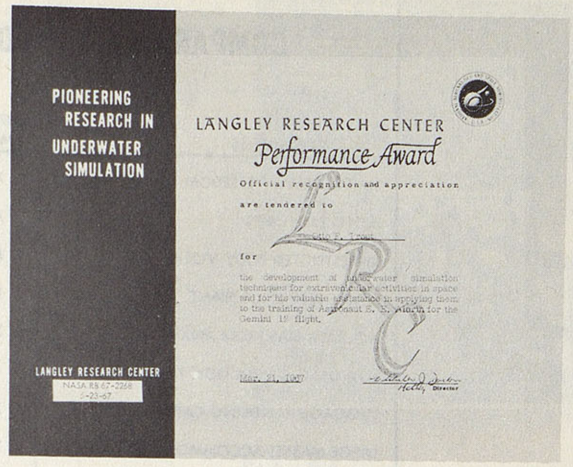

Fig. 37

He returned to the water tank to re-evaluate his experience in flight. He found the underwater experience very beneficial in practicing his actual EVA tasks.

We have two other studies underway using water simulation. The Garrett Corporation is utilizing neutral buoyancy for Langley to study man's performance of maintenance tasks in zero gravity, such as erecting an antenna assembly. Several restraint devices are being used in this study.

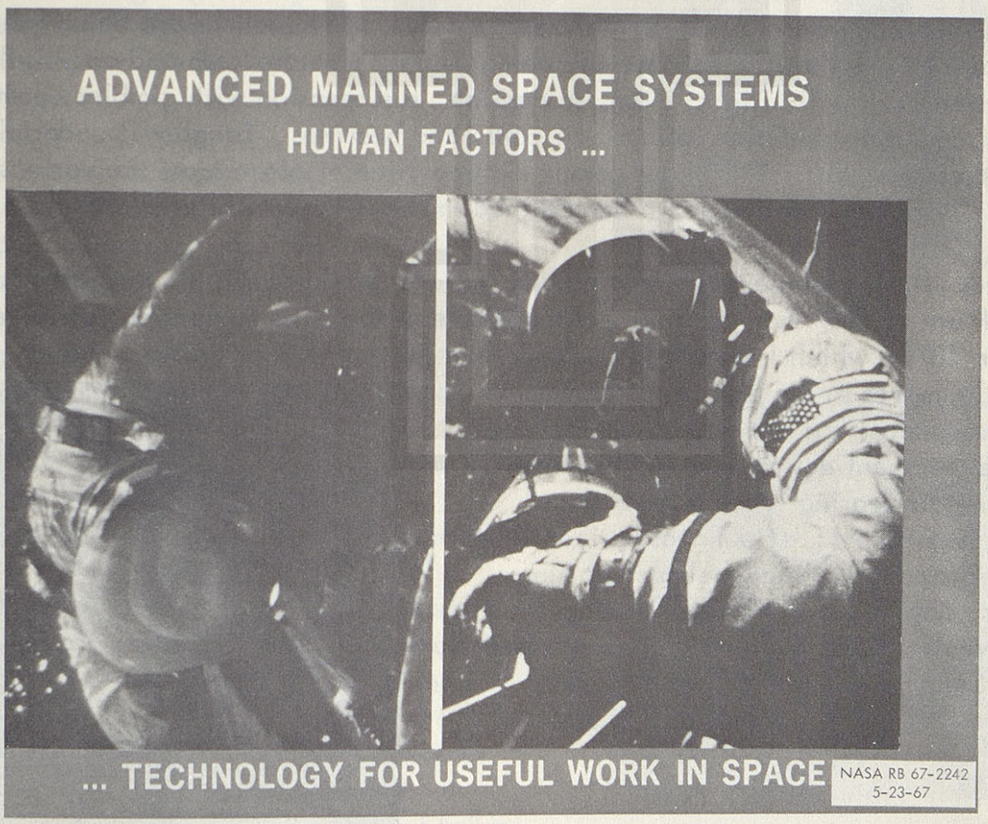

Fig. 38

COMPARISON OF REDUCED GRAVITY SIMULATIONS

CAPABILITIES	WATER IMMERSION	PARABOLIC FLIGHT	SLING SUSPENSION	SLING SUS. & GIMBALS	AIR PADS	AIR BEARINGS AIR PADS & SPRINGS
SIX DEGREES OF FREEDOM	X	X		X		X
LONG TEST TIMES	X		X	X	X	X
UNRESTRICTED BODY MOTIONS	X	X				
STABLE REFERENCE FRAME	X		X	X		X
NO DATA BIAS FROM ANXIETY	X		X	X	X	X
LOW DRAG OR FRICTION EFFECTS		X			X	X
LUGGAGE HANDLING CAPABILITIES	X	X				
LARGE MASSES ACCOMMODATED	X		X	X	X	X
DELICATE EQUIPMENT HANDLING	X		X	X	X	X
VALID PROPULSION TESTING				X		X
STABILITY SYSTEM TESTS POSSIBLE		X		X		
OVERALL EFFECTIVENESS RATING (PRIMARY SOURCE: LRC)	8	5	5	8	5	8

NASA RB 67-2296
5-23-67

Fig. 39

In addition to the underwater simulation of zero gravity, other methods are being used. Compared in Figure 39 are six different methods being used to simulate zero and one-sixth gravity: water immersion, parabolic flight, sling, suspension, a suspension with gimbles, combinations, and air pads, and a combination springs, air pads, and bearings. Langley is undertaking a study to compare these methods. This might permit extrapolation of data across the various simulation techniques. Space verification might be obtained in the S-IV-B Orbital Workshop.

I have already illustrated the water method and you are familiar with the aircraft parabolic flights which are of very short duration. An example of the sling suspension is the Jet Shoes study (Figure 40) on which I reported last year. In this case he moves in the horizontal plane. The Jet Shoe concept has been approved for AAP flight experiment definition. An example of air pad and air bearing is the maintenance study shown in Figure 41. He moves horizontally on the air pads while gimbels permit him to rotate his body. Another method having vertical movement uses negator springs suspended from air pads above, has developed this six degree of freedom simulator shown in Figure 42.

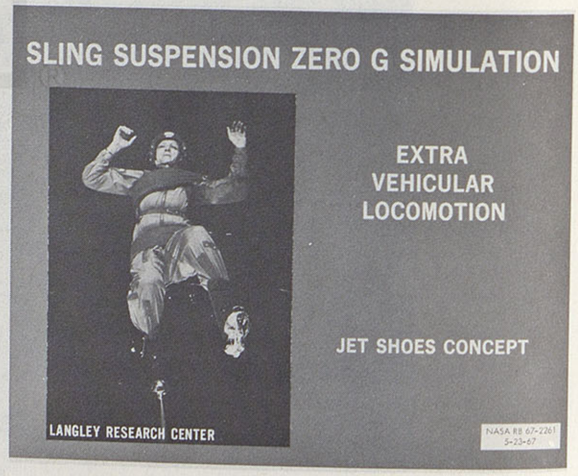

Fig. 40

Fig. 41

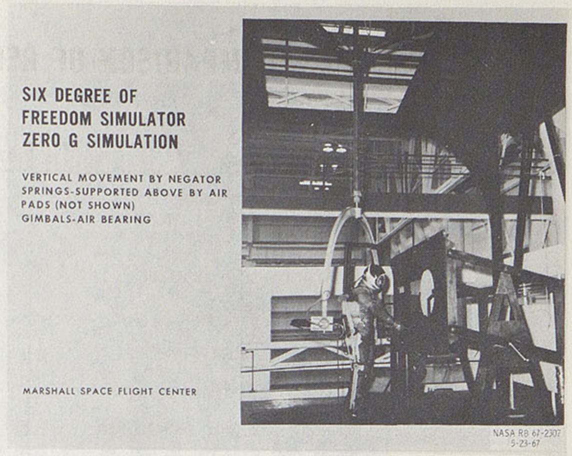

Fig. 42

In the area of individual lunar propulsion, Langley has developed a one-man propulsion unit, depicted in Figure 43, which is intended to study the basic dynamics of manned extra-vehicular propelled equipment. A combination cable suspension and gimbal arrangement will be used to simulate the one-sixth gravity. The unit has two rocket motors using hydrogen peroxide fuel.

A similar system built by the Bell Aerosystems Corporation is undergoing testing at Langley for OMSF and the Marshall Space Flight Center. It is using the Lunar Landing research facility shown in Figure 44.

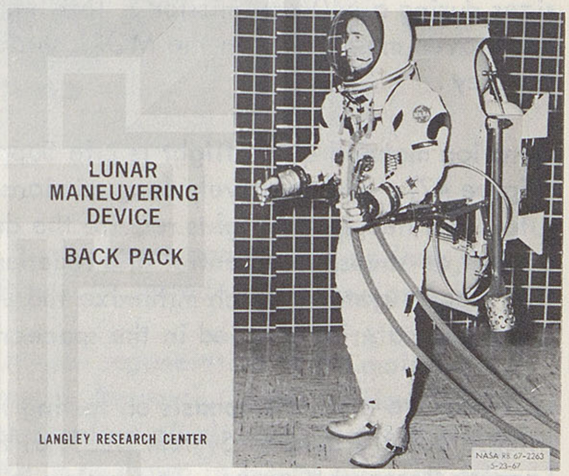

Fig. 43

In studying the human engineering interface between the RX-3 hard suit (Figure 45) and a lunar vehicle concept we used the tank simulator of the Army Tank and Automotive Center.

The seating dynamics with the hard suit were studied by programming various lunar surfaces and vehicle velocities into the simulator. The speed ranged from 2.5 mph to 7.5 mph.

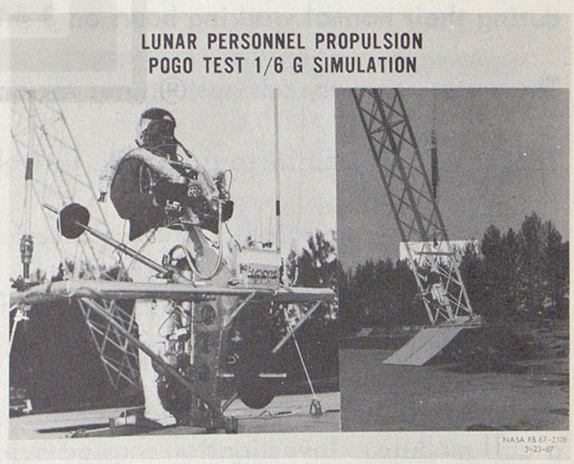

Fig. 44

As listed in Figure 46, computerized information concepts are being used in several areas of interest. The Preliminary Requirements Model (PRM) of the Space Station Computer Program has been used by the Langley Research Center to study the effects of proposed experiment packages in an orbital laboratory on manpower skills and crew sizes. The upper graph shows the sensitivity of the percent of expeiment hours completed as a function of degree of cross training the crew.

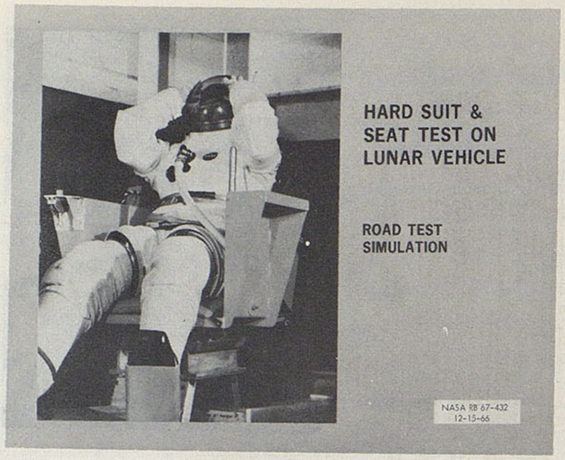

Fig. 45

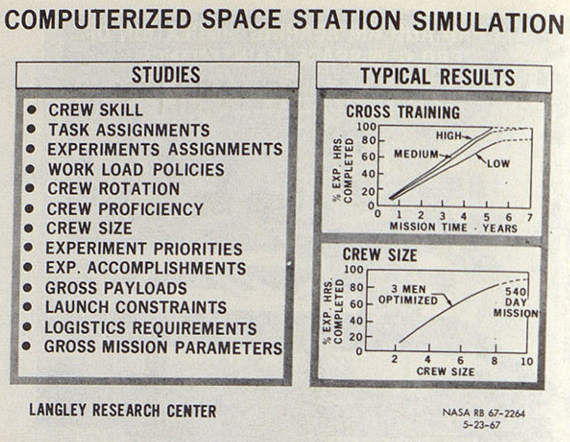

Fig. 46

The lower graph in Figure 46 shows the percent of experiment hours completed by various crew sizes during a 540-day mission. This technique has proven most useful in the MORL studies at Langley.

Duration manned space flight is Life Support (Figure 47). The relatively long missions of future manned space flights require the development of atmosphere control and regenerative life support systems which minimize the expendable materials carried in the spacecraft.

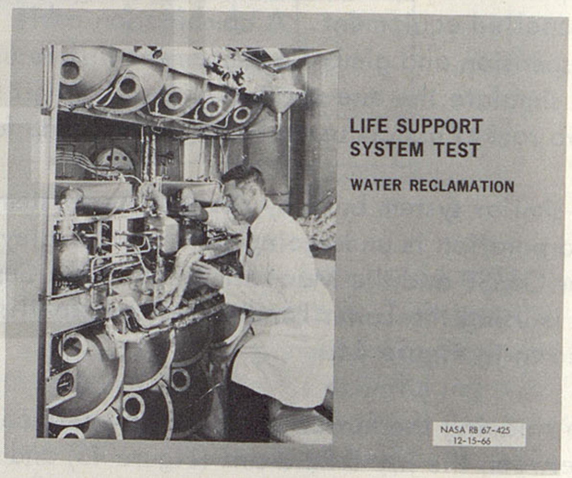

Fig. 47

Last year we placed emphasis on testing this Integrated Life Support System (ILSS) at the Langley Research Center. This system is a regenerative type-recycling oxygen and water. We completed a 7-day closed door test with this equipment. The engineers acted as subjects during their normal working hours on 3 shifts, coming and going as necessary.

The water recovery sub-system uses replaceable wicks.

The water is stored in zero G tanks. A bladder arrangement forces the water out as needed.

The system is monitored outside by television and by instrumentation. Atmospheric constitutents are monitored continuously,backed up by a wet chemical laboratory test . A few problems were expected in the test and did occur during the early phases. The difficulties included corrosion leakage of the electrolysis cell cooling tubes.

Early in the run, it was noted that nitrogen was leaking into the coolant circuit somewhere in a cell module. Investigation showed evidence of corrosion at the point where the tube penetrated the electrolyte spacer shown in Figure 48. This is the type of trouble that might be expected on a long duration mission. This module had been in use off and on for over a year.

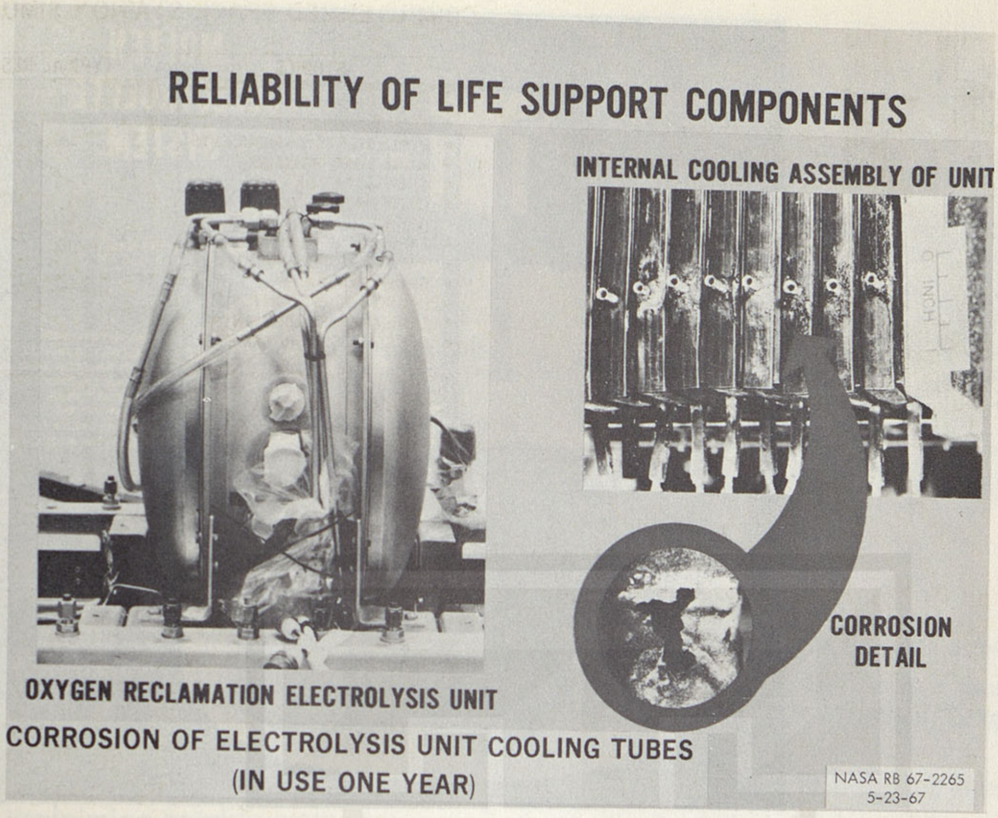

Fig. 48

We plan to continue these tests throughout this next year to gain more actual data on long term equipment performance. Later more advanced components will be tested in this simulator.

One of our advanced sub-systems under development for oxygen regeneration is the molten electrolyte (Figure 49) process being developed for the Langley Research Center by Hamilton Standard of Windsor Locks, Connecticut. This system uses a molten alkali carbonate electrolyte at 1200°F. Here the cabin gas is brought into the hot mixture as shown in Figure 50. The carbon ions move to the right electrode and are deposited. The molecular oxygen is liberated at the left electrode and enriches the remaining air as it passes back to the cabin. We have tried several different electrode designs for the carbon electrode. We use a gold anode which presently liberates 98% pure oxygen.

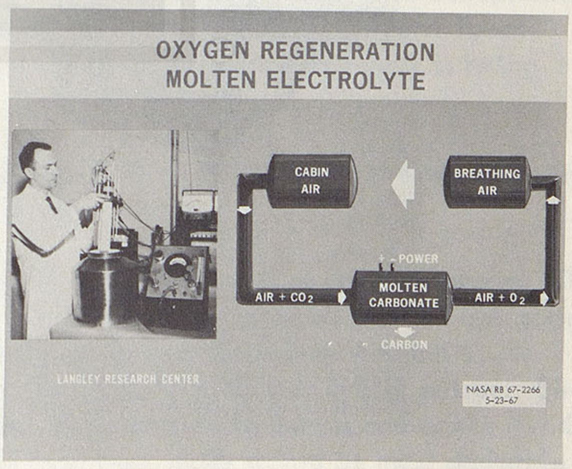

Fig. 49

One of the more difficult problems in life support processes is humidity control in zero gravity, depicted in Figure 51. One new concept for this water separation is being investigated for Langley by Lockheed. It utilizes hydrophobic (non-wetting) and hydrophilic (wetting) surfaces to effect phase separation. The air stream, containing the water droplets is drawn off the hydrophobic surface onto the hydrophilic surface, and are collected through tiny holes. The water extracted from the air stream can then be processed as condensate to make potable water.

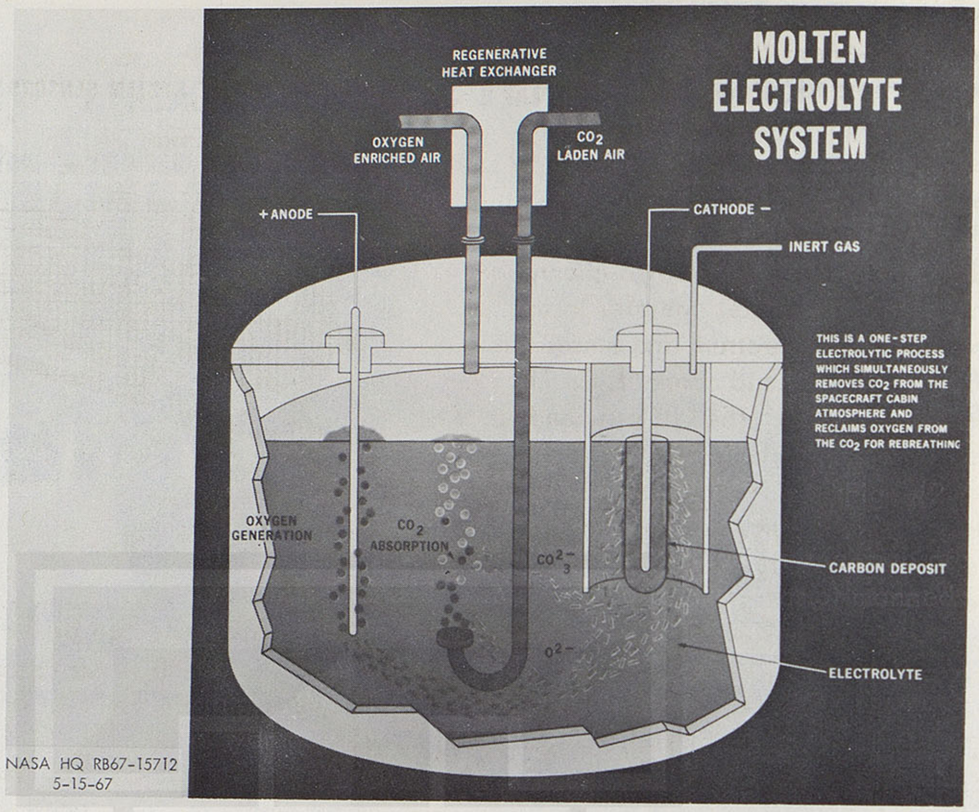
MOLTEN ELECTROLYTE SYSTEM
REGENERATIVE HEAT EXCHANGER
OXYGEN ENRICHED AIR
CO_2 LADEN AIR
+ ANODE
CATHODE −
INERT GAS
THIS IS A ONE-STEP ELECTROLYTIC PROCESS WHICH SIMULTANEOUSLY REMOVES CO_2 FROM THE SPACECRAFT CABIN ATMOSPHERE AND RECLAIMS OXYGEN FROM THE CO_2 FOR REBREATHING
OXYGEN GENERATION
CO_2 ABSORPTION
CO_3^{2-}
O^{2-}
CARBON DEPOSIT
ELECTROLYTE
NASA HQ RB67-15712
5-15-67

Fig. 50

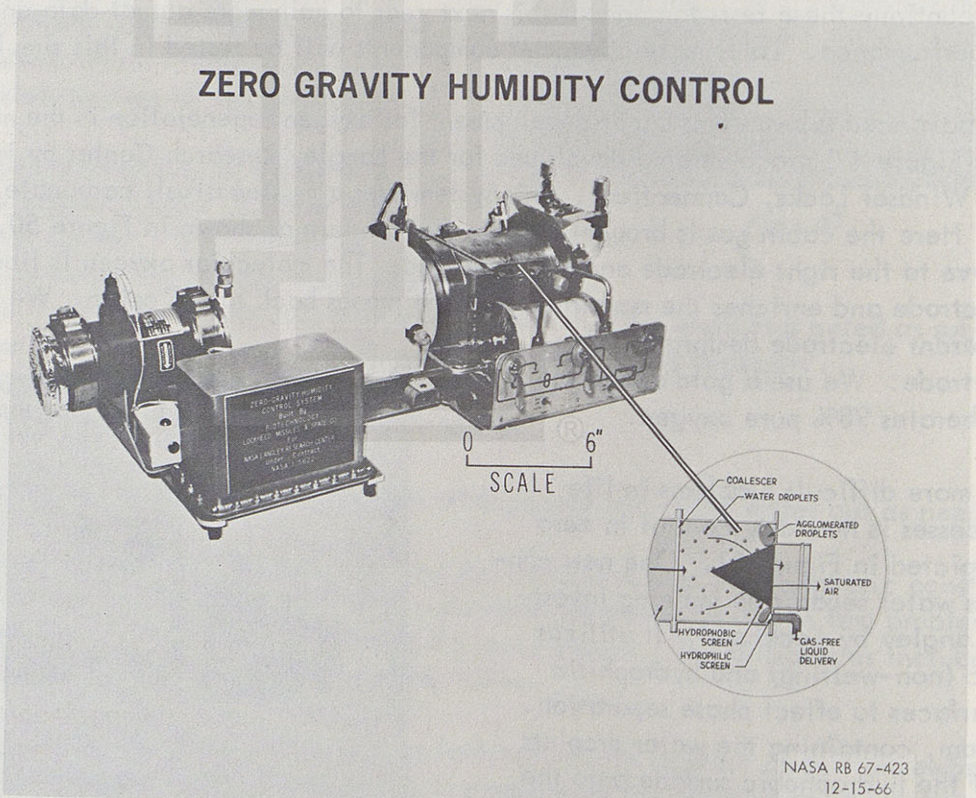
ZERO GRAVITY HUMIDITY CONTROL
0
6"
SCALE
COALESCER
WATER DROPLETS
AGGLOMERATED DROPLETS
SATURATED AIR
HYDROPHOBIC SCREEN
HYDROPHILIC SCREEN
GAS-FREE LIQUID DELIVERY
NASA RB 67-423
12-15-66

Fig. 51

The Langley Research Center is continuing our work on the development of reliable, flight type, two gas sensors for atmospheric control. They are completing two development efforts. The breadboard instrument shown in Figure 52 is being developed by Perkin-Elmer. It measures continuously oxygen, carbon dioxide, water vapor, and the inert gas. It is a two channel instrument. The first channel operates in the infrared portion of the spectrum and senses the carbon dioxide. The second channel, by UV senses oxygen and water. The UV provided by the miniature Zenon discharge lamp passes through a chopper which is synchronized to decode the UV and IR signals. The amount of inert gas is determined electronically using these values and the total pressure. The other device uses a mass spect technique, in which the ionized gases are deflected by a magnet according to their mass, into a collector, indicating their concentration. It is manufactured by the Aerospace Division of Perkin Elmer, formally the Scientific Data System Company, of Pomona, California. These units will be delivered later this year.

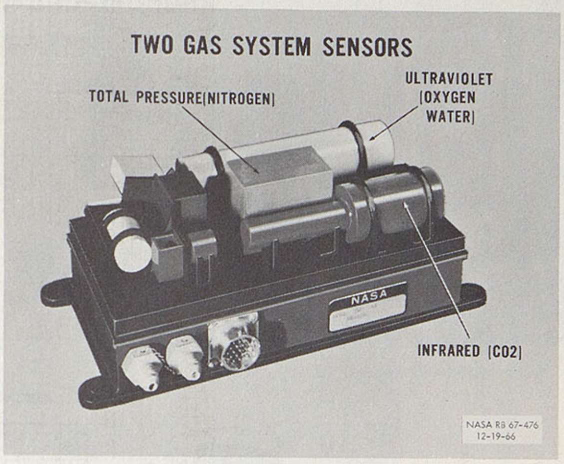

Fig. 52

As shown in Figure 53, we have several new concepts under study for re-cycling water. One method for reclaiming potable water from urine which offers great promise is under study for Langley by Hamilton Standard. It utilizes a membrane diffusion technique. Urine contains various electrolytes, water soluble and suspended organics and a variety of volatile substances with boiling points so close to water that separation by distillation is difficult. In the membrane diffusion technique, illustrated in Figure 54, the water passes through a selective membrane and evaporates from the other side into an evacuated chamber where it is condensed by a cooled porous plate. The concept is capable of using waste heat to provide the driving force necessary to overcome the resistance of the membrane to water vapor flow. It uses capillary action for condensation and collection of purified water. Testing and membrane improvement studies will continue in the laboratory.

Our research in food management for long duration flight is concerned with food storage, preparation and consumption techniques. This past year we became concerned with the acceptability of the food for long periods of time. As I mentioned earlier, an Academy of Science Panel reviewed this problem for us. Some of our compressed food which you saw last year is being tested for acceptability and nutrition.

The crews bypassed specially prepared meals for beef steaks which they cooked themselves. The aircraft are now so configured for this morale boosting item.

For cooking such conventional foods in space, we are investigating small microwave ovens. The oven shown in Figure 55 is installed in an airline on a European run. Several airlines are going over to microwave techniques primarily because of the time saving in heating the meals. A frozen 14 oz. steak, as shown here, can be cooked in two minutes with two cyclic pulses. Since ice is transparent to microwaves, the first pulse defrosts the steak while the second cooks it. On very long interplanetary missions, the regeneration of food from water would be most desirable (Figure 56).

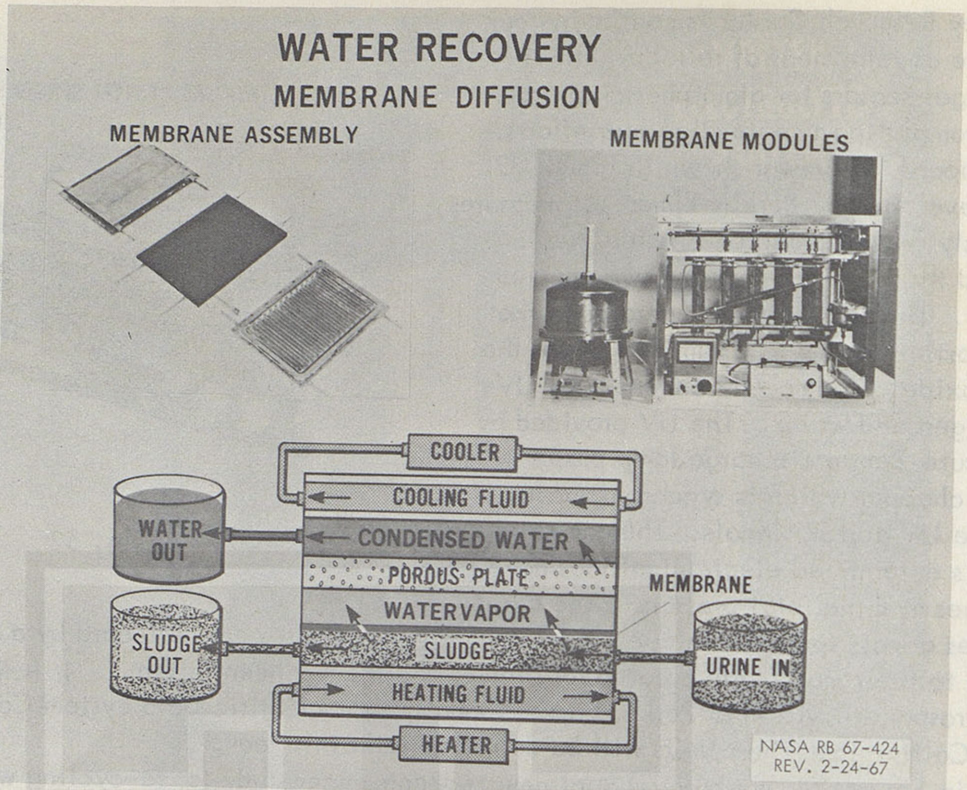
WATER RECOVERY
MEMBRANE DIFFUSION
MEMBRANE ASSEMBLY
MEMBRANE MODULES
COOLER
COOLING FLUID
WATER OUT
CONDENSED WATER
POROUS PLATE
MEMBRANE
WATERVAPOR
SLUDGE OUT
SLUDGE
URINE IN
HEATING FLUID
HEATER
NASA RB 67-424
REV. 2-24-67

Fig. 53

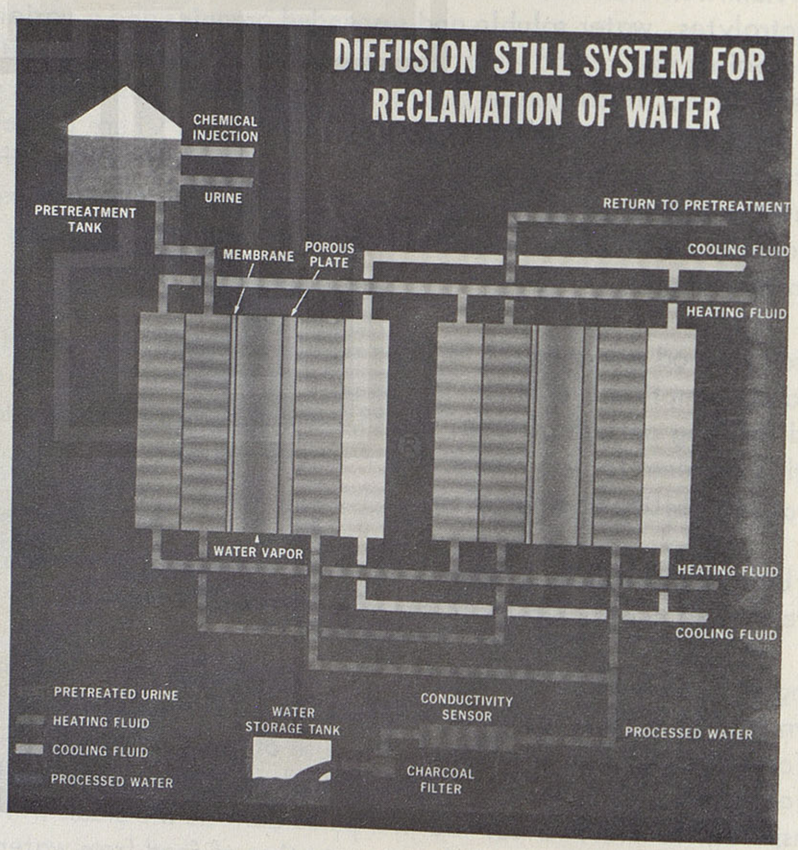
DIFFUSION STILL SYSTEM FOR RECLAMATION OF WATER
CHEMICAL INJECTION
URINE
PRETREATMENT TANK
RETURN TO PRETREATMENT
COOLING FLUID
MEMBRANE
POROUS PLATE
HEATING FLUID
WATER VAPOR
HEATING FLUID
COOLING FLUID
PRETREATED URINE
HEATING FLUID
COOLING FLUID
PROCESSED WATER
WATER STORAGE TANK
CONDUCTIVITY SENSOR
PROCESSED WATER
CHARCOAL FILTER
NASA HQ RB67-15713
5-15-67

Fig. 54

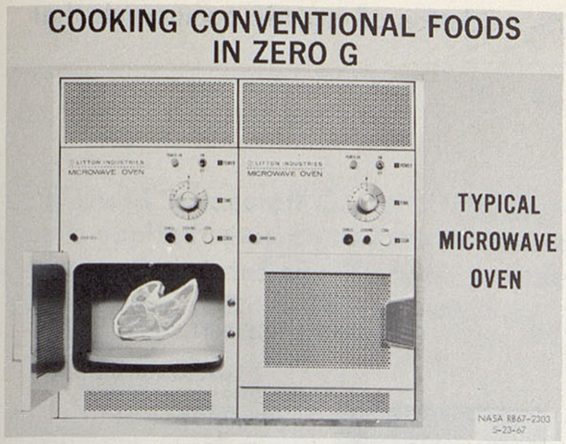

Fig. 55

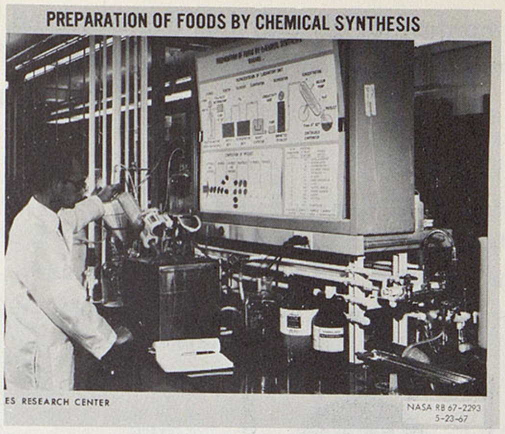

Fig. 56

In the synthesis of sugars for possible use as food in prolonged space mission, Dr. Shapina, of Ames, found it is possible to prepare diets containing very large amounts of simple organic compounds which gave good growth to young rats. Ames plans to obtain industrial assistance in the preparation of these compounds for larger scale tests next year.

As illustrated in Figure 57, for waste management, we have several advanced techniques under study.

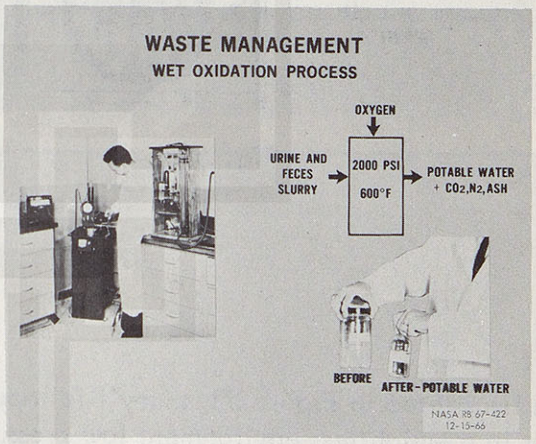

Fig. 57

A new technique called the wet oxidization process, is being developed by the Whirlpool Corporation of Benton Harbor, Michigan. They are studying the basic principle of combusting wastes with air at high pressures. This oxidizes the organic matter in a wet state completely, with end products of steam, nitrogen, carbon dioxide, and ash. The gases can then be recovered by conventional methods.

In a joint program with the Water Pollution Control Administration (WPCA), Department of the Interior, we are studying another oxidative process on sewage effluents. This process uses normal temperatures and pressures which makes the process attractive to earth systems as well as to space systems. The Taft Sanitary Engineering Center (Figure 58) of the Federal Water Pollution Control Administration will monitor this effort for us.

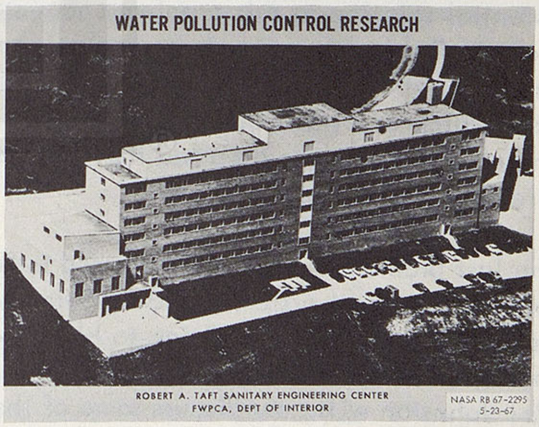

Fig. 58

The contractor already has demonstrated better than 50% oxidation of organic compounds that normally cannot be attacked by bacteria.

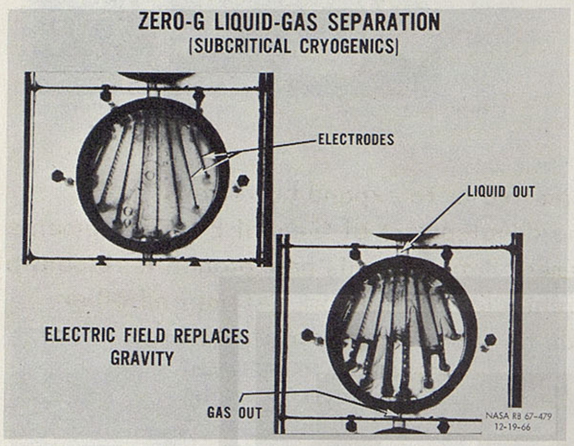

Fig. 59

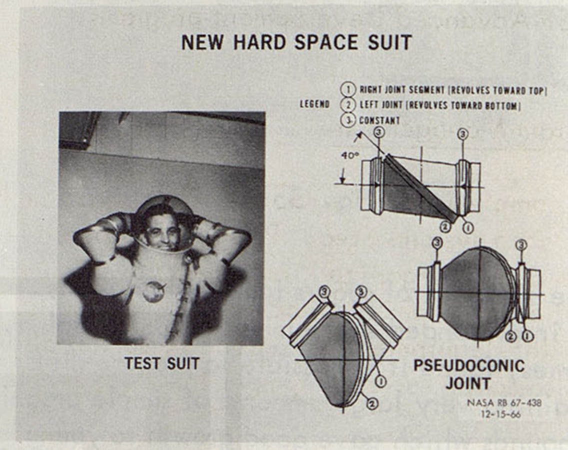

Fig. 60

As illustrated in Figure 59, many life support systems of the future will utilize cryogenic stores, but in a weightless environment low pressure cryogenics do not separate from the gas as in aircraft gravity systems, so that gas only can be withdrawn. At present super-critical techniques are used in weightlessness with the accompanying weight penalty. A sub-critical gas storage system would be attractive if the gas and liquid could be separated in zero-gravity. One potential solution to this problem under study for us by the Air Force at Wright Field uses an electric field to impart a force replacing the gravity field which normally orient such liquid gas mixtures here on earth. The fluid in the tank is oriented by means of fan shaped electrodes upon which a voltage of several thousand volts is imposed. Practically zero current is required. The electrodes are so oriented that surface tension applies a force to the liquid in the same direction as the electric field.

The last problem area to be discussed is Personal Protective Systems, such as space suits, personal life support systems, and restraint systems. Mr. Dick Johnston, will discuss most of our work in this area. In addition to his work, the Ames Research Center developed the new hard space suit and is shown in Figure 60. It uses a new pseudoconic joint with very little torque. Mr. Johnston will now discuss some of the advanced technology efforts his group is doing for us in OART.

CREW SYSTEMS EQUIPMENT

By: Richard S. Johnston (MSC)

The Manned Spacecraft Center life support systems development programs are primarily directed towards applied research and the development of equipment for approved manned space flight programs. This briefing will cover program management, Apollo support, OART projects, and OMSF Advanced Development programs.

Program Management

The completion of the Gemini flight program has permitted us to expand our efforts in the advanced systems area. Personnel responsible for the development of Gemini EVA equipments have been reorganized into an Extravehicular Equipment Branch. This new branch is responsible for the development of advanced space suits, extravehicular life support systems and other ancillary equipments. (Branch personnel also provide an in-house capability to solve minor Apollo space suite equipment interface problems.)

Figure 1 shows a summary of the Crew Systems Division budget for the current fiscal year. The total budget was 32.5 million dollars. OART funds accounted for 2.7 percent, Gemini support 2.8 percent, AAP support 10.2 percent, and Apollo support 84.3 percent. The Apollo budget mainly provides for the development, qualification and procurement of government furnished equipments. The AAP funding is being used primarily for the development of experiments equipment. The Gemini budget was used to close out the support required for the last manned flights. The table shows that our planned commitments have, by in large, been met. Our OART program, which has been a commitment problem in past years, is essentially 100 percent committed.

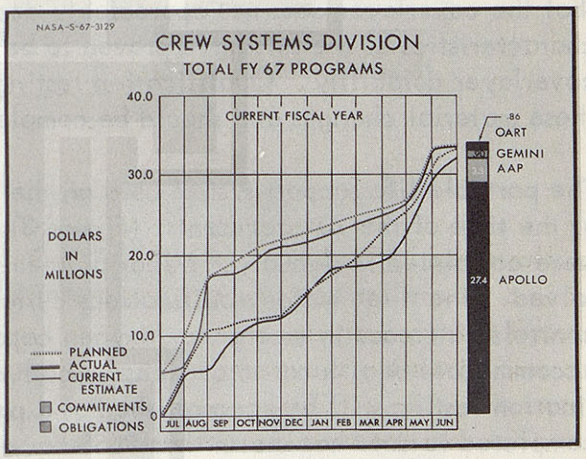

Fig. 1

Apollo Support

The Apollo crew equipment and life support systems have, as a result of the Apollo 204 accident, undergone an extensive design review. Major emphasis has been devoted to the removal of combustible nonemtallics from crew equipment and the spacecraft crew bay area. The spacecraft environmental control system design has been reviewed and changes are being made to enhance crew safety. The results of these reviews and the proposed changes to both crew equipment and environmental control systems have been reported in depth previously and are covered in two MSC working papers (Ref. 1 and 2), therefore I would only like to give a short status report on a couple of the major items.

Extravehicular Mobility Unit

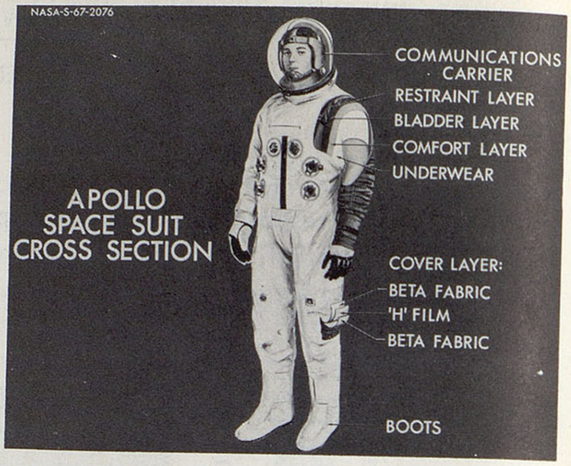

Fig. 2

The space suit has undergone an extensive redesign to eliminate as many combustibles as possible. Figure 2 shows a drawing of the Apollo space suit and illustrates how a flame protective coverlayer is being integrated into the basic garment. The outer coverlayer is being changed from a high temperature nylon to a noncombustible beta fabric and the super-insulation material is being changed from dacron to fiber glass and H film. The integrated coverlayer replaces a seprate thermal micrometeoroid garment which would have been donned by the crew prior to lunar exploration. The new coverlayer serves many purposes: fire protection, micrometeoroid protection, thermal insulation, thermal reflectance, and scuff protection to the basic space suit. Flame impingement tests have shown that the integrated coverlayer can withstand an 1800°F flame for approximately 10 times longer than the previous intravehicular space suit. The first prototype suit with a beta fabric coverlayer was delivered to MSC in early May. Preliminary evaluation has shown that the coverlayer does not appreciably decrease pressurized mobility, however, the abrasion characteristics of the suit have proven to be inadequate and steps are being taken to increase coverlayer durability. Qualification testing of the space suit will be repeated as a result of these material changes and should be completed this fall.

The portable life support system used on the lunar surface was well into its qualification program at the time of the 204 accident. (Figure 3) Three manned tests under simulated lunar conditions were completed in January. Minor problems were encountered which are currently being resolved. The three major modifications currently being implemented are: relocation of the PLSS controls, increase in emergency oxygen capacity and redesign of the communication systems to accommodate dual lunar excursions by both crew members at the same time. Additional qualification testing will be accomplished as a part of the space suit requalification. System testing completed to date has shown that PLSS has a capability to handle heat rejection rates in excess of 5000 Btu's/hr. The space suit liquid colled garment is capable of removing approximately 2200 Btu's/hr with minimum sweating. Possible improvements in this liquid cooled garment are being made to extend the metabolic capabilities of the EMU. This thermal removal capability is much greater than the Gemini EVA life support system.

CSM Environmental Control System

The Block II command module environmental control system design has been reviewed again and basically the system has been found acceptable, however, changes are being made to reduce the fire hazards and to increase crew safety and operational ease. These changes may be summarized as follows: (Figure 4)

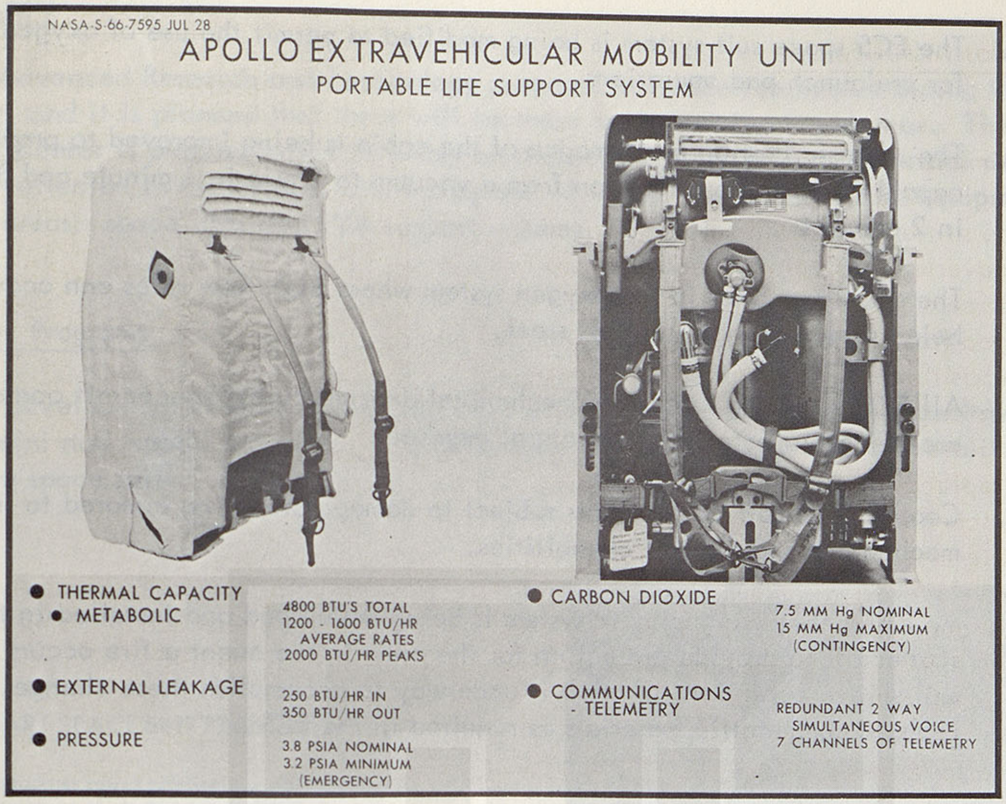
NASA-S-66-7595 JUL 28
APOLLO EXTRAVEHICULAR MOBILITY UNIT
PORTABLE LIFE SUPPORT SYSTEM
● THERMAL CAPACITY
● METABOLIC
4800 BTU'S TOTAL
1200 - 1600 BTU/HR
AVERAGE RATES
2000 BTU/HR PEAKS
● EXTERNAL LEAKAGE
250 BTU/HR IN
350 BTU/HR OUT
● PRESSURE
3.8 PSIA NOMINAL
3.2 PSIA MINIMUM
(EMERGENCY)
● CARBON DIOXIDE
7.5 MM Hg NOMINAL
15 MM Hg MAXIMUM
(CONTINGENCY)
● COMMUNICATIONS
- TELEMETRY
REDUNDANT 2 WAY
SIMULTANEOUS VOICE
7 CHANNELS OF TELEMETRY

Fig. 3

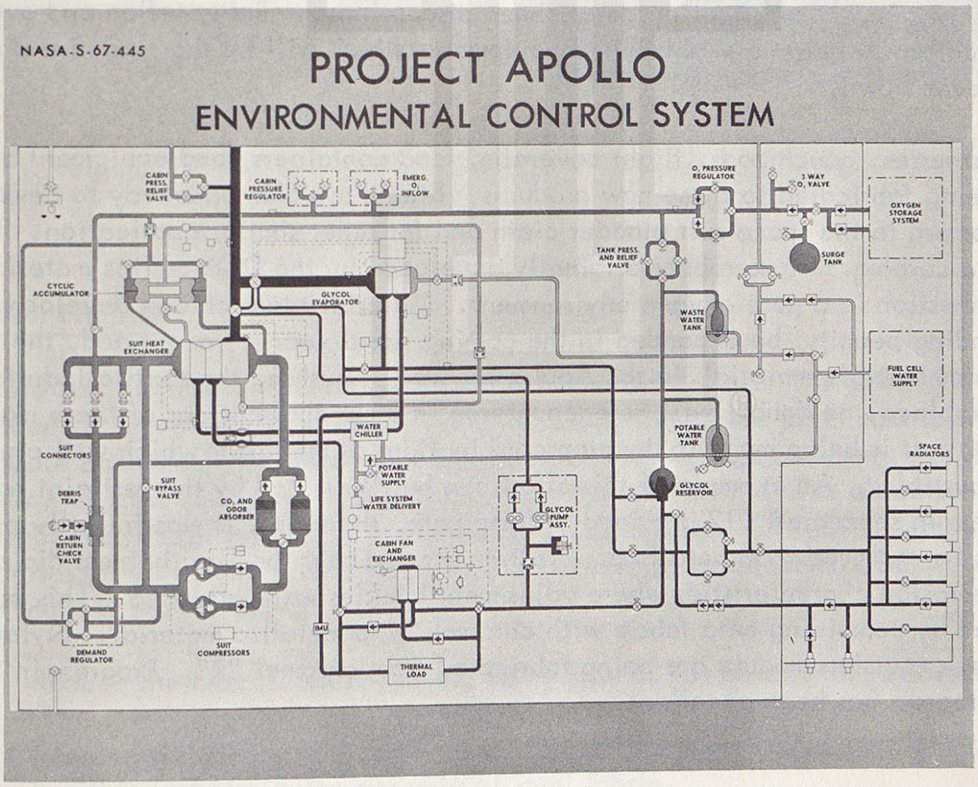
NASA-S-67-445
PROJECT APOLLO
ENVIRONMENTAL CONTROL SYSTEM

Fig. 4

1. The ECS space suit system is being modified to permit the use of oxygen or air for prelaunch pad operations.

2. The repressurization performance of the cabin is being improved to provide a capability of repressurization from a vacuum to 3 psia in 1 minute and 3.5 psia in 2 minutes.

3. The aluminum lines in the oxygen system where high flow rates can occur are being replaced with stainless steel.

4. All ECS plumbing subject to mechanical damage during spacecraft operations are being protected with structural members.

5. Coolant line soft solder joints subject to damage are being armored to increase mechanical and thermal capabilities.

6. An emergency oxygen mask system is being developed and installed in the spacecraft to provide protection for the crew in the event a fire occurs during shirtsleeve operation. Action is underway to accomplish these changes and to replace nonmetallic materials as required in the ECS.

Crew Equipment Materials

The use of nylon for fabrication of crew equipments which are exposed to the crew bay atmosphere has, for all practical purposes, been discontinued. Beta, teflon and even metal fabrics are currently being assembled into equipments which will be the most fire proof crew equipment ever flown.

Restraint harnesses, couch pads, flight coveralls, food containers, and equipment bags are currently being fabricated to these new products. Efforts are also underway to develop new materials for use in the space suit bladder cloth and for other similar application. This material is a carboxy nitroso rubber originally developed by the DOD. This material will not support combustion in a pure oxygen environment. Material research and development programs will, as funding permits, be expanded in the coming fiscal year. I might add, the utilization of new noncombustible materials in the Apollo program is pushing the textile industry state-of-the-art. Problems, no doubt, will be encountered in some applications of these materials, but, every effort is being made to develop combinations of materials which will preclude the use of combustibles. An example of this effort can be illustrated by the restraint harness. The nylon harness in spacecraft 012 provided a flame path, therefore, it was initially proposed that this harness be replaced with beta fiber. Testing showed that the beta harness did not have sufficient abrasion characteristics where adjustment buckles were attached. This problem is being solved by combining beta fabric with chromel "r" a metallic material. Nylon ropes for the lunar excursion module are being fabricated from chromel "R". Progress in this materials program has been excellent.

OART Projects

Office of Advanced Research and Technology programs have been expanded during this current fiscal year, and it is planned that these will increase in the coming fiscal year. The Manned Spacecraft Center is placing maximum effort on the development of extravehicular equipment and this is reflected in the current OART program. I would like to cover this equipment in two broad areas: space suits and EVA support systems.

Space Suit Programs

Space suit development, Figure 5, contracts are being established based on experience gained in the Gemini and Apollo programs. The development programs vary from space suit components to complete space suits.

NASA-S-67-3126

OART SPACE SUIT PROGRAMS

- HARD STRUCTURE LUNAR EXPLORATION SUIT ASSEMBLY
- INTRAVEHICULAR SPACE SUIT DEVELOPMENT
- CONSTANT-VOLUME SOFT EVA SUIT DEVELOPMENT
- PRESSURE GLOVE DEVELOPMENT
- THERMAL GRID BODY HEAT TRANSFER SYSTEM
- EVAPORATIVE COOLING GARMENT SYSTEM
- BETA FABRIC UNDERWEAR AND ACCESSORIES
- EVA THERMAL PROTECTION MATERIALS

Fig. 5

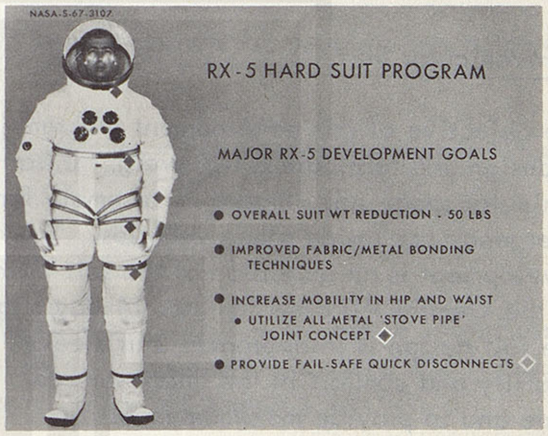

Fig. 6

RX-5 Hard Suit Program

The Litton hard suit contract has been continued for this fiscal year. The model RX-4 was delivered under last year's contract and is currently being evaluated for compatibility with the lunar module and other advanced lunar spacecraft. The suit has excellent mobility and will have future application for extended lunar exploration missions. The objective of the current contract is to develop a flight prototype model of the hard suit (RX-5), Figure 6, and prepare it for design verification testing. The specific design improvements being pursued by this program include the following:

a. Reduce the overall weight of the RX-4 from 63 lbs to a 50-lb hard suit assembly

b. Improve reliability and crew safety through the use of advanced fabric/metal bonding techniques for assembly of joint fabric.

c. Increase the mobility range in waist and hip joints to enhance kneeling capability. The rotary bearing/seal concept of the "stovepipe" joint design has been demonstrated in initial development to be very effective in providing increased range for waist and hip motions.

d. Provide fail-safe quick disconnects for maintaining high reliability and crewman safety.

e. Miscellaneous modifications are being made to improve the operational characteristics of the suit assembly by relocating equipment to more accessible areas and utilizing items of equipment "standardized" by the Gemini and Apollo programs to provide commonality where applicable.

The RX-5 hard suit will be in a development status where it logically could be qualified for flight use.

Intravehicular Suit

The objective of this development program is to design and fabricate a lightweight intravehicular space suit, Figure 7, assembly for emergency use inside space vehicles. This development is an extension of the suit worn by the Gemini VII crew for that 14-day flight. The suit design is to approach "shirtsleeve" mobility and comfort in the unpressurized mode and to provide maximum mobility in the pressurized mode. For emergency depressurized cabin operation, the suit shall provide a habitable environment while pressurized and operating at pressures up to 5.0 psia for five days continuous wear. This pressure will allow the suit to be used with a two-gas atmosphere.

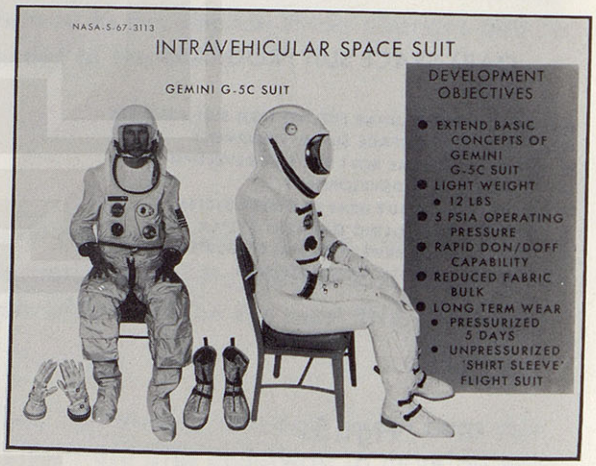

Fig. 7

The suit design will permit intermittent donning and doffing of the assembly to permit completion of a mission of one year's duration.

Design emphasis is being placed on suit reliability, comfort for long-term wear, low weight, low bulk, quick donning characteristics, and mobility performance consistent with cabin functional requirements. Currently, proposals are being reviewed for this contract.

Constant-Volume Extravehicular Space Suit Assembly

The extravehicular space suit assembly, Figure 8, program objectives include the design, development, and fabrication of a fabric space suit assembly incorporating sealed rotary bearings in each shoulder and thigh to form articulated joints. The design concept is to provide an extravehicular space suit assembly which combines the constant-volume, low-torque mobility system of a hard structure space suit with the lightweight, minimum-storage bulk of a "soft" suit assembly. The suit is intended for wear during orbital extravehicular operations and such emergency operations as necessitated by the mission. Features of the Ames articulated suit and the Apollo Block II suit are being incorporated into this suit. The suit operating pressure has been established at a pressure of 5 psia to allow the use of a two-gas atmosphere. Concurrent with this design effort, advances are being made to permit the use of metal fabrics in a welded construction concept of the "soft" space suit. This concept would permit the use of an impregnated metal fabric serving both as the prime structural member of the assembly and the gas-retaining layer. The use of the welded construction technique for "soft" suits appears to be opening new avenues to space suit design.

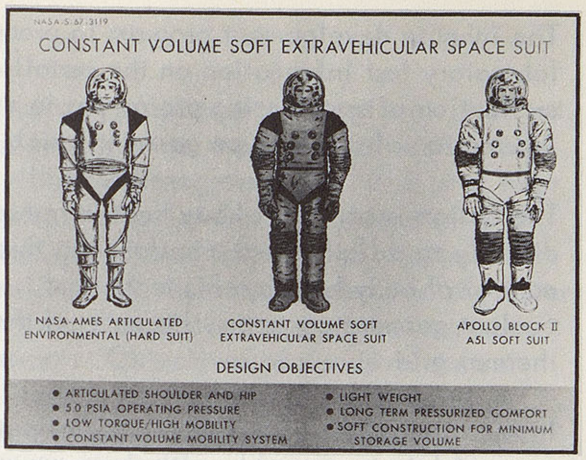

Fig. 8

Currently, proposals are being received from industry for the design and development efforts.

EV Glove Development

The Gemini flights demonstrated the need for improved glove mobility to reduce joint operating torques and spring-back. The design goal of this program is to provide a glove which requires very low joint torque for grasping and no torque to maintain the grasping position.

In addition to the mobility features, emphasis is being placed on the utilization of materials which will provide the necessary thermal, meteoroid, and abrasion protection, yet will provide a comfortable, lightweight, and low-bulk assembly.

Proposals in response to the MSC statement of work are being evaluated.

Thermal Grid Conductive Heat Transfer System

The thermal grid development program, Figure 9, was established to design and construct a lightweight, comfortable body temperature control fabric garment which will utilize a liquid heat transfer loop in combination with a metallic fiber thermal grid conductor to provide efficient body heat dissipation.

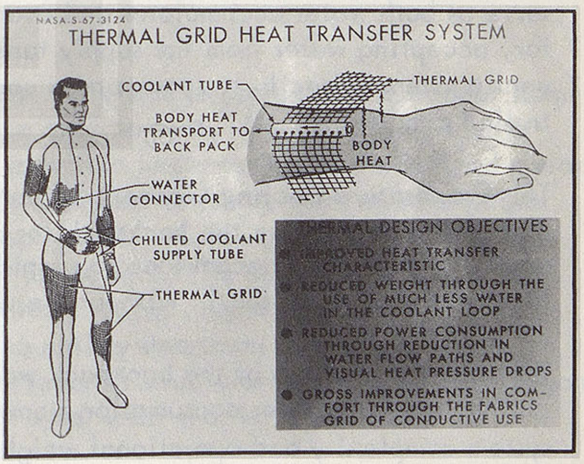

Fig. 9

The inhouse development program in process includes (1) A study of theoretical data and laboratory test information on the metallic grid concept of heat transfer, (2) A comparative evaluation of engineering prototypes to establish heat transfer capabilities, and (3) the fabrication of a prototype garment which will provide full body cooling.

The design is such that body heat is transported by thermal conduction from the skin surface directly to a liquid heat transfer loop through a metallic, conductive grid network. The control of body heat by this technique is expected to prove more efficient than existing liquid coolant garment concepts, because of the larger area of coverage afforded by the metallic thermal grid.

In the later phase of this development program, it is planned to incorporate the thermal grid concept into an assembly with the pressure glove to provide passive cooling or warming of the hands. The provision of adequate passive hand cooling will be a significant advancement of the state-of-the-art in body temperature control. To date, the cooling has been achieved by attempting to wash ventilation gases over the back of the hand. This concept has been ineffective in achieving cooling of the fingers and only marginal for the palm and back of the hand.

Evaporative Cooling Garment System

The objective of this program is to develop an advanced body cooling garment, Figure 10, that will remove body heat from a suited crewman and reject it directly to space. The system consits basically of a water supply, evaporative cooling patches, and a temperature control exhaust valve. The cooling patches are separated from the crewman by an impermeable membrane and a comfort layer that allows heat to be conducted from the man into the evaporant in the patches. The cooling patches serve as both water accumulator and evaporator, accepting water from the supply tank and venting steam directly to space under controlled conditions.

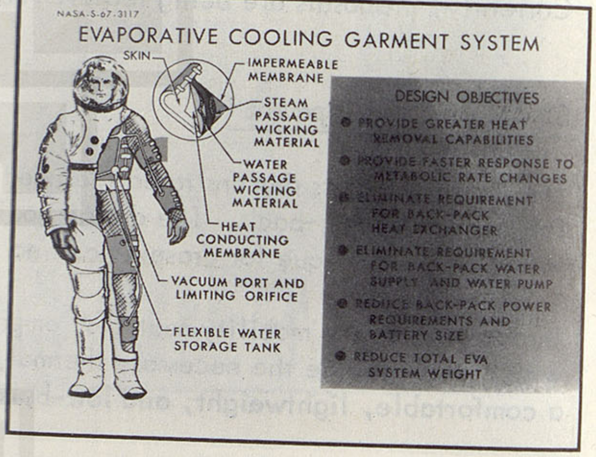

Fig. 10

The Evaporative Cooling Garment System is a unique system in that it does not require an external evaporator in the backpack for rejecting body heat from a space-suited crewman; and it is capable of accommodating rapid fluxuations in metabolic rates ranging from 400 Btu/hr through 5000 Btu/hr without the use of a water circulation pump and attendant tubing.

With the elimination of the backpack water evaporator and the water circulating pump, water tubing, and the power consumption from the PLSS, it is anticipated that a decrease in overall system complexity and operational weight can be achieved with this system.

Contract negotiations are in process to establish a joint NASA/USAF development contract for this effort. Previous contractor efforts have proved the validity of the design concept. A prototype system will be delivered for MSC evaluation.

Development of Flameproof Constant Wear Garment

In FY 65, an OART contract was let by MSC to develop a fire resistant constant wear garment, Figure 11, made of beta fabric. At this period fiberglass cloth was available for fabricating clothing. However, skin irritation problems existed with this fiberglass cloth. The beta fiber garments produced under this contract were evaluated by the Baylor College of Medicine to determine the dermatological effects of prolonged wear. Results of these tests indicated that the beta fabric underwear did not cause skin problems, but that the wearing abrasion characteristics were poor. At the time of the 204 accident an extension to the development contract was being negotiated with the Fabric Research Laboratory. Objectives of the development were to increase durability, increase seam strength, improve tear resistance, and abrasion resistance. This contract has been accelerated and is providing direct Apollo support. Initial procurement of beta fabric underwear is being made under the contract.

Fig. 11

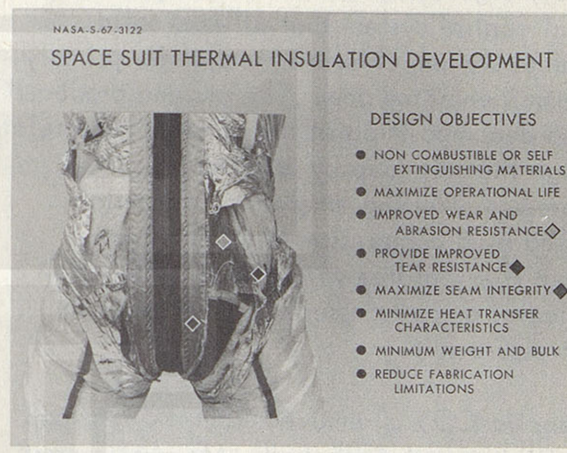

Fig. 12

Space Suit Thermal Insultation Development

Space suits require thermal insulation for extravehicular activities to protect the astronaut from the temperature extremes of the space and lunar surface environment. Previously-used extravehicular suit thermal insulations, Figure 12, (e.g., radiative heat barriers of aluminized mylar alternated with nonwoven dacron spacer layers), while adequate for short-term extravehicular missions, have disadvantages which would limit the applicability to future extended missions. The prime disadvantages of the current superinsulation are shown. The are as follows: (1) Aluminum coating is worn from mylar film by repeated flexing. (2) Mylar has an upper operating temperature limit of 300°F, and its insulating ability decreases appreciably with increased physical compression. (3) The mylar/dacron layup is structurally weak and yields seams with poor tensile qualities. This photograph shows the worst wear that has been observed in the Gemini EVA suits.

In view of these known disadvantages, a program is being initiated to develop an improved extravehicular space suit thermal insulation suitable for use on extended extravehicular missions. The objectives of this program are as follows: (1) Improve the mechanical properties so as to have an insulation which is either noncombustible or self-extinguishing, light in weight, low in bulk, adequately durable for extended missions (e.g., high seam strength), operational through a temperature range of -250°F to +350°F, and readily applicable to space suit fabrication; and (2) improve the thermal properties so as to maintain a maximum insulating ability while physically compressed, minimize heat flow through the insulation during extravehicular day conditions, and provide variable control the heat flow during extravehicular night conditions in order to decrease heat loads on the life support system.

Portable Environmental Control System

The Portable Environmental Control System (PECS), Figure 13, is a closed-loop environmental control system that utilizes solid chemical sodium chlorate candles for primary and emergency oxygen. The oxygen produced by the decomposition of the candles is circulated through the suit loop by a battery-powered compressor. During emergency operation, typified by a compressor failure, primary oxygen is circulated through the system by an ejector pump to assure CO_2 washout in the pressure suit.

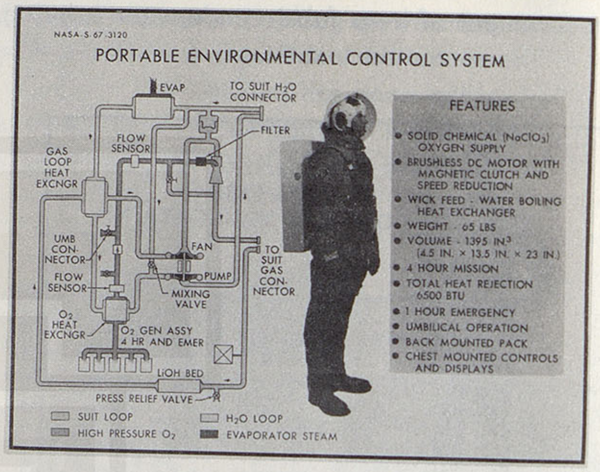

Fig. 13

Metabolic CO_2 is removed from the gas loop by a lithium hydroxide bed. Metabolic heat is transported from the man through a water-cooled garment. Heat transported to the PECS is rejected from the liquid loop through a water boiler heat exchanger. Temperature control is achieved by water boiler pressure modulation and by liquid bypass around the liquid loop heat exchanger. Heat rejection is sized for a 1500 BTU/hr rate with peaks to 2000 Btu/hr. The pack provides a total heat rejection capability of 6500 Btu.

The PECS is designed to operate through a four-hour mission, with an additional 30-40 minute emergency oxygen reserve. For extravehicular operations in the near vicinity of the spacecraft or lunar base, the pack may be operated by umbilical supply of oxygen and electrical power. Present package configuration is 4 1/2" x 13.5" x 23", or approximately 1395 cubic inches.

The prototype units developed have successfully completed a series of performance evaluation tests. Work planned for the coming year will optimize the design of the oxygen generator and will establish and demonstrate the reliability of the sodium chlorate oxygen supply for space flight applications. This work will be followed by manned testing of the development units.

Variable Flexibility Tether

The EVA tasks during Gemini 9A, 10, and 11 missions indicated the requirement to provide astronaut restraint at the work station in order to gain useful work tasks. During Gemini 12 EVA, it was demonstrated that the astronaut could accomplish useful two-handed work tasks at the work site with the use of a flexible waist tether and rigid feet (dutch boots) restraints. Astronaut Aldrin commented that the dutch boots provided the optimum restraint. However, at unprepared work sites where the dutch boots will not be provided, there will be a requirement for a universal flexible/rigid waist tether. Such a variable waist tether is presently under development.

The variable flexibility tether system, Figure 14, consists of one right and one left hand assembly. Each assembly consists of an anchor/take-up unit, interlocking ball and socket link cable, and a distal end clamping/attachment device. The anchor/take-up unit is small and compact, fitting on the astronaut in the hip area. The take-up unit controls the degree of cable rigidity/flexibility The ball and socket link cable retains the set degree of rigidity/flexibility and shape until changed by the astronaut. The distal end will be provided with a universal quick-disconnect for connecting preselected clamping/attachment devices. The system will enable an astronaut, under weightless space flight conditions, to perform various tasks more effectively by providing a restraint which will resist the linear forces and torques exerted. The system will be utilized for two-handed heavy work tasks during AAP and S-IVB Workshop missions.

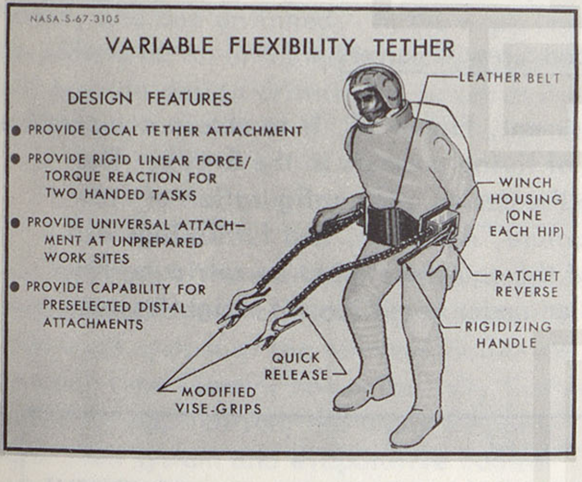

Fig. 14

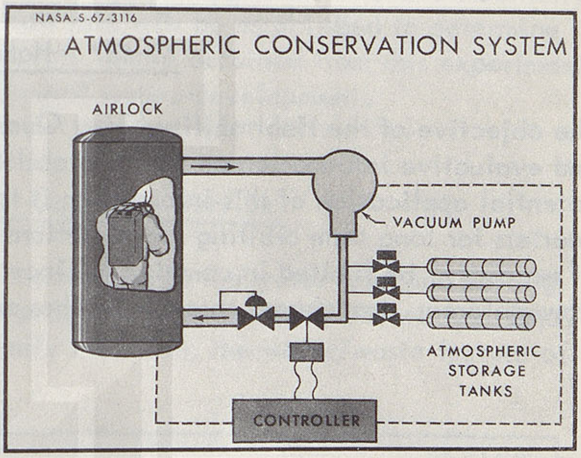

Fig. 15

Development of a Zero Gravity Vacuum Pump for Atmospheric Conservation

To meet the demand of future space program goals such as manned orbiting laboratories or interplanetary exploration, it is necessary to develop a vacuum pump suitable, Figure 15, for zero gravity application. Vacuum pumping systems may be required for such tasks as conservation of spacecraft atmosphere during extravehicular operations, vacuum desorption of molecular sieve beds, evacuation of airlocks, transfer of atmospheric content from one module or compartment to another, etc. Available data on vacuum pumps consists of industrial manuals which contain information on pumps that have not been designed for spacecraft application. Power requirements and hardware weights of such units cannot be tolerated in spacecraft design; also, certain characteristics are required in pump design to allow successful operation in zero gravity.

The primary objective of this program is the detailed design and fabrication of a prototype, zero gravity applicable vacuum pump for testing. The work being performed is broken into two phases.

The initial study phase will establish parametric data for the preliminary design of a zero gravity vacuum pump. Off-design performance analysis will be made. This analysis will reveal the effect on performance of such variations as longer or shorter pump-down time, different pressure levels, and changes in atmospheric density.

In the follow on contract, approved vacuum pump design will be fabricated into a flight prototype. The unit will be thoroughly tested under various conditions to determine the efficiency and required power of the pumping system.

OMSF Advanced Development Support:

AAP Experiments Equipment

As presently envisioned, the initial AAP missions will, wherever possible, utilize equipment presently designed and produced for the Apollo Program.

Crew Systems Division responsibilities relative to AAP experiments, Figure 16, varies from that of Principal Investigator to equipment subsystem managers for the AAP medical experiments. The following is a brief explanation relating to the efforts involved in the AAP experiments area:

M-487 - Habitability and Crew Quarters

The objective of the Habitability/Crew Quarters experiment, Figure 17, is to obtain comparative and evaluative information on the habitability aspects of living quarters in the S-IVB. The potential application of this information is to establish the design and configuration of crew quarters for long term orbiting space stations. The structure, materials, and furnishings will of necessity, be limited in complexity since portions of the equipment must be retrieved from stowage areas, transferred through hatches and assembled under conditions of weightlessness.

NASA-S-67-3102

OMSF - AAP PROGRAMS
ORBITAL WORKSHOP

- ENGINEERING EXPERIMENTS
  - HABITABILITY AND CREW QUARTERS
  - ZERO 'g' HIGH PRESSURE GAS EXPULSION
  - ZERO 'g' HEAT EXCHANGER SERVICE
  - ASTRONAUT EVA HARDWARE EVALUATION
  - ASTRONAUT MANEUVERING EVALUATION
- MEDICAL EXPERIMENTS HARDWARE
  - LOWER BODY NEGATIVE PRESSURE DEVICE
  - BICYCLE ERGOMETER
  - CLOSED CIRCUIT METABOLIC ANALYZER
  - URINE SAMPLING AND VOLUME MEASURING SYSTEM
  - VECTORCARDIOGRAPH

Fig. 16

NASA-S-67-3109

HABITABILITY/CREW QUARTERS EQUIPMENT

PREINSTALLED	ASTRONAUT INSTALLED
● PARTITIONS (WALLS, FRAME, DOORS)	● SLEEP STATIONS
● FLOOR	● URINE COLLECTION VOLUME MEASURING DEVICE*
● OVERBOARD VACUUM	● MASS MEASURING DEVICE *
● WIRING	● FECAL COLLECTION UNIT
	● WATER UNITS
	● FOOD AND FOOD CONSOLE
	● PERSONAL HYGIENE EQUIPMENT

* TO BE PROVIDED BY EXPERIMENT M052, BONE AND MUSCLE CHANGES

Fig. 17

Specific areas to be investigated include: sleep stations, food waste management systems, personal hygiene equipment, mobility aids, suit donning station, and basic sizing of crew compartments. The crew compartment will consist of a five segment preinstalled structure, designed to reduce intravehicular and extravehicular requirements on the astronaut. The preinstalled equipment and the equipment requiring installation by the astronauts are shown.

M-488 - Zero G High Pressure Gas Expulsion

In the Gemini Program, the Extravehicular Life Support System (ELSS) used for EVA was designed to use high pressure vessels that included copper fins. These fins transferred heat from the vessel wall to the inner volume of the gas. The fin requirement was based on results of theoretical analysis. However, there exists the probability of inaccuracies in the analytical techniques used due to assumptions made concerning zero G and its effects on heat transfer. The need for internal fins in gas cylinder design is therefore still hypothetical for certain ranges of flow and initial pressure and requires resolution. The experimental design as described herein will permit an accurate analysis and then determine whether the requirement exists for internal fins in cylinder design under the above specified evaluations.

The objective of this experiment is the determination of the thermodynamic state of the fluid within high pressure storage vessels during prolonged high flow rates. The experiment package is designed as a self-contained unit consisting of two high pressure oxygen bottles, one internally finned, and one unfinned. In the experiment a high flow rate will be established to determine the effects on an unfinned bottle and one that contains fins. Data obtained from this experiment will provide design criteria for future environmental control system development.

M-489 - Zero G Heat Exchanger Service

The "unknowns" surrounding zero G evaporative heat exchangers in the water feed and boiling areas have plagued ECS designers since the first space program. For example, the manual feed, flood-type system of the Mercury boiler was not thermally effective; the water/waste feature of the pool-type Gemini boiler has very limited spacecraft application; the Block I Apollo water feed system and evaporative control technique caused steam duct blockage; the Block II Apollo evaporator system has over compensated for previous problems making the design complex.

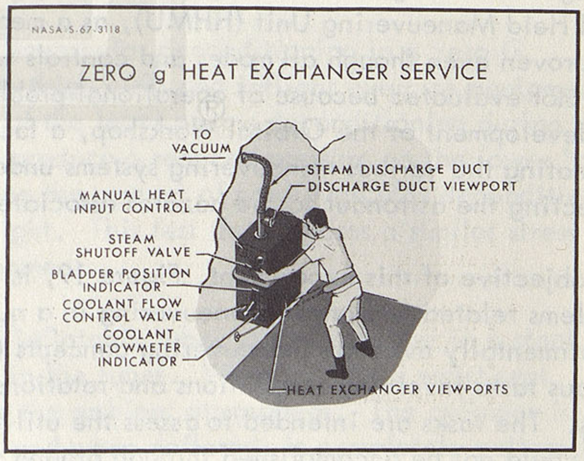

Fig. 18

The objectives of this experiment, Figure 18, are essentially oriented to investigations and determinations of the various aspects of zero gravity water boiling and heat exchanger water feed systems. This data will enable meaningful design studies to precede any boiler application and thus increase the success margin for meeting a new requirement.

The experiment package is a self-contained unit consisting of several individual heat exchanger water boiler modules and one complete water boiler with a core constructed to one of the individual modules. Instrumentation is appropriately located throughout the unit in order to provide required performance data. View ports will be provided, if possible, to allow visual observation of boiling and water feed phenomena. In addition, the system shall include the necessary componentry to fulfill the stated objectives of the experiment.

M-508 - Astronaut EVA Hardware Evaluations

The equipment used in this experiment has been selected on the basis of flight experience and operational problems associated with the Gemini EVA's, and on a careful analysis of planned and projected missions that will require the astronaut to perform useful tasks in space. Further considerations are involved with the difficulties in producing weightless conditions for experimental purposes that often introduce artifacts attributed to the method of study, rather than the variables under investigation. Since the state-of-the-art in ground based simulations make it impossible to sort out the adverse factors induced by simulation techniques, the requirement exists for an evaluation in a true zero gravity environment to produce valid evaluations which can be used in a constructive manner.

The purpose of this experiment is to evaluate, in a systematic manner, extravehicular hardware and activities that are currently program oriented or for which requirements may exist for future EVA applications. The hardware, consisting of crew/equipment transfer devices, power and manual tools, restraints and tether systems, space suit systems and suit work performance system, will be evaluated over continuous periods in the zero G environment of the Orbital Workshop where crew activities can be documented under laboratory conditions without endangering the astronaut. Results of this experiment will be correlated with ground based facilities, design criteria for hardware development and data on work expenditure to perform specific tasks, plus engineering requirements for life support systems.

M-509 - Astronaut Maneuvering Evaluation

During Gemini flights IV and X, the feasibility of using a personal propulsion system, i.e., Hand Held Maneuvering Unit (HHMU), as a means for controlling body attitude and translation was proven even though all modes and controls were not utilized. More sophisticated systems were not evaluated because of operational problems encountered during the EVA missions. With the development of the Orbital Workshop, a facility is provided that offers adequate volume for evaluating the various maneuvering systems under closely controlled conditions and without subjecting the astronaut to the hazards associated with free space.

The objective of this experiment, Figure 19, is to investigate in a systematic manner, the problems related to manned maneuvering in a null gravity environment. The approach is to experimentally evaluate maneuvering concepts (stabilized and unstablized) by performance of various tasks involving translations and rotations for the astronaut to perform with the maneuvering units. The tasks are intended to assess the utility of various null gravity maneuvering techniques that could not be accomplished through ground simulations. Results will be extrapolated to identify fundamental characteristics of manned maneuvering for use in future system design and correlate ground simulation results with inflight tests. Experimental hardware being considered for evaluation includes the Hand Held Maneuvering Unit (HHMU), Control Moment Gyro Maneuvering Unit (CMGMU) and the Rate Gyro Maneuvering Unit (RGMU).

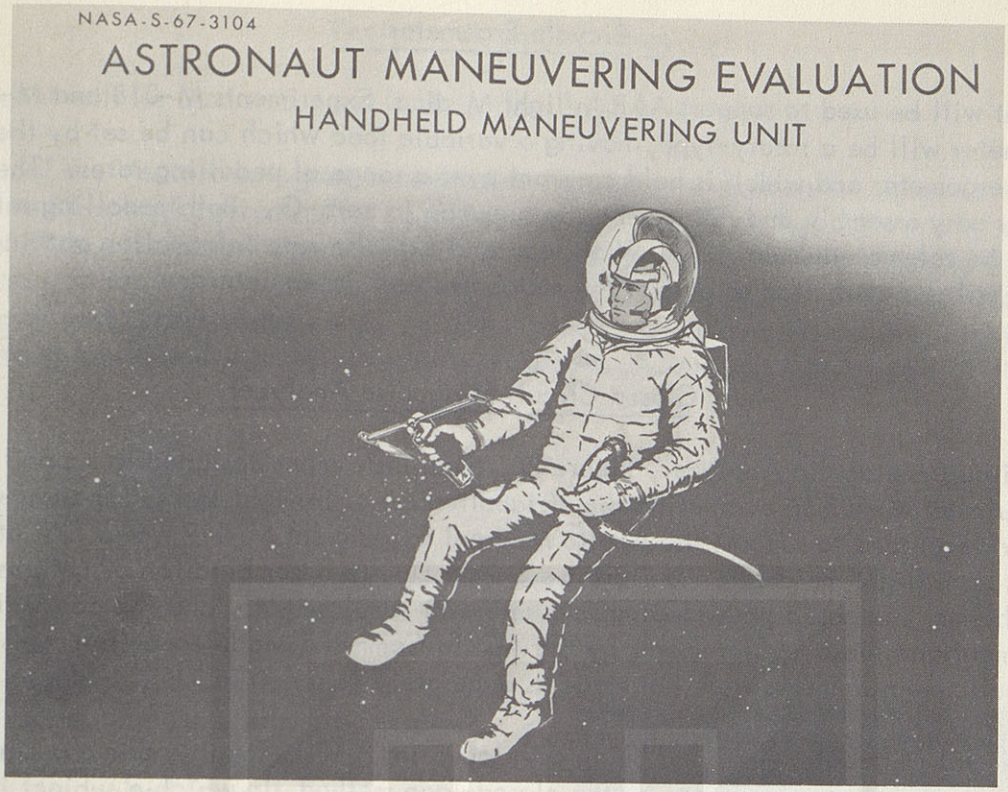

Fig. 19

Medical Experiments Equipment

The following hardware is being developed to support the AAP medical experiments:

Lower Body Negative Pressure Device (LBNP)

This equipment will be used to support Inflight Medical Experiment M-051.

During the Gemini Program, efforts to prevent cardiovascular deconditioning in a zero G environment were made through the use of pulsating thigh cuffs and inflight exercise equipment. It is now desired to make quantative measurements of the level of this deconditioning during the Apollo Applications Program. This equipment will produce a reduced pressure on the lower half of a crewman's body during space flight to determine the amount of cardiovascular deconditioning which has occurred at any given time during the flight. This test thus imposes a similar stress to that of a tilt-table performed in a one-G environment.

The LBNP consists of a cylinder made of a series of inflatable tubes joined together in a stack. The device is supported entirely by pressurized gas in the tubes. When in use, a waist seal provides positive isolation of the inner volume from the ambient atmosphere. The cylinder is elliptical, 20 inches x 15 inches x 48 inches long, and when deflated, is completely collapsible.

Bicycle Ergometer

This equipment will be used to support AAP Inflight Medical Experiments M-018 and M-050. The bicycle ergometer will be a rotary-type, having a variable load which can be set by the crewman pedalling the ergometer and which is held constant over a range of pedalling rates. The ergometer is intended for easy assembly and disassembly by one man in zero-G. Both pedalling rate and workload will be telemetered real time. Workload and exercise rate information obtained from the ergometer will be evaluated as part of the metabolic cost determination.

Closed Circuit Metabolic Analyzer

The Closed Circuit Metabolic Analyzer, Figure 20, is an instrument designed to support AAP Medical Experiment M-505 in evaluating the metabolic cost of inflight tasks. The gas volume and analysis meter developed to support the Apollo Medical Experiment M-019 was a first attempt at developing an inflight metabolic monitoring system. Due to a combination of unforeseen technical problems, increased physiological measurement requirements, and the constraints imposed on this equipment and these measurements by the Apollo Command Module environments, the desired metabolic measurements were not made as accurately as required.

The Closed Circuit Metabolic Analyzer being developed for AAP is capable of measuring both metabolic rate and respiratory quotient by the closed-loop method, in which a subject is allowed to rebreathe pure oxygen from a calibrated spirometer which contains an adsorber for removing carbon dioxide from the expired breath.

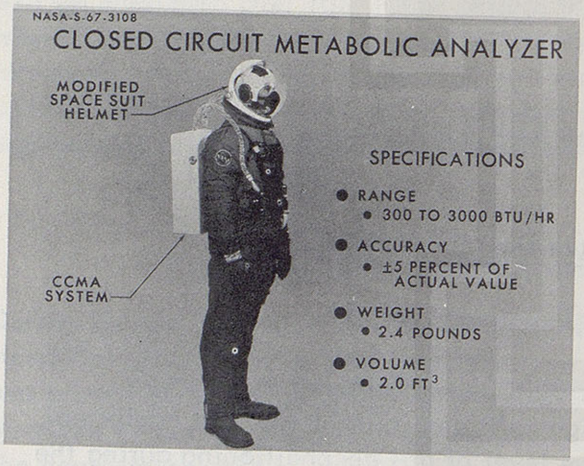

Fig. 20

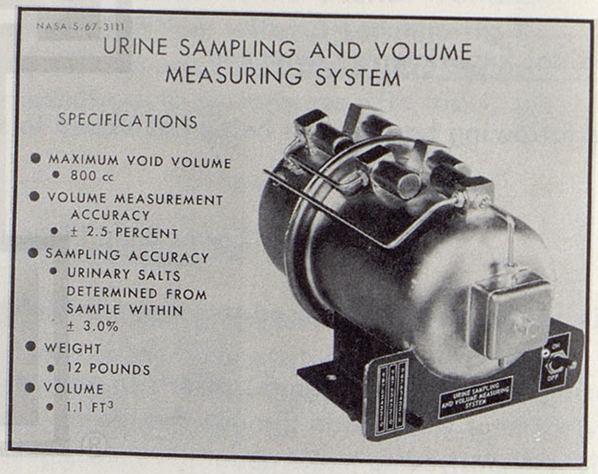

Fig. 21

Urine Sampling and Volume Measuring System

The urine measuring equipment developed for Gemini and Apollo projects was not acceptable to crew members and did not provide accurate data. This equipment, Figure 21, being developed to support AAP Medical Experiment M-052, will measure the quantity of each urine void by three crewmen in a zero g, low ambient pressure environment and acquire a proportional gas-free sample of each of these voids, in 24-hour increments for subsequent laboratory examination. Minimal manipulation on the part of the crewman will be required to activate and use the system. Astro-naut, date, and void volume data will automatically be recorded directly on the sample container as each void is made into the equipment.

Vectorcardiograph System

This equipment will be used to support AAP Inflight Experiment M-018.

The purpose of the Vectorcardiogram is to provide three electrocardiogram signals derived from the Frank Lead Network System. The equipment consists of a Frank Lead Network, a calibration system, and three electrocardiograph amplifiers. A group of body-worn electrodes is also part of the system. It has been determined in ground-based studies that these vectorcardiographic signals give an indication of the condition of the cardiobascular system and the flight equipment presently being fabricated is to be utilized to determine these conditions as part of the inflight experiment.

OMSF Supporting Development Programs:

Design and Fabrication of a Waste Collection and Processing System

The objective of this program is the development of an engineering prototype water reclamation system. The program was initiated to further the technology required for water reclamation on long duration, non-fuel cell powered missions. The prototype hardware consists of a commode and urinal for the collection and transport of urine and feces, vapor compression vacuum distillation units for reclaiming water and water sterilization and quality monitoring equipment. The hardware packaging arrangement is shown in Figure 22.

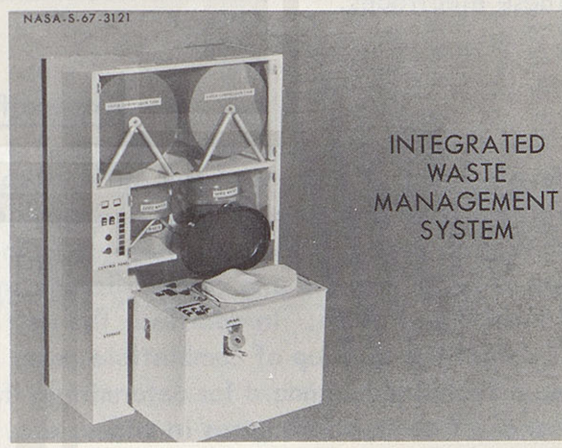

Fig. 22

Both urine and fecal processing units employ the vapor compression process to recover water. Fluid orientation is maintained by rotating the units.

Post treatment of the recovered water is performed to effect sterilization prior to storage. Instrumentation is also provided to monitor quality of recovered water.

Program is currently in design phase. Estimated completion date for hardware fabrication and assembly is September 1967. Performance testing of the system will be performed prior to delivery to MSC. Estimated program completion date is October 1967. Extensive long-term testing is presently planned at LRC.

Rapid Response Metabolic Sensor

The rapid response metabolic sensor permits breath-by-breath determinations of metabolic rate and determinations of cardiac output by the Fick method through very rapid analysis of both inspired and expired flow rate and partial pressures of oxygen, carbon dioxide, and water vapor. The unit consists of a single package containing all transducers, signal conditioners, and necessary power supplies. Spacecraft power and signal outputs to the telemetry system are supplied through a single electrical cable. Oxygen and water vapor are measured by an ultraviolet spectrophotometer. Carbon dioxide is measured by a system utilizing the absorption characteristic of CO_2 in the infrared spectrum. With this system, no hoses or valves are required, thus minimizing the pressure drop. The subject inhales gas from the spacecraft cabin atmosphere through the metabolic sensor where it is analyzed. The gas is then expired through the metabolic sensor where it is once again analyzed and exhausted into the spacecraft cabin. From the inspired and expired analyses, the physiological performance of the subject may be determined.

Thoracic Blood Flow Measuring Device

This equipment will be utilized to support Inflight Experiment M-017. The Impedance Cardiograph is presented as a method of making thoracic blood flow measurements. This is accomplished by impressing a high-frequency, constant-current signal on the outer bands of a set of tetra polar bond electrodes placed around the neck and mid-section of the crewman and detecting the impedance change across the thoracic cavity by detecting the voltage change on the inner bonds of these electrodes.

Spacecraft Cabin Analyzer

A development program has been initiated to develop a hand analyzer, Figure 23, capable of detecting partial pressures of oxygen in the range of 0-300 mm/Hg and carbon dioxide in 0-25 mm/Hg pressure. In addition, the unit will detect the buildup of combustible gases using a technique standard for determining the presence of combustible gases in mines, etc. The unit will employ a comman gage weighing only approximately 2.5 pounds. The unit will be developed to flight status.

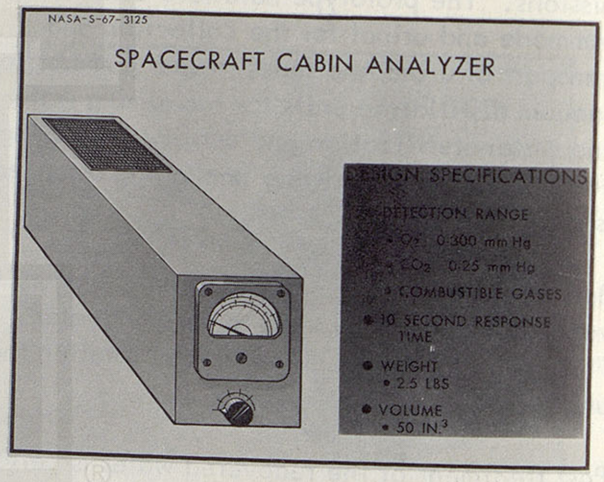

Fig. 23

Summary

During the last year, we successfully completed our Gemini extravehicular flights and showed that man indeed has a useful place in performing extravehicular tasks. Our advanced development programs have been expanded to provide a strong technology base for future manned space flight programs. The Apollo tragedy has left an indelible mark on those of us responsible for the development of crew equipment and we have a new dedication to the tasks that lie ahead.

MANNED SPACE MEDICINE PROGRAMS

INTRODUCTION

By: S. P. Vinograd, M.D.

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

SPACE MEDICINE
OFFICE OF MANNED SPACE FLIGHT
PROGRAM REVIEW 1967

- LIFE SUPPORT SYSTEMS - MR. JOHNSTON
- IN-FLIGHT MEDICAL EXPERIMENTS - DR. VINOGRAD
- MEDICAL SUPPORT OF MANNED SPACE FLIGHT - DR. BERRY
- BACK CONTAMINATION - COLONEL PICKERING

NASA HQ MM67-6507
5-10-67

Fig. 1

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

SPACE MEDICINE

A STAFF ELEMENT WITH PRINCIPAL RESPONSIBILITY TO PROVIDE THE ASSOCIATE ADMINISTRATOR FOR MANNED SPACE FLIGHT WITH ADVICE AND RECOMMENDATIONS PERTAINING TO THE MEDICAL ASPECTS OF MANNED SPACE FLIGHT PLANS, REQUIREMENTS AND PROGRAMS.

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Fig. 2

SPACE MEDICINE
PRIMARY FUNCTIONS

- DEVELOP MEDICAL POLICY AND PROVIDE TECHNICAL SUPPORT TO OMSF PROGRAM AND STAFF OFFICES.
- PLAN AND MANAGE INFLIGHT MEDICAL EXPERIMENTS.
- MONITOR MEDICAL ACTIVITIES AT OMSF CENTERS.
- MONTOR OMSF BILOGICAL CONTAINMENT ACTIVITIES.
- COORDINATE MSF MEDICAL ACTIVITIES WITH OTHER GOVERNMENT AND APPROPRIATE CIVILIAN AGENCIES.

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Fig. 3

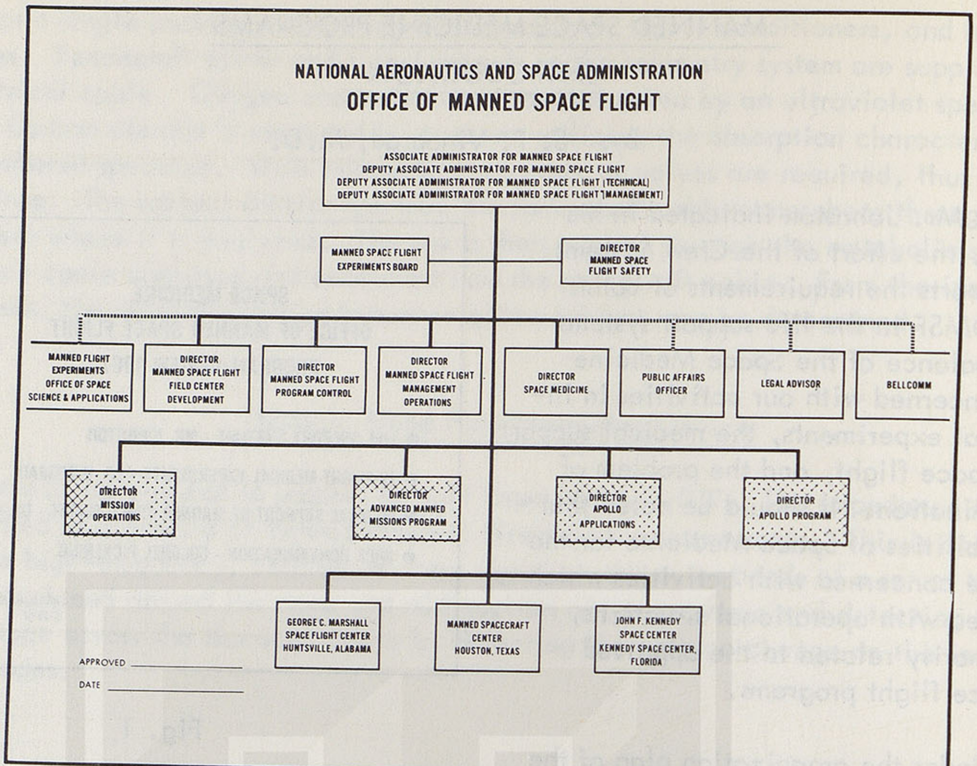

Fig. 4

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

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

IN-FLIGHT MEDICAL EXPERIMENTS

By: S. P. Vinograd, M.D.

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

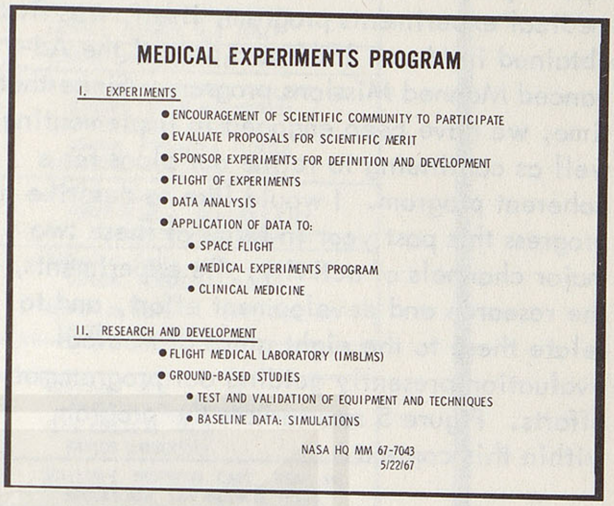

Fig. 1

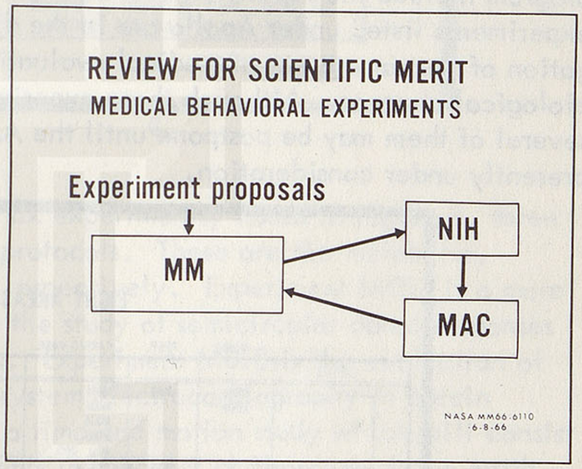

Fig. 2

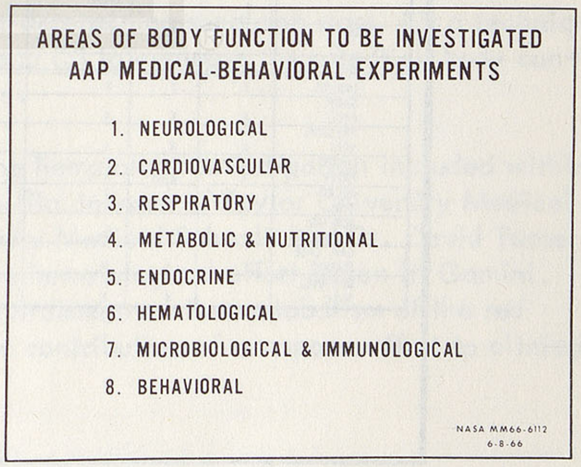

Fig. 3

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

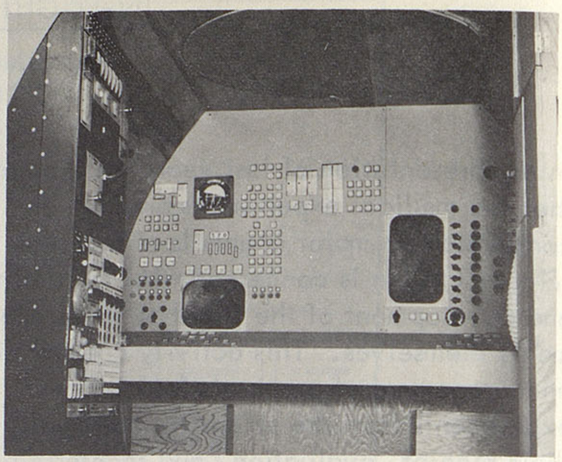

Fig. 4

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

EIGHT AREAS OF MEDICAL EVALUATION

	NEURO.	RESP.	CARDIO-VASC.	METAB. & NUTRITION	ENDOCR.	HEMATOL.	MICROBIOL.	BEHAV.
EXPTMS.								
GEM.	M008 M009	M003	M001 M003 M004 M005 MED. OPS.	M005 M006 M007	M005	MED. OPS.		MED. OPS.
AP.		M020	M012 M017 M023 M048	M012 M019		M011	MED. OPS.	
AAP	M053 (M054)	M051	M018 M051 (M057)	M050 M052 M056 M058	M052	M051		M055
DEF.			(X-46)	(X-33)	(X-30)	X-24 (X-42)		
R&D								
IMBLMS	X	X	X	X	X	X	X	X
SAMP. PRES.	X	X	X	X	X	X		X
PHYSICAL METH	X	X	X	X	X	X		X
FILTER PAPER	X	X	X	X	X	X		X
MICRO-BIOL.							X	
NON-INV. V. PRES.			X					
CAP. CAGE PLETRY.			X					
CO_2 ANAL. TECH.		X	X	X				

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Fig. 5

AAP MEDICAL EXPERIMENTS

APPROVED BY MSFEB (IN DEVELOPMENT PHASE)		
M050	METABOLIC ACTIVITY	EDWARD L. MICHEL (MSC)
M051	CARDIOVASCULAR FUNCTION ASSESSMENT	ROBERT L. JOHNSON, M.D. (MSC) CRAIG L. FISCHER, M.D. (MSC)
M052	BONE AND MUSCLE CHANGES	PAUL A. LaCHANCE, PH.D. (MSC)
M053	HUMAN VESTIBULAR FUNCTION	ASHTON GRAYBIEL, CAPT., USN, MC USNAMI, PENSACOLA, FLORIDA EARL F. MILLER II, PH.D. USNAMI, PENSACOLA, FLORIDA RICHARD E. WAITE, M.SC. (MSC)
M055	TIME AND MOTION STUDY	JOSEPH F. KUBIS, PH.D. FORDHAM UNIV., NEW YORK CITY E. J. McLAUGHLIN, PH.D. (NASA HQ)
M018	VECTORCARDIOGRAM	RAPHAEL F. SMITH, LCDR, USN, MC USNAMI, PENSACOLA, FLORIDA NEWTON W. ALLEBACH, CAPT., USN, MC BUMED, WASHINGTON, D.C.
AWAITING MSFEB REVIEW		
M054	NEUROLOGICAL STUDY (EEG)	ROSS ADEY, M.D. UNIVERSITY OF CALIFORNIA PETER KELLAWAY, PH.D. BAYLOR UNIVERSITY
M056	SMALL MASS MEASUREMENT DEVICE	WILLIAM E. THORNTON, CAPT., USAF, MC BROOKS AFB, SAN ANTONIO, TEXAS
M057	TOTAL BODY EXERCISE SYSTEM	WILLIAM E. THORNTON, CAPT., USAF, MC BROOKS AFB, SAN ANTONIO, TEXAS
M058	HUMAN MASS MEASUREMENT DEVICE	WILLIAM E. THORNTON, CAPT., USAF, MC BROOKS AFB, SAN ANTONIO, TEXAS

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Fig. 6

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

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

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

MEDICAL EXPERIMENTS

IN DEFINITION PHASE (UNDER SPONSORSHIP)

X-24	ANALYSIS OF STABLE AND RADIOISOTOPHIC CO AND CO_2 IN BREATH	JOHN H. LAWRENCE, M.D. HARRY S. WINCHELL, M.D., PH.D. U. OF CALIFORNIA
X-30	HORMONE MEASUREMENTS ON URINE OF ASTRONAUTS	DON H. NELSON, M.D. LATTER DAY SAINTS HOSPITAL

PROMISING - (SCIENTIFIC MERIT EVALUATION NOT YET COMPLETE)

X-33	HUMAN GASTRIC ACTIVITY DURING WEIGHTLESSNESS	MALCOLM L. PETERSON, M.D. WASHINGTON UNIVERSITY
X-46	SPACE BALLISTOCARDIOGRAPH	DON M. CUNNINGHAM UNIVERSITY OF CALIFORNIA

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Fig. 7

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

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

MEMBERS OF MEDICAL ADVISORY COUNCIL

NAME	AFFILIATION
CARLSON, LOREN, PH.D. CHAIRMAN, DEPARTMENT OF PHYSIOLOGY	UNIVERSITY OF CALIFORNIA
GRAYBIEL, ASHTON, CAPT., USN, MC DIRECTOR OF RESEARCH	U.S. NAVAL AEROSPACE MEDICAL INSTITUTE
JENSEN, WALLACE N., M.D. PROFESSOR OF MEDICINE	UNIVERSITY OF PITTSBURGH
KUBIS, JOSEPH, PH.D. PROFESSOR OF PSYCHOLOGY	FORDHAM UNIVERSITY
LUFT, ULRICH, M.D. HEAD, DEPARTMENT OF PHYSIOLOGY	LOVELACE FOUNDATION
ORLANSKY, JESSE, PH.D. RESEARCH ENGINEERING & SUPPORT DIV.	INSTITUTE FOR DEFENSE ANALYSES
WARREN, JAMES V., M.D. PROFESSOR & CHAIRMAN, DEPARTMENT OF MEDICINE	OHIO STATE UNIVERSITY
WHEDON, G. DONALD, M.D. DIRECTOR, NATIONAL INSTITUTE OF ARTHRITIS AND METABOLIC DISEASES	NATIONAL INSTITUTES OF HEALTH
WOOD, EARL, M.D., PH.D. PROFESSOR OF PHYSIOLOGY	MAYO CLINIC

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Fig. 8

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

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

MEDICAL EXPERIMENTS PROGRAM
RESEARCH AND DEVELOPMENT

EFFORT	CONTRACTOR/GRANTEE	PROCUREMENT	CONTRACT OR GRANT (MONITOR)
IMBLMS (PHASE B)	LMSC GE	RFP CONTRACT (HQ)	CONTRACT (HQ)
PHYSICAL METHODS OF BIOCHEMICAL ANALYSIS	SPACELABS/BIOSCIENCE LABS. HAYES INTERNATIONAL	RFP	CONTRACT (HQ → MSC)
SAMPLE PRESERVATION TECHNIQUES	SPACELABS/BIOSCIENCE LABS. GE	RFP	CONTRACT (HQ → MSC)
MICROBIOLOGICAL TECHNIQUES	IBM SPACE GENERAL	RFP	CONTRACT HQ → MSC)
VENOUS PRESSURE NON-INVASIVE TECH.	BIOSYSTEMS	RFP	CONTRACT (HQ → MSC)
FILTER PAPER TECH. FOR BIOCHEM. ANALYSIS	MICHAEL REESE HOSPITAL	UNSOL. PROP.	GRANT (HQ → MSC)
CAPACITANCE CAGE PLETHYSMOGRAPHY	UNIVERSITY OF CALIF. (DAVIS	UNSOL. PROP.	GRANT (MSC)
CO_2 ANAL. TECH., BREATH BY BREATH	PERKIN-ELMER	RFP	MSC

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Fig. 9

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

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

SPACE FLIGHT MEDICAL EXPERIMENTS PROGRAM

I. EXPERIMENT
   A. DEFINITION
   B. DEVELOPMENT
II. BIOMEDICAL LABORATORY MEASUREMENT SYSTEM
   A. FINAL STUDY PHASE
   B. DESIGN PHASE
   C. DEVELOPMENT AND TEST PHASE
III. REQUIRED GROUND-BASED STUDIES
   A. EQUIPMENT AND TECHNIQUE VALIDATION AND TEST
   B. SIMULATION AND BASELINE STUDIES
IV. OPERATIONAL SUPPORT FOR EXPERIMENTS

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Fig. 10

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

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

MEDICAL SUPPORT OF MANNED SPACE FLIGHT

By: Charles A. Berry, M.D. (MSC)

Last year Life Sciences was described as the study and support of life processes and it was noted that in NASA it was a team effort ranging from the basic biological sciences to Clinical Space Medicine. Today, you have already heard detailed presentations relating to the basic biology and biosciences and life support hardware. There are really two principal goals of these studies.

1. Evaluation of the effect of space flight variables on a specific animal, plant, or organism for science's sake.

2. Relating these studies to manned flight if possible.

We feel the ultimate effort is the conquering of space by man. Thus, our medical objectives in the manned space-flight program are to provide medical support for man, enabling him to fly safely in order to answer the following questions:

1. How long can man be exposed to the space-flight environment without producing significant physiologic or performance decrement?

2. What are the causes of the observed changes?

3. Are preventive measures or treatment needed, and if so, what are best?

There have been a number of predicted environmental effects and human responses which did not match well with the reality of the findings from the Gemini Program. These have been discussed in the final Gemini report.

When one embarks upon an exploration of the unknown, it is both appropriate and justifiable to launch a broad-based research program delving into the potential problem areas - both remote and proximate. There can be no substitute, however, for the actual flight or mission experience in bringing into sharp focus the real-world bio-medical problems, and for dismissing into oblivion other hypothesized but nonexistent trouble areas.

The physiological positive findings from our flight program to date are summarized in Figure 1.

The shape of the curves thus far are very interesting and the extension with the question to 120 days leaves us wondering whether the changes have peaked and are on their way to normal, will cycle, or start a new continuous climb. The small number of data points represented must not be forgotten in our use of these data.

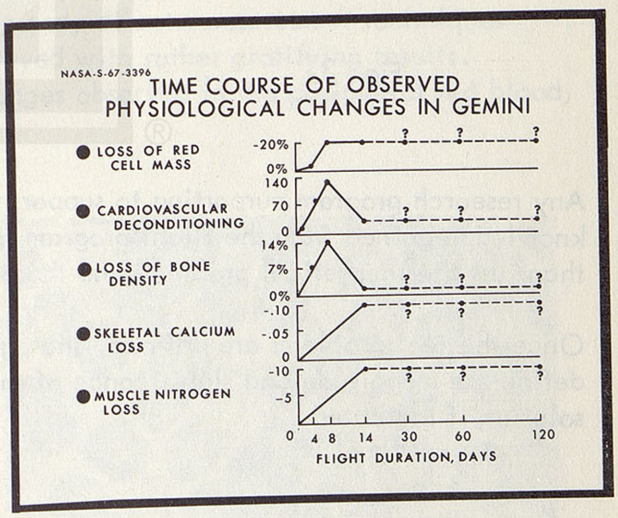

Fig. 1

The body systems studied thus far in actual flight are tabulated in Figure 2 and shown anatomically in Figures 3, 4, and 5. It should be emphasized that it is physiologically erroneous to show a body system divorced from other body systems. Unlike many engineering systems, body systems are closely inter-related and have many cross control mechanisms. This makes prediction of action after theoretically removing a single body "black box" impossible. These body systems must be instrumented at least as well as spacecraft systems and tell why they fail or function imperfectly, but it must be done with "tender loving care."

STATUS OF HUMAN FUNCTIONAL SYSTEM STUDIES
ESSENTIAL FOR SUPPORT OF MANNED SPACE FLIGHT
MAY, 1967

SYSTEM OR FUNCTION	FLIGHT-RELATED CHANGES DETECTED	DEPTH OF INVESTIGATION
NEUROLOGICAL	NO	MINIMAL
BEHAVIORAL	NO	NONE
CARDIOVASCULAR	YES	EXTENSIVE
PULMONARY	NO	MINIMAL
BODY FLUIDS	YES	MODERATE
MUSCULOSKELETAL	YES	MODERATE
METABOLIC EFFICIENCY	NO	MINIMAL
GASTROINTESTINAL	NO	MINIMAL
GENITOURINARY	NO	MINIMAL
ENDOCRINE	YES	MINIMAL
IMMUNOCELLULAR DEFENSES	YES	MINIMAL

Fig. 2

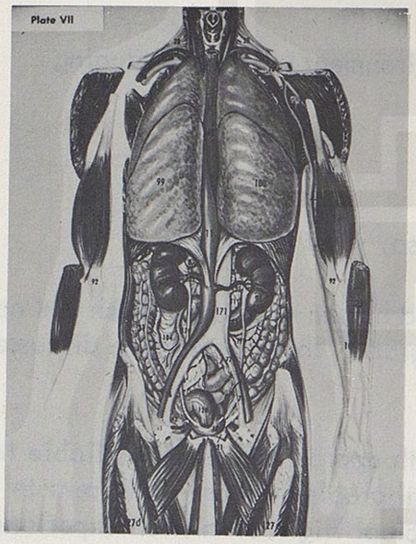

Fig. 3

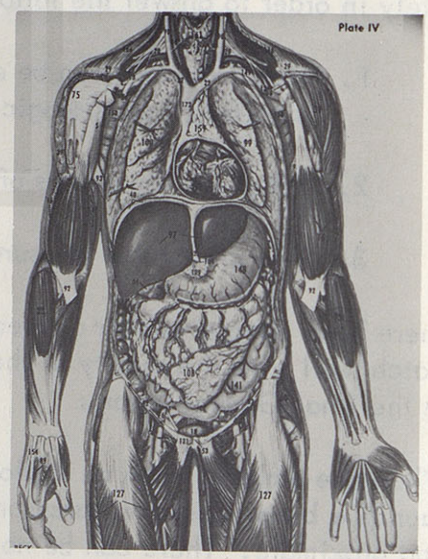

Fig. 4

Any research program purporting to support the flight of man should take advantage of the working knowledge gained from the flight program to be sure it is devoting emphasis to the real rather than just the theoretical problems and therefore is effective and economical.

Once the real problems are defined, the agency's research resources should be marshalled to define the magnitude and significance of the problem and to provide a timely and effective solution if indicated.

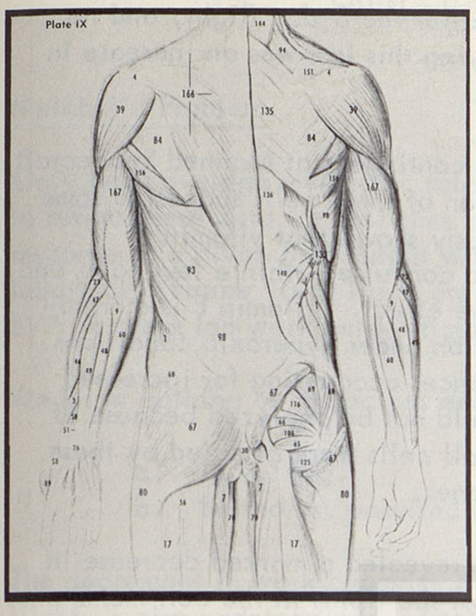

Fig. 5

RED CELL LOSS SYNOPSIS

OBSERVATIONS	SOURCES & TECHNIQUES	SIGNIFICANCE
VERY SLIGHT PROGRESSIVE DROP IN HEMATOCRIT	ALTITUDE CHAMBER & BED REST STUDIES PERIPHERAL HEMATOCRITS	INDETERMINATE: TECHNIQUES IMPRECISE
20% LOSS OF RBC MASS (INCREASED CELL SIZE, DESTRUCTION, FRAGILITY)	8 & 14-DAY GEMINI FLIGHTS ISOTOPE TAGGING	OXYGEN TOXICITY VS. OTHER FACTORS
CELL MEMBRANE LESION:	GEMINI X FLIGHT	TOXIC EFFECT OF O_2
LIPIDS (FATS) OXIDIZED	CELL MEMBRANE LIPID ANALYSIS	+ ? OTHER FACTORS; POSSIBLE TOCOPHEROL PROTECTION
AAP FLIGHTS (MIXED GAS)	COMPREHENSIVE SOPHISTICATED TECHNIQUES	FACTOR OUT OXYGEN TOXICITY

Fig. 6

A case in point is the loss of red blood cells documented following the longer Gemini flights (Figure 6). The clinical literature had documented the fact that patients confined to bed for extended periods of time exhibited a decrease in blood volume and a slight but measurable drop in red blood cells (hematocrit). Early studies simulating weightlessness had revealed evidence of decreased hematocrit, particularly on resuming a vigorous exercise regimen. Early atmosphere validation studies also revealed a slight but definite decrease in hemoglobin levels. In all these studies, however, the measurement technique employed was quite gross (peripheral hematocrit or hemoglobin determinations). It is a well-demonstrated fact that dehydration is reflected in the blood by an increase in hematocrit, that is, an apparent increase in red blood cells. We know from the Mercury flight experience, that dehydration with its increase in hematocrit would also occur in the Gemini flights, and that this would easily mask any mild to moderate loss of red cells occasioned by other factors (oxygen toxicity, inactivity followed by resumption of viborous exercise.) It became quite apparent that more definite and sophisticated measurements were required. To this end, direct measurement techniques (radioisotope tagging and dilution methods) were employed with rather gratifying results. Figures 7 and 8 emphasize the gross morphological changes observed in the peripheral red blood cells (pre- vs. post-flight).

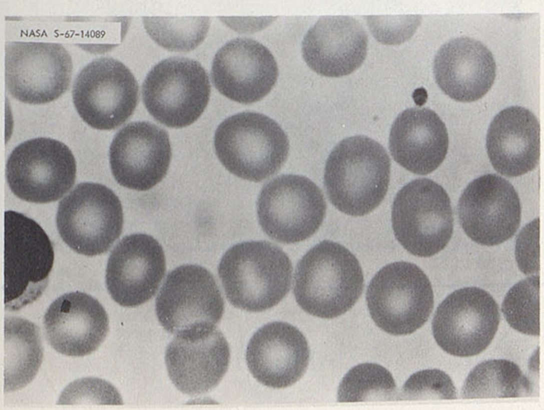

Fig. 7

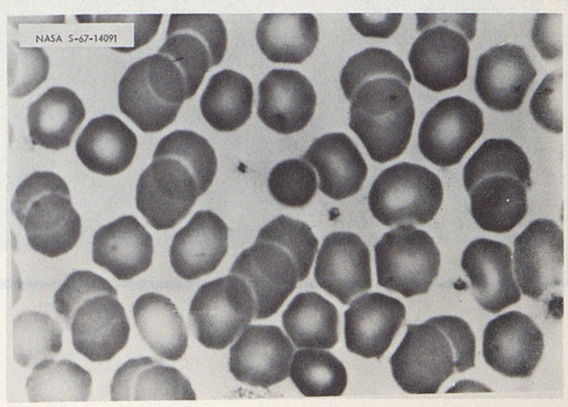

Fig. 8

The Gemini red cell losses reached a maximum of 20 percent after the 8-day flight, and no greater loss was observed after the 14-day flight. Accompanying this loss was an increase in cell size with resulting increased fragility or cell destruction.

These findings stimulated much interest among the biomedical contingent at Manned Spacecraft Center. The increase in red cell size and increased destruction of these cells suggested some deleterious effect on the cell membrane. Mengel had previously shown that vitamin E deficient animals when exposed to hyperbaric oxygen begin to convulse within a few hours and further showed that vitamin E (tocopherol) exerted a protective effect. Vitamin E is a lipid-reducing substance which "protects" lipids or fats from oxidation under hyperoxic conditions. Mengel concluded that peroxidases modified CNS lipid substances accounting for increased irritability, convulsions and death. The cells of the CNS could not be analyzed because of their inaccessibility. We reasoned, however, that probably all cells were affected by these peroxidases, since all cells contain lipid in their cell membranes.

In subsequent flights such as Gemini X, further investigations revealed a marked decrease in postflight blood tocopherol levels and stricking modification of the lipids in the cell membranes.

The evolution of this study of man in his new environment emphasizes the fact that the ideal place to study the response of man to space flight is during the actual mission. Simulations are necessary, but generally fall far short of providing the required data. The results of this effort have been enthusiastically received by hematologists in the scientific community throughout this country, and have stimulated intensified research along similar lines at other government and university research centers.

Whether the red cell destruction phenomenon reaches a plateau at about 20 percent red cell loss or whether this process may reach a point at which it impairs human function must be left for future studies to define. The adoption of a mixed atmosphere for missions beyond Apollo will offer a unique opportunity to observe this phenomenon in the absence of hyperoxic conditions. In this case, any red cell decrement must be the result of other factors in the space environment.

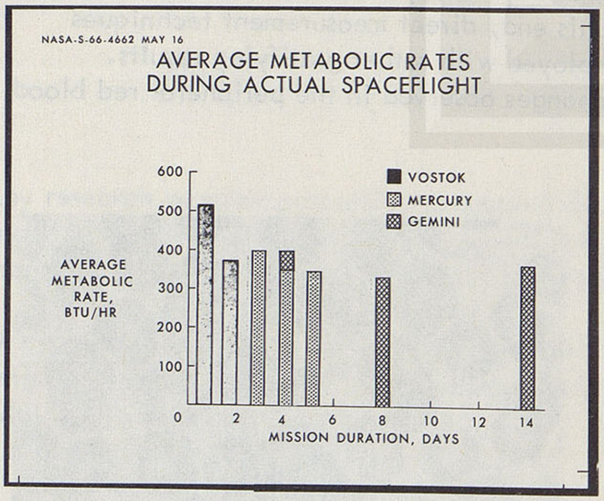

Fig. 9

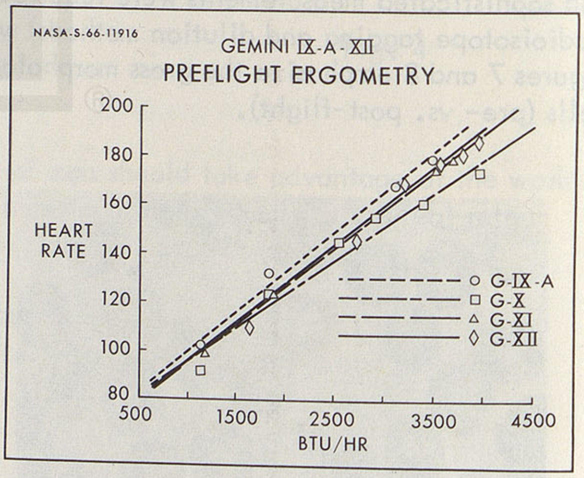

Fig. 10

Other Critical Problem Areas Defined By Flight Experience to Date

Metabolic Problem

Only gross average metabolic rates have been determined to date. (Figure 9) In an attempt to refine these data for real time monitoring use during EVA, we determined the heart rate response to a given BTU output with increased workloads on a bicycle ergometer in the laboratory (Figure 10). There are many sources of error in relating the heat rate observed in EVA to these lab work output figures.

We know nothing of the actual energy expenditure during inflight tasks:

a. lg vs. Og.
b. Suited vs. unsuited modes.

The decrement in work capacity of an astronaut as a function of time during extended space flights is also undetermined. These data are required as a basis for intelligent mission planning (time line analyses), especially for the ambitious workloads proposed for AAP. The leisurely pacing of workloads or tasks are only a compromise "interim" solution and not satisfactory for either emergency modes, or the ambitious programmed tasks which must be accomplished within the mission time constraints avoiding undue fatigue.

Bicycle ergometer (Figure 11) and metabolic rate devices, (Figure 12), such as the closed-circuit metabolic analyzer (AAP) and breath-by-breath metabolic rate device (OART) previously described will provide much of the vitally needed metabolic data required for realistic future mission planning. They represent advanced state-of-the-art and will be difficult to develop and properly validate by ground testing within the extremely narrow time constraints of presently-configured AAP missions.

It cannot be over-emphasized how urgently flight data of this type are required for it is a top priority problem area.

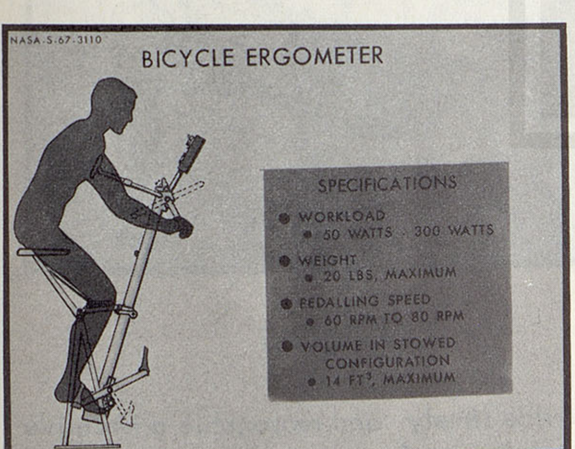

Fig. 11

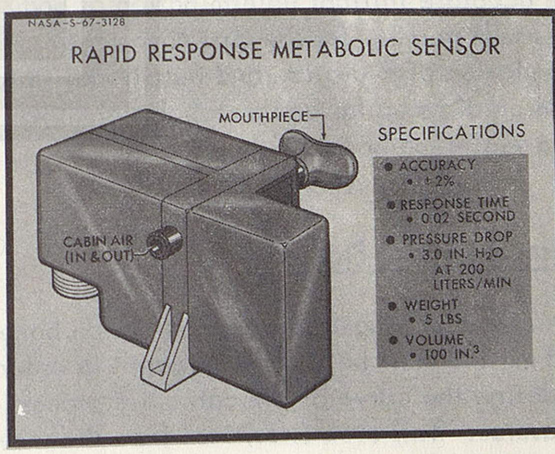

Fig. 12

Cardiovascular Problem

In the cardiovascular area, we still have much to learn regarding the rate, degree and significance of human adaptation to null gravity. At what point in time does the process become asymptotic? Is there any discernible effect on astronaut performance at this time? We do not presently have answers to these questions. Our cardiovascular measurement techniques have evolved progressively through Mercury and Gemini (viz., ECG, blood pressure, phonocardiograph and tilt-table tests) as previously reported, and have helped immeasurably in defining the orthostatic hypotensive phenomenon. Further measurements of a more sophisticated nature are planned for AAP. These include vectorcardiography, thoracic blood flow (cardiac output derivative), lower body negative pressure, and body mass determination (sponsored by the Air Force).

Vectorcardiography will provide more precise information concerning the electrical activity of the heart. The thoracic blood flow device has passed preliminary validation studies exhibiting excellent correlation with cardiac output as determined by classical dye and isotope dilution techniques in normal and abnormal hearts, at rest, after exercise and during acceleration (centrifuge studies).

The above equipment was originally destined to be used in early Apollo. These items will be flight qualified and properly validated probably in time for AAP. This emphasizes, in no uncertain terms, the long lead time required for an orderly progression of development and validation for equipment representing an advance in the state-of-the-art.

It should be noted that reliable clinical laboratory equipment requires many years to validate fully and become useful and widely accepted by the medical profession.

(LBNP) lower body negative pressure (Figure 13) will provide an inflight provocative test of the whole cardiovascular system periodically during long flights to define the curve of the adaptation of deconditioning process.

The accurate inflight determination of body mass will permit, for the first time, the correlation of hydration and nutritional status with cardiovascular and metabolic changes on a real-time basis.

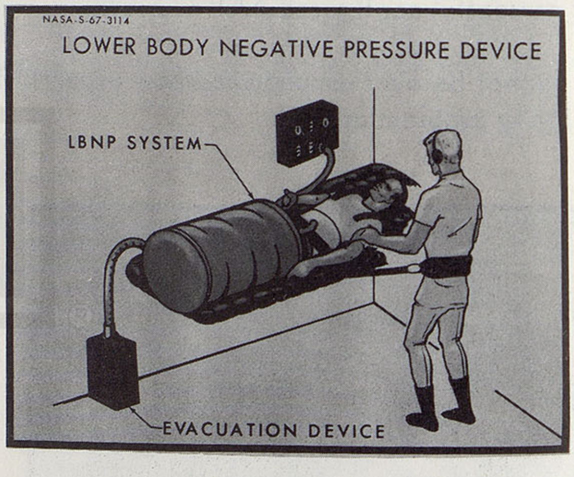

Fig. 13

Musculoskeletal Problem

The effect of long-duration missions on bone and muscle must be studied in depth in order to define the curve of the catabolic process and to provide timely and reasonable preventive measures. This area is critical from the viewpoint of renal stone formation and diminution in bone strength.

Long-term bedrest studies have been initiated to equate or correlate total skeletal calcium loss with densitometric loss of selected bony structures. The ultimate aim here is to utilize inflight bone densitometry with a direct, real-time readout capability, unencumbered by the use of X-ray films. This would eliminate the need for cumbersome and technically difficult calcium balance studies and would provide for the first time a real-time evaluation of skeletal integrity at any given point in time.

Time does not permit me to discuss our research needs in two additional problem areas. Suffice it to mention, however, that much work has yet to be done in the area of vestibular physiology, particularly with respect to providing more earth-like living modes on projected space station type vehicles. This is particularly true if we are considering a rotating living quarters area in conjunction with a null gravity investigative area.

Finally, the many unknowns of interplanetary radiation and its effects on man remain a difficult and challenging problem area concerning which we have as yet precious little information.

It should be our goal then to at least confirm the 14-day data where possible during the Apollo flights and then initiate studies to investigate in depth why certain changes occur and by using orbital laboratory facilities like the SIVB Workshop and follow-on labs as they become available. The data should be collected to predict ahead to longer duration orbital and planetary flights.

I think some of the problems of importance in these longer duration missions will be those relating to behavioral - confinement responses, radiation (where we are adopting a risk vs. gain mission dose schedule), and provision of palatable diets, water, and adequate waste management systems. In essence these are habitability problems and further effort must be devoted to their study. Care should be exerted to observe body systems problems developing as a result of habitability fixes like vestibular difficulties resulting from rotating the spacecraft.

It is also time we devoted some effort to determining how we can profitably use the space environment for medical purposes not just protect from it. Will it really someday be useful in the treatment of the cardiac, the bed ridden and the burn patient? Some planning now may help us to get such answers.

BACK CONTAMINATION, COMMITTEE RESPONSIBILITIES AND LRL STATUS

By: Col. John E. Pickering

In discussing the problem of back contamination there are two distinct responsibilities which much be considered. First is the legal problem to protect the public's health, agriculture, and other living resources. Although our present day knowledge of the lunar environment suggests a very low probability of the existence of life forms as we know them it provides no information that assures the absence of life. Our second responsibility is to preserve the scientific integrity of the returned lunar samples in a pristine or near-pristine state. As a consequence, an inter-agency committee has been functioning (for more than a year) as an advisory body to the Administrator of NASA and to the other elements of NASA and to the other elements of NASA that are directly involved with the Manned Lunar Sample Program (Figure 1).

INTERAGENCY COMMITTEE ON BACK CONTAMINATION

- MEMBERS
  - DR. SENCER, PUBLIC HEALTH SERVICE
  - DR. BAGBY, PUBLIC HEALTH SERVICE
  - DR. SAULMON, DEPARTMENT OF AGRICULTURE
  - DR. BUCKLEY, DEPARTMENT OF THE INTERIOR
  - DR. VISHNIAC, NATIONAL ACADEMY OF SCIENCES
  - DR. REIFFEL, OFFICE OF MANNED SPACE FLIGHT
  - COLONEL PICKERING, OFFICE OF MANNED SPACE FLIGHT
  - DR. KLEIN, AMES RESEARCH CENTER
  - MR. HALL, OFFICE OF SPACE SCIENCE AND APPLICATIONS
  - DR. BERRY, MANNED SPACECRAFT CENTER
  - DR. HESS, MANNED SPACECRAFT CENTER

NASA HQ MM 67-6464
4/30/67

Fig. 1

PROBLEM

- PROTECTION--STATUTORY GUIDELINES

• TITLE 7	AGRICULTURE
• TITLE 9	ANIMALS AND ANIMAL PRODUCTS
• TITLE 42	PUBLIC HEALTH
• TITLE 43	PUBLIC LANDS INTERIOR
• TITLE 49	TRANSPORTATION
• TITLE 50	WILDLIFE AND FISHERIES
• PUBLIC LAW 410	PUBLIC HEALTH

NASA HQ MM 67-6462
4/30/67

Fig. 2

The Committee has tried to develop practical provisions forprovisions for protecting the earth's ecology from possible infectious, toxic, or otherwise harmful lunar materials to man, animals, and planets. The guidelines of the Committee's concern in this area have been abstracted from the Code of Federal Regulations (Figure 2) which form in part the basis of an interagency agreement.

Since the returned lunar samples will be analyzed in depth by many of the leading scientists in this country and abroad, the validity of their efforts are dependent in large measure upon the prevention of contamination of the lunar samples with matter from earth. Thus sample acquisition, sample handling, and the maintenance of two-way containment require precise standards and procedures. Therefore it is incumbent upon the LRL staff to establish and conduct: (1) thorough selection and training programs for the technicians in the laboratory, (2) comprehensive astronaut training programs in microbiological techniques of aseptic sampling, and (3) perform very careful and accurate acceptance tests on the facility itself (Figure 3).

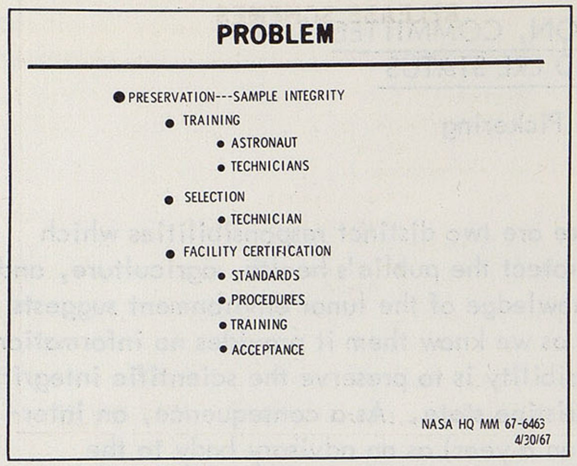

Fig. 3

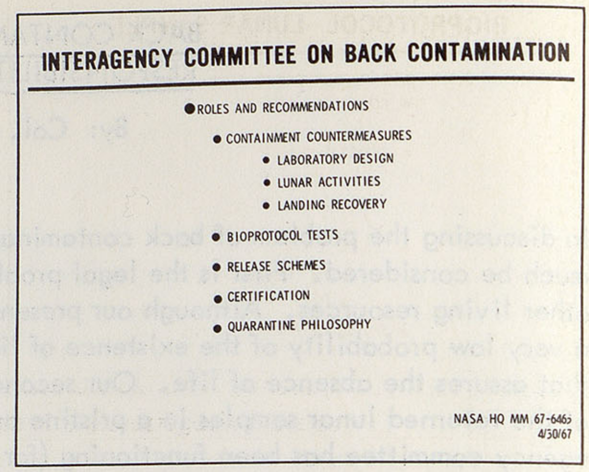

Fig. 4

Although policy considerations have been paramount, certain technical matters have also been considered in some detail. Specific findings and recommendations have been presented for subsequent guidance in overall mission planning (Figure 4). For example, containment countermeasures involving laboratory redesign, housekeeping measures for lunar surface activity as well as landing and recovery procedures have all been documented and forwarded to MSC for their consideration. A very major effort has been directed toward specific and sensitive biological tests to determine the presence or absence of replicating or viable organisms. This bio-protocol, as it is called, was initially prepared with the consultation of over 200 scientists expert in their specific disciplines. It has since undergone four additional reviews to reduce it to those tests which are specific to quarantine. There have been the constraints of space and time to further select out other inappropriate test systems. The corollary to the bioprotocol is the establishment of a quarantine release scheme (both for astronauts and samples). Specific conditions and/or results have been discussed and procedures developed against each of these propositions. Provision has been made for Committee review at appropriate times prior to recommending either an unconditional or conditional release.

With the pending completion of the LRL, efforts are now underway to review the procedures and standards by which the facility can be certified as a two-way isolation and containment facility. These will be specific tests, using microbiological techniques, to assure the absence of leaks as well as the efficiency of the many biological barriers.

To digress for just a moment, it may be appropriate at this time to reiterate the quarantine philosophy of the Committee:

> "It is our recommendation that quarantine continue for several missions. It is not possible at this juncture to establish a time phasing for the termination of this requirement. What constitutes significant and new information can only be evaluated as each mission is accomplished. Certainly as lunar samples are procured at greater depth beneath the lunar surface, a new environment is established and quarantine testing of necessity must continue."

BIOPROTOCOL--LUNAR SAMPLE

- PRIME SAMPLE
- CONVENTIONAL SAMPLE
- IN VIVO SYSTEMS
  - ANIMAL
  - PLANT
- IN VITRO SYSTEMS
  - BACTERIOLOGY
  - TISSUE CULTURES
- GROSS OBSERVATIONAL ANALYSIS

NASA HQ MM 67-6466
4/30/67

Fig. 5

RELEASE SCHEMES

- ASTRONAUT
  - PROPOSITION 1
    NEGATIVE
  - PROPOSITION 2
    POSITIVE - DIAGNOSED
    POSITIVE - NOT READILY DIAGNOSED
  - PROPOSITION 3
    RUPTURE OR SPILL
    (2 ABOVE)

NASA HQ MM 67-6467
4/30/67

Fig. 6

The outline of the above recommendations as they apply to biological tests during quarantine and conditions of sample and astronaut release are illustrated in Figures 5, 6, and 7. The details are contained in the annual report to the Administrator from the Interagency Committee on Back Contamination.

RELEASE SCHEMES LUNAR

- SAMPLE
  - PROPOSITION 1
    NON REPLICATING - NON DELETERIOUS*
  - PROPOSITION 2
    REPLICATING - NON DELETERIOUS
    TERRESTRIAL*
    UNKNOWN
  - PROPOSITION 3
    CONTINUED DELETERIOUS
    REPLICATING
    PATHOGENIC
    PHASE II QUARANTINE
    CONDITIONAL RELEASE

*UNCONDITIONAL RELEASE

NASA HQ MM 67-6468
4/30/67

Fig. 7

Construction of the LRL is slightly ahead of schedule (Figure 8). Phase I (structural phase) was completed in the February-March time period (Figure 9). Phase II is proceeding toward the planned completion date of August 1967 with no apparent problems. As a matter of fact, it is contemplated that portions of the laboratory will be occupied as early as June 23 (Figure 10). This is not to suggest, however, that checkout, certification, and mission simulation in the laboratory will follow with the same dispatch. Experience has shown in other containment type laboratories that to be completely functional requires on the order of 9-12 months. Quarantine acceptance tests as presently defined are not only quite extensive but quite detailed, so before a full-scale sample mission can be simulated and conducted, there is much work yet to be done (Figure 11).

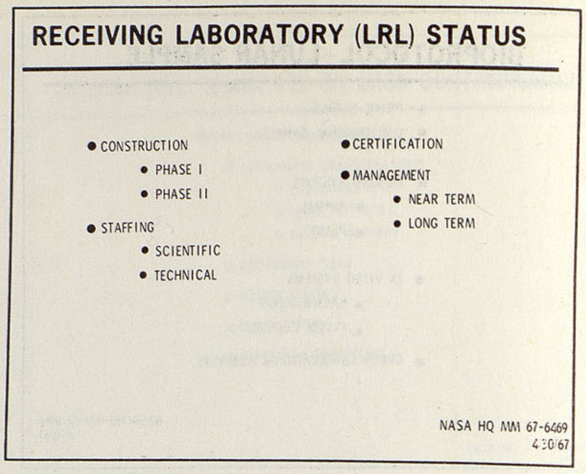

Fig. 8

Staffing is progressing and is notable in the technician support area. So far no major difficulties or shortages have been experienced in technical skills required.

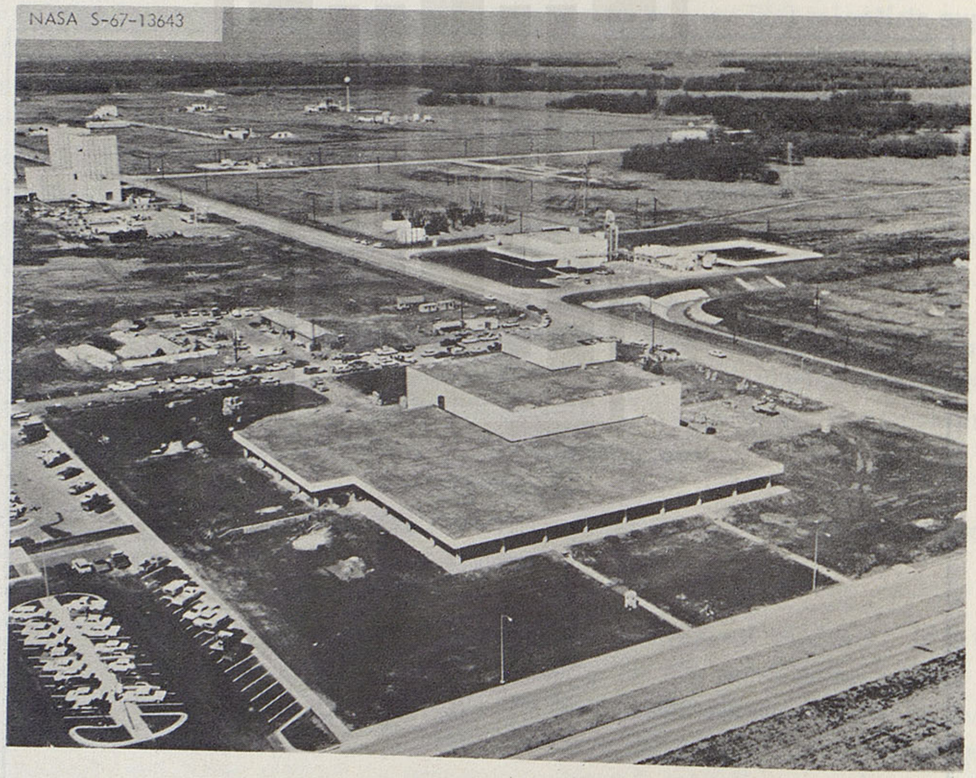

Fig. 9

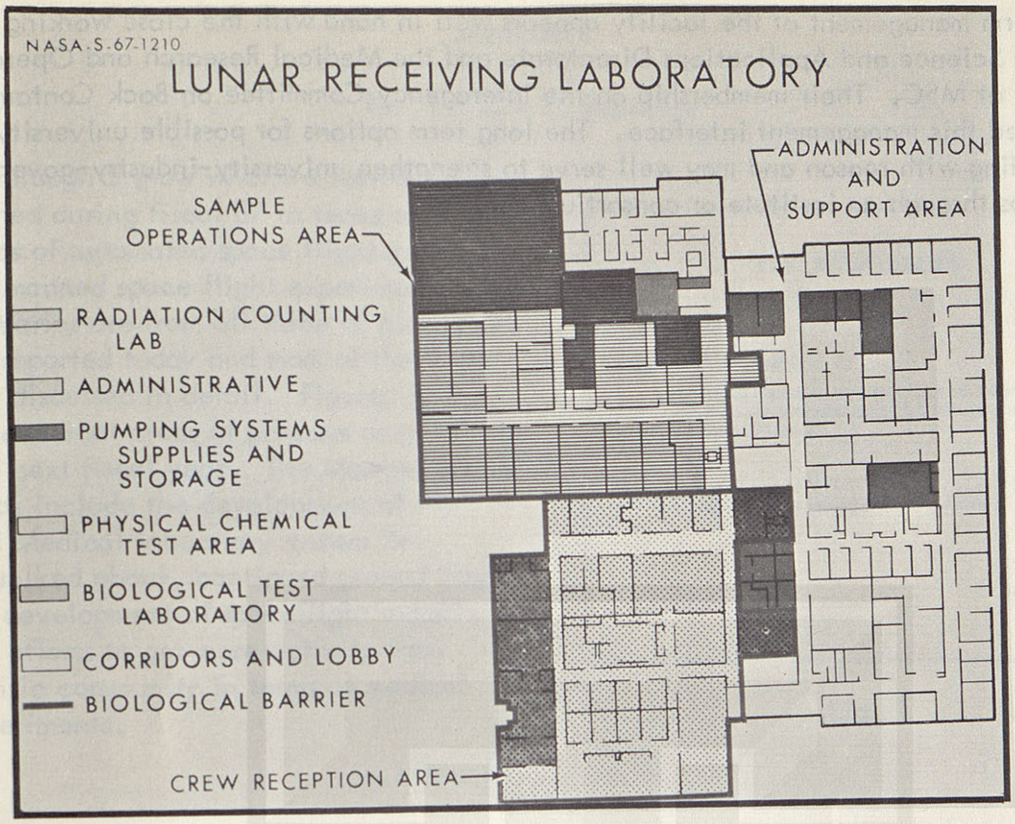
NASA-S-67-1210
LUNAR RECEIVING LABORATORY
ADMINISTRATION AND SUPPORT AREA
SAMPLE OPERATIONS AREA
RADIATION COUNTING LAB
ADMINISTRATIVE
PUMPING SYSTEMS SUPPLIES AND STORAGE
PHYSICAL CHEMICAL TEST AREA
BIOLOGICAL TEST LABORATORY
CORRIDORS AND LOBBY
BIOLOGICAL BARRIER
CREW RECEPTION AREA

Fig. 10

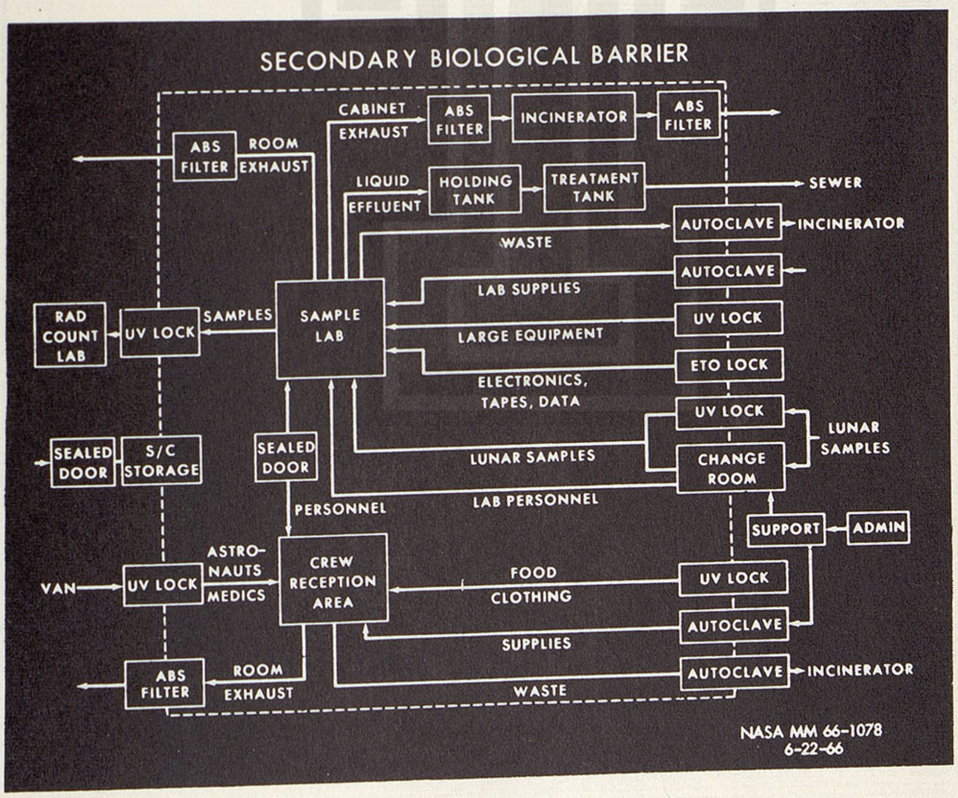
SECONDARY BIOLOGICAL BARRIER
CABINET EXHAUST
ABS FILTER
INCINERATOR
ABS FILTER
ABS FILTER
ROOM EXHAUST
LIQUID EFFLUENT
HOLDING TANK
TREATMENT TANK
SEWER
AUTOCLAVE
INCINERATOR
WASTE
AUTOCLAVE
LAB SUPPLIES
RAD COUNT LAB
UV LOCK
SAMPLES
SAMPLE LAB
UV LOCK
LARGE EQUIPMENT
ETO LOCK
ELECTRONICS, TAPES, DATA
UV LOCK
LUNAR SAMPLES
LUNAR SAMPLES
CHANGE ROOM
SEALED DOOR
S/C STORAGE
SEALED DOOR
LAB PERSONNEL
PERSONNEL
SUPPORT
ADMIN
ASTRO-NAUTS MEDICS
CREW RECEPTION AREA
VAN
UV LOCK
FOOD CLOTHING
UV LOCK
AUTOCLAVE
SUPPLIES
ABS FILTER
ROOM EXHAUST
WASTE
AUTOCLAVE
INCINERATOR
NASA MM 66-1078
6-22-66

Fig. 11

The near term management of the facility appears well in hand with the close working relationships of the Science and Applications Directorate and the Medical Research and Operations Directorate at MSC. Their membership on the Interagency Committee on Back Contamination has enhanced this management interface. The long term options for possible university alliances are proceeding with reason and may well serve to strengthen university-industry-government relationships through an institute or consortium concept.

®

SUMMARY

By: Dr. Orr E. Reynolds

Figures 1 through 5 show what we feel has been accomplished during fiscal 67 in terms of work in the areas of automated space flight experiments and manned space flight experiments. These summaries are from all three of the offices who have reported today and most of the items have been discussed in detail. Figures 6, 7, and 8 are candidat areas of program emphasis during the next fiscal year. The Manned Space Flight areas include the development of the integrated Medical laboratory system Dr. Vinograd talked about, continued ground based research, development of spaceflight experiments and efforts to get more activity from the scientific community in terms of medical flight experiments.

FY 67 ACCOMPLISHMENTS

SPACE FLIGHT (AUTOMATED)

- BIOSATELLITE - DEMONSTRATED CAPABILITY OF SPACECRAFT, AND OPERATIONS AND EXPERIMENT TEAMS FOR CONDUCT OF 3 DAY LAUNCH AND ORBITAL OPERATIONS — SB
- DESIGNED GRAVITY PREFERENCE PAYLOAD FOR AEROBEE — SB

NASA SB 67-2325
5-23-67

Fig. 1

FY 67 ACCOMPLISHMENTS

SPACE FLIGHT (MANNED)

- SIMULATION STUDIES OF EVA WORK TECHNIQUES — RB
- SELECTION OF TWO GAS (69% OXYGEN 31% NITROGEN) FOR ORBITAL WORKSHOP ATMOSPHERE — MM
- AAP BIO A - IDENTIFIED POTENTIAL EXPERIMENTS — SB
- STUDIES ON LOW WORK LEVEL SPACE SUITS RX-4 AND AX-1 — RB
- COORDINATED AF/NASA MEDICAL FLIGHT EXPERIMENTS PROGRAM — MM
- FIRST SEVEN DAY MANNED CLOSED DOOR TEST OF AN INTEGRATED REGENERATIVE LIFE SUPPORT SYSTEM — RB
- QUALIFICATION OF 15 APOLLO FLIGHT EXPERIMENTS — MM, RB, SB
- SUCCESSFULLY ACCOMPLISHED 2 GEMINI EXPERIMENTS — SB

NASA SB 67-2357
5-23-67

Fig. 2

In Bioscience we expect to complete our 3-day Biosatellite flight, perform various advanced studies on future missions, complete the definition of experiments for Voyager '73 of biological significance, continue our SR&T work, get the initial phase of our module system for primate experiments completed, and to do our part of getting ready for lunar sample analysis when the lunar sample arrives.

Biotechnology and Human research, the three factors with emphasis are 1) the factors in aeronautics mentioned by Dr. Jones, 2) attention to man's adaptiveness to long-term exposure to space environment, and 3) to study workload in space suits and EVA work techniques.

A general item is to finish the preparation of the U. S. contribution to the chapters for the joint publication with the Soviet Union "Foundations of Space Biology & Medicine." That completes the presentation of the Life Sciences Review.

FY 67 ACCOMPLISHMENTS

PLANETARY QUARANTINE (OUTBOUND AND BACK CONTAMINATION CONTROL)

• ORGANIZATION OF INTERAGENCY COMMITTEE ON BACK CONTAMINATION	MM, SB
• COMPLETION OF INTEGRATED LUNAR RECEIVING LABORATORY (LRL)	MM, SB
• APPROVAL OF PRELIMINARY BIOLOGICAL AND MEDICAL OPERATIONAL PROCEDURES FOR LRL	MM, SB
• IMPROVED CONCEPTUAL AGREEMENT ON THE PROBABILITY OF CONTAMINATING THE PLANETS	SB
• REDUCTION OF THERMAL REQUIREMENTS FOR SPACECRAFT STERILIZATION	SB
• ESTABLISHED BIO-ASSAY PROCEDURES FOR SPACECRAFT CONTAMINATION	SB
• COMPLETION OF STERILIZATION ASSEMBLY DEVELOPMENT LABORATORY (SADL)	SB

NASA SB 67-2424
5-23-67

Fig. 3

FY 67 ACCOMPLISHMENTS

GROUND BASED RESEARCH RELATIVE TO LIFE SCIENCES

● INITIATION OF PSYCHOACOUSTIC STUDIES OF AIRCRAFT NOISE AND SONIC BOOM	RB
● NEW FUNDAMENTAL KNOWLEDGE IN BIOLOGY	SB
● USE OF HELIUM FOR A NEW METHOD OF DEPRESSING METABOLISM AND PROTECTION AGAINST RADIATION	SB
● DEVELOPMENT OF CONCEPT FOR A MODULAR MEDICAL/BEHAVIORAL MEASUREMENT SYSTEM	MM
● STUDIES OF THRESHOLD OXYGEN TOXICITY LEVELS FOR THREE ANIMAL SPECIES (RATS, RABBITS, DOGS)	RB
● IMPROVED IMPLANTABLE PHYSIOLOGICAL SENSORS	SB, RB
● COMBUSTION STUDIES IN VARIOUS ATMOSPHERES	RB
● IN FLIGHT MEASUREMENT OF SKELETAL MINERAL CHANGES	SB

NASA SB 67-2324
5-23-67

Fig. 4

FY 67 ACCOMPLISHMENTS

GENERAL

- COMPLETED AGREEMENTS WITH AF AND NAVY FOR ROTATION OF 23 MILITARY MEDICAL AND MEDICAL TECHNICIAN POSITIONS
- SYMPOSIA AND CONFERENCE

  SPACE MEDICINE - 4
  EXAMPLE: MEDICAL/BEHAVIORAL EFFECTS OF CONFINEMENT

  BIOSCIENCE PROGRAMS - 9
  EXAMPLE: THEORETICAL BIOLOGY SUMMER COLLOQUIUM

  BIOTECHNOLOGY & HUMAN RESEARCH DIVISION - 6
  EXAMPLE: SPACE SCIENCE BOARD SUMMER STUDY ON CARDIOVASCULAR AND RESPIRATORY PHYSIOLOGY FOR LONG-TERM SPACE FLIGHT

- CONDUCTED SECOND ANNUAL BIO-SPACE TECHNOLOGY TRAINING PROGRAM

NASA SB 67-2465
5-23-67

Fig. 5

PROGRAM EMPHASIS FOR FY 68

SPACE MEDICINE

- DEVELOPMENT OF MEDICAL AND BEHAVIORAL INTEGRATED LABORATORY MEASUREMENT SYSTEM
- CONTINUATION OF GROUND-BASED RESEARCH EFFORT
- EXPANSION OF EXPERIMENT SUPPORT PROGRAM
- INCREASE EFFORTS TO INVOLVE THE SCIENTIFIC COMMUNITY IN THESE PROGRAMS

BIOSCIENCE

- COMPLETE 3 DAY BIOSATELLITE "B" FLIGHT
- COMPLETE BIOPIONEER STUDY, BIOSATELLITE BLOCK II STUDY AND INITIATE BIOSATELLITE BLOCK III STUDY
- IN CONJUNCTION WITH VOYAGER PROGRAM OFFICE, DEFINE VOYAGER FY 73 EXPERIMENTS
- CONTINUE GROUND-BASED RESEARCH EFFORT IN BOTH THE EXOBIOLOGY AND SPACE ENVIRONMENT AREAS
- DEVELOP INITIAL PHASE OF BIOLOGICAL MODULE SYSTEM FOR PRIMATE EXPERIMENTS
- PARTICIPATE IN PREPARATION FOR LUNAR SAMPLE ANALYSIS

NASA SB 67-2463
5-23-67

Fig. 6

PROGRAM EMPHASIS FOR FY 68

BIOTECHNOLOGY AND HUMAN RESEARCH

- FACTORS IN AERONAUTICS (NOISE AND SAFETY)
- MAN'S ADAPTIVENESS TO LONG-TERM EXPOSURE TO SPACE ENVIRONMENT:
  - REQUIREMENT FOR ARTIFICIAL "G"
  - SYSTEMS ANALYSIS OF PHYSIOLOGICAL MECHANISMS
  - ISOLATION AND CONFINEMENT
  - BIOINSTRUMENTATION
  - ESSENTIAL FLIGHT EXPERIMENTS
- ATMOSPHERIC ENVIRONMENT FOR EXTENDED MANNED SPACE FLIGHT
- LONG DURATION TWO GAS REGENERATIVE LIFE SUPPORT SYSTEMS
- LOW WORK LOAD SPACE SUITS
- EVA WORK TECHNIQUES

NASA SB 67-2464
5-23-67

Fig. 7

PROGRAM EMPHASIS FOR FY 68

GENERAL

- US/USSR JOINT PUBLICATION "FOUNDATIONS OF SPACE BIOLOGY AND MEDICINE"-PREPARATION OF U.S. CONTRIBUTION TO CHAPTERS.

NASA SB 67-2453
5-23-67

Fig. 8

GP O 928-256