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FINAL REPORT

SUMMER INSTITUTE IN SPACE BIOLOGY

1969

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# FINAL REPORT

## 1969 SUMMER INSTITUTE IN SPACE BIOLOGY, UCLA

The 1969 Summer Institute in Space Biology, held at UCLA and NASA Ames Research Center attracted 250 applicants representing every state in the Union. From these, 30 highly qualified applicants were selected on the basis of scholastic excellence, enthusiastic recommendations, and convincingly literate personal letters of application. These 20 male and 10 female upperdivision undergraduate students pursued majors which included biology, physiology, physics, chemistry, mathematics and several branches of engineering. As a group they presented qualities of high motivation, considerable scientific curiosity, and explicit interest in the various goals of NASA.

The program offered them was extended to 5 weeks this year: 4 weeks at UCLA and 1 week at ARC. Once again, the theme of the Institute was Mammalian Systems in Space, with the expressed emphasis on basic biological systems in the context of the problems of acquisition of biological signals from difficult environments and their analysis by modern digital computing techniques. This comprehensive approach which encompassed many disciplines was supported by faculty drawn principally from the Space Biology Laboratory, Brain Research Insitute, UCLA; the departments of medicine, neurology and psychiatry, UCLA Center for the Health Sciences; the department of physiology, USC; and the life science research division, ARC. A survey of the accompanying curriculum will emphasize this exciting and unusual Institute which would be difficult to duplicate elsewhere.

In addition to this core curriculum, advantage was taken of the previous year's experience with a project assignment. That project, which concerned experimental proposals for vestibular research, aroused great interest on the part of the students and they generated a considerable amount of work on various aspects of the proposal. The subject was introduced late in the Institute, however, and the students unanimously agreed that they would have preferred it earlier. Thus, this year, three projects were introduced in the first week. They were:

1) Design a biological experiment for a moon laboratory; design may include engineering and electronic aspects.

2) Assume that a flight to Mars is technically feasible; formulate desirable crew characteristics, including personality ones, and devise tests to evaluate these characteristics.

3) Consider the possibility of intelligent life elsewhere in the Universe, and devise a message which may be communicative. Include a description of the transmission method envisaged.

The first two problems were tackled as class projects, including self-organized teams, and the last as an individual task. Formal presentation of the final report was made to members of the faculty and the rest of the student body in the final week of the Institute. Their efforts are attached to this report as appendices for review as desired. As the Summer Institute continues to evolve, the curricula will remain sensitive to students' ideas on how it will best serve their needs, though not controlled by them.

The week spent at ARC was judged outstanding by the students. Here, the unanimous reaction could be expressed as the experience of actual space endeavor where they were exposed to the technology which was previously a classroom academic exercise. They valued the relatively brief introductory lecture and the more prolonged laboratory exposure. With one or two exceptions, other field trips were less successful. The consensus of the evaluation of the experience at UCLA was that a difficult task of presenting comprehensive material from many disciplines in an interdisciplinary manner was excellently handled. Of outstanding interest this year was the experimentally complex primate biosatellite flight: the principal investigator, project manager, and a tracking station monitor of that flight were present as faculty to describe this intricate mission. Some students expressed it as being their outstanding educational experience to date in the formal evaluation they made after conclusion of the Institute. Many pleaded for shorter lectures and more library time in future years. All agreed that it was a valuable experience and strongly urged its continued availability for students in future summers. The growth in stature of the Summer Institute is evident in professors recommending only their best students as being capable of useful participation, and in the increasing requests from leading graduate and professional schools in the country for our evaluation of Institute students who are seeking admission to their programs.

Respectfully submitted on behalf of
the faculty.

John Hanley

John Hanley, M.D.
Faculty Coordinator
Summer Institute in Space Biology

UCLA 1969 Summer Institute in Space Biology

Sponsored by the National Aeronautics and Space Administration

Brain Research Institute

University of California, Los Angeles

July 28 - August 29, 1969

UCLA--USC

FACULTY FOR SUMMER INSTITUTE IN SPACE BIOLOGY

July 28--August 29, 1969

DR. W. ROSS ADEY--Director, Space Biology Laboratory; Professor of Anatomy and Physiology

MR. PIERRE HAHN--Director, Biosatellite Project

DR. JOHN HANLEY--Assistant Professor of Psychiatry (in residence); Assistant Research Psychiatrist

DR. JAMES HAYWARD--Assistant Professor of Anatomy

DR. JAMES HENRY--Professor, Department of Physiology, USC

DR. GUNNAR HEUSER--Assistant Research Anatomist; Assistant Professor of Medicine (in residence)

DR. JOHN MEEHAN--Professor, Department of Physiology, USC

DR. AMOS NORMAN--Professor of Radiology

MR. LIONEL ROVNER--CoDirector, Data Processing Laboratory

DR. JOHN SCHLAG--Professor of Anatomy

DR. DONALD WALTER--Associate Professor of Physiology; Associate Research Anatomist

DR. RICHARD WALTER--Professor of Medicine in Neurology

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UCLA Activity Schedule

Lecture Hall 53-105
Health Sciences Center

| Date | Day | Lecturer--Activity |
|---|---|---|
| July 28 | Mon | Dr. John French - Welcome<br>Dr. John Hanley - Introduction<br>Projects Presentation |
| July 29 | Tues | 9-12 - Dr. J. Henry - Environmental Adaptation and Homeostasis<br>1-4 - Dr. Donald Walter - Computer Operations and Applications |
| July 30 | Wed | 9-12 - Dr. J. Henry - Environmental Adaptation and Homeostasis<br>1-4 - Dr. A. Norman - Radiation Physics |
| July 31 | Thurs | 9-12 - Dr. P. Meehan - Cardiovascular Control Mechanisms<br>1-4 - Dr. A. Norman - Radiation Biology |
| Aug 1 | Fri | 9-12 - Dr. P. Meehan - Cardiovascular Control Mechanisms<br>1-4 - Dr. J. Schlag - Brain Activity |
| Aug 4 | Mon | 9-12 - Dr. D. Walter - Neuroanatomy<br>1-4 - Dr. R. Walter - Neurologic Disorders |
| Aug 5 | Tues | 9-12 - Dr. J. Schlag - Vestibular Oculomotor Functions<br>1-4 - Panel discussion on Neurophysiology Functions in Space |
| Aug 6 | Wed | Field Trip to USC Centrifuge |
| Aug 7 | Thurs | 9-12 - Dr. J. Hayward - Cyclic Function in Mammalian Organisms<br>1-4 - Dr. D. Walter - Data Analysis and Presentation |
| Aug 8 | Fri | 9-12 - Dr. D. Walter - Data Analysis and Presentation<br>1-4 - |
| Aug 11 - Aug 19 | | Ames Research Center (see section labeled ARC) |
| Aug 20 | Wed | 9-12 - Mr. P. Hahn - Biosatellite<br>1-4 - Mr. L. Rovner - Data Acquisition |
| Aug 21 | Thurs | 9-12 - Mr. L. Rovner - Data Acquisition<br>1-4 - Study Groups |
| Aug 22 | Fri | Field Trip to Point Mugu |

| | | |
|---|---|---|
| Aug 25 | Mon | Dr. W.R. Adey - Telemetry |
| Aug 26 | Tues | 9-12 - Mr. P. Hahn - Equipment Reliability<br>1-4 - Dr. G. Heuser - Neuroendocrine Function |
| Aug 27 | Wed | Field Trip |
| Aug 28 | Thurs | Student Presentations |
| Aug 29 | Fri | 9-12 - Dr. J. Hanley - Psychological Problems of Space Flight<br>1-4 - Dr. W.R. Adey - US and Soviet Manned Space Flight Programs |

1. Class Hours: All lectures will be given in 53-105 Health Sciences

   9:00 am - 12:00 pm
   1:00 pm - 4:00 pm
   (10 minute break at 10:30 am and 2:30 pm)

2. A final examination will be given on the last day:

   Friday, August 29

# The Lunar Biological Laboratory

By

Ronald Reed
Paula Lippsett
Tim Byers
Keith Apelgren
Jim Blizzard
Marilou Okano

August 25, 1969

## The Lunar Biological Laboratory

The first biological laboratories based on the lunar surface could possibly consist of a group of test animals and the systems necessary to maintain them for some determined length of time on the lunar surface. This single experimental group would then be recovered for inspection along with the telemetered data obtained during the actual experiment.

Although this is a valid experimental technique the proposal of our group is for a somewhat more complex (and perhaps later) experimental system which we believe will provide for more efficient, more flexible, more numerous, and more prolonged experiments. Also, in the long run, this system would prove less costly than most other proposals.

In the hope of speeding production and cutting costs by utilizing present day knowledge and developed systems to the fullest we have selected the LEM descent stage as the basic vehicle in our experimental system. Of course, the LEM would be modified somewhat in order to utilize all available space. Subassemblies removed to make room for environmental and telemetry equipment would include some of the batteries (due to an expected lower power profile for landing), the ECS water, gaseous and supercritical oxygen supply, the present Apollo experimental package, and the communication erectable S-Band antenna. The above space (approx. 50 $ft^3$) would be further supplemented by saddlebag configurations on the exterior of the present hull (amounting to approx. 30 $ft^3$).

Mated with this modified LEM would be the actual housing for the interchangeable experimental packages. The basic working unit of the system (Lunar Biological Laboratory) is the "drawer," in which may be housed a great variety of experiments.

Each drawer is connected to the environmental and telemetering systems of the LBL by four main connections--these will be discussed in more detail later with relation to the basic systems in which they are incorporated. Let it suffice at this point to say that these connections (telemetry, power, waste, and nutrients) are to be replicated in each experimental package designed for use in the LBL so that they may be interchanged.

## INSTALLATION

For launch the Saturn V rocket will probably be used much as it has been in recent Apollo flights. If the total weight of the LBL is estimated at about 50,000 pounds (18,000 more than the LEM) we still have an additional payload capacity for extra construction materials or experimental packages not related to the LBL in excess of 40,000 pounds.

An initial earth parking orbit provides a period in which the exact relative positions of the spacecraft and moon could be determined. After necessary flight computations are made firing of the third stage would carry the payload on a lunar trajectory. Somewhere in this flight to the moon the adapter panels would be opened and the LBL assembly would move away from the third stage. Nearing the moon the LBL would be swung around and a small engine firing would slow it into lunar orbit--where it would remain until final calculations for landing had been accomplished.

In order to lessen the probability of landing the LBL in a dangerously rough area the landing spot would have been selected previously by exploring astronaut teams. When a suitable area had been found it would be marked with a radio beacon which could be used to direct the LBL in its final descent from the lunar orbit calculated to take it over the landing site. Since the time lag (1.25 seconds on each leg of the earth-moon loop) would be too great for direct control of final landing maneuvers it might be feasible to have the landing monitored by astronauts either on the surface or in a lunar orbit overhead.

Inspection of the LBL on the lunar surface would be accomplished via telemetry on earth and by visual inspection of a following astronaut team. If all were found to be operational this team would return to their craft and bring out the experimental packages which they had carried from earth.

Depending upon the distance of the astronauts vehicle from the LBL a variably complex portable life support system (PLSS) would be needed to transport the experiments to and from the LBL. Upon reaching the LBL the astronauts would ascend with the package to the level of the "drawers." Here they would separate the package from the PLSS after sealing its various external openings (enabling it to be transferred to the "drawer"). After opening an exterior hull door the astronauts would pull out a frame on sliding rollers into which the experimental package could be fitted and secured. Now the power, nutrients, telemetry, and waste hoses may be plugged in. All that is left to do is push in the drawer and secure the outer door.

## SYSTEMS

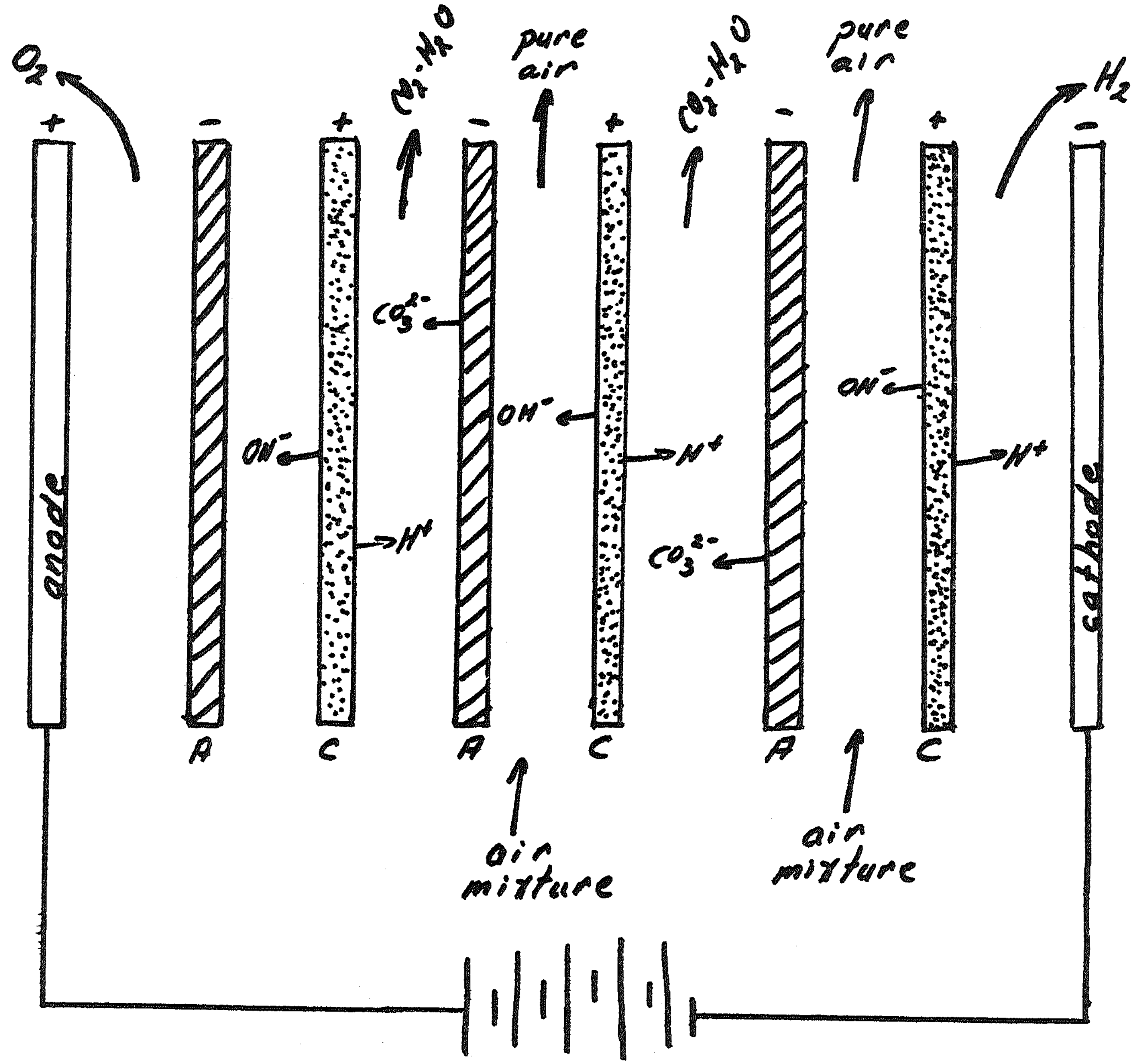
### Nutrients and Wastes

Two plugs will be provided for a combined nutrient and waste use. The waste plug will provide passage for both urine and feces as they pass from the bottom of the package. The nutrient plug will actually have several purposes. As it enters the package it will contain separate paths for food, water, and air circulation (divided into an air input and an air output). It should not be thought that once inside the experimental package these different aspects will be grouped in one place. On the contrary, once inside these lines may branch to various points for peak efficiency.

The entire system would be so interconnected in its various aspects that it would really be impossible to strictly divide the problem into one of nutrients and one of wastes. What we are planning for the LBL is a semi-closed system which would recycle most of the wastes while still providing for removal of some of them for study and replacement of some resources by attending astronauts.

Besides trace contaminants carbon dioxide and water vapor will probably be the two main ingredients in the atmosphere which we will need to closely control in concentration.

# $CO_2$ REMOVAL




A= anionic membrane

C= cationic membrane

Carbon dioxide may be removed by electrodialysis--a system having advantages over adsorptive methods because it is a static continuous process and not a batch process. At present this method requires some work to increase membrane reliability and to improve efficiency, but with some research it should become a very feasible method.

Removal by electrodialysis is based on the transport of the carbonate ion, under the influence of an applied electrical potential, through an ion exchange membrane. Discharge of the $CO_2$ from the carbonate is accomplished in an adjacent compartment of the cell by reaction with hydrogen ions coming from the water in the system. Physically an electrodialysis cell consists simply of alternating, spaced anionic and cationic ion exchange membranes. Between each pair of membranes is a thin layer of ion exchange resin. Carbon dioxide reacts with the anionic resin to produce carbonate ion and hydrogen ions. The carbonate ions migrate through the anionic membrane toward the anode while the hydrogen ions move through the cationic membrane toward the cathode. The Carbon dioxide and hydrogen ions react to form water and carbon dioxide.

It should be mentioned that in this system a small amount of hydrogen and oxygen gas is produced within the cell--the oxygen can be recycled to the experimental packages while the hydrogen may be used for further treatment of wastes.

Possible methods for oxygen recovery from carbon dioxide might include the following:

1. Methanation of $CO_2$ followed by pyrolysis of the $CH_4$
2. Low pressure pyrolysis ($2CO_2 \longrightarrow 2CO + O_2$; $2CO \longrightarrow CO_2 + C$)
3. Bosch process ($CO_2 + 2H_2 \longrightarrow C + 2H_2O$)
4. Fischer-Tropsch ($CO_2 + H_2 \longrightarrow C_nH_{8n} + H_2O$)
5. Direct electrolysis ($CO_2 \longrightarrow C + O_2$)

At present methanation of $CO_2$ by the Sabatier reaction has been proven a fairly successful method. The basic reaction is as follows: $CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$. Electrolysis of the resulting water liberates oxygen for the experimental animals and the hydrogen can be recycled into the same process. If the cycle were allowed to continue in this fashion without an outside source of hydrogen or recovery of the hydrogen from the methane produced the entire system would gradually slow to a stop. The most direct method to close this cycle is pyrolysis: $CH_4 \quad C + H_2$. This final reaction is endothermic and must be carried out at very high temperatures. Also it has been found that at present the conversion rate is slow and frequent recycling is required. If this final conversion of methane were not found feasible for the LBL the $CH_4$ could be eliminated and hydrogen could be provided from one of the many other sources (via electrolysis).

One additional method for oxygen recovery which is very efficient involves electrolysis of water vapor in the air. This system, under development at Ames Research Center, has several major advantages:

1. no condensation equipment is required
2. the system is in some measure self-compensating and adds to control of cabin humidity
3. hydrogen is produced as a useful by-product
4. the system is gravity independent
5. the cells are not contaminated by $CO_2$
6. there are no moving parts

Urine could be regenerated into usable products by several methods (e.g. compression distillation, air evaporation, and electrodialysis). However, the system of reverse osmosis seems to be almost a perect match for the LBL's requirements. Its advantages include low weight, size & power requirements; operation is at ambient temperature; by-products from the electrolysis are not toxic and are further utilizable; no expendables are needed. Further, it is vital that sterilization is inherent in this system since a central processing unit for all the LBL's experimental packages must eliminate the chance of disease spreading by chance throughout the system.

In the reverse osmosis process urine is placed next to a dialyzing membrane and subjected to a hydrostatic pressure that exceeds the osmotic pressure of the solution (under these conditions water will pass out of the salt solution depending upon the selective properties of the membrane). Prior treatments are necessary, however, to remove urea and other organics which might also pass into the pure water through the membrane. In this cell this treatment involves use of an electrolytic technique which decomposes urea to carbon dioxide, nitrogen, hydrogen and water.

Anode: $6Cl^- \longrightarrow 3Cl_2 + 6e^-$

Cathode: $6H_2O + 6Na^+ + 6e^- \longrightarrow 3H_2 + 6OH^- + 6Na^+$

The chlorine produced reacts with the sodium hydroxide by the following reaction: $3Cl_2 + 6Na^+ + 6OH^- \rightarrow 3NaOCl + 3Na^+ + 3Cl^- + 3H_2O$. The hypochlorite can oxidize the urea:

$$CO(NH_2)_2 + 3NaOCl \rightarrow N_2 + 3NaCl + 2H_2O + CO_2$$

The overall reaction for the treatment would simply show the treatment of urea with water to yield carbon dioxide, nitrogen and hydrogen ($CO(NH_2) + H_2O \rightarrow CO_2 + N_2 + 3H_2$).

The hypochlorite formed is a powerful oxidizer and disinfectant. In addition to attacking and decomposing the urea it decomposes any other organic contaminants and sterilizes the water. Total count of bacteria in test samples has gone from 9,900,000 to less than 5/ml during an electrolysis run.

The reverse osmosis system then operates to remove the remaining inorganic salts from the input. It can be seen that as the water is gradually removed from the salt solution is osmotic pressure will rise. If nothing is done to remove the salts an operating pressure of 5,000 lb/sq. in. would be required to remove 96.5% of the salts. It should be easily seen that some removal of the salts will be required during the osmosis process. These by-products will then be either discarded or utilized in other systems.

One of the most direct methods to dispose of the fecal material which was not being stored for inspection at a later date would be to place it in some type of chamber containing microorganisms capable of living with the feces as a food source. It has been found that some microorganisms, by aerobic action, can degrade as much as 97% of the organic solids in feces to carbon dioxide, ammonia gas, and methane. These gases could be used or vented into the lunar "atmosphere." The remaining mass could be stored or incinerated to yield carbon dioxide, carbon monoxide, and water.

Food for the specimens would not be provided through any regenerative cycle in the LBL. It is our thought that it would be more convenient for the astronauts to fill food bins on each monthly trip. This would give experimenters more control over and more data concerning the exact nature of the animals' food. Of course, in any consideration of nutrient supply, whatever it may be, it is expected that some provision will have been made for an emergency supply.

References:
1. C.T. Leondes & R.W. Vance (eds), Lunar Missions and Exploration, John Wiley & Sons, Inc., N.Y., 1964, pp. 467-468, 475.
2. Leonard Elikan (ed), Aerospace Life Support, Chem. Eng. Progress Symposium Series, Vol. 62, #63, American Institute of Chemical Engineers, N.Y., 1966, pp. 5-9.

## TEMPERATURE

Thermal variations within the LBL will stem from several sources. From the external environment we will have to cope with fluctuations in the lunar temperature itself due to the presence or absence of of solar radiation. From within we are concerned with heat given off by the animals because of metabolism, from various electrical circuitry and components, and from different parts of the waste and nutrient regenerative systems.

Extreme temperature variations caused by the lunar environment will be avoided by maintaining some insulation within the walls of the LBL. Peak heat loads from outside will also be combated by the reflective outer coating which will cover the LBL's surface. These precautions will not be sufficient, however, to maintain complete temperature control within the LBL. Depending upon the experiment in progress different experimental packages will require different temperatures. A semiconductor heat pump, being by-directional, seems applicable to shift these inner heat fluctuations to our best advantage. (This process has been widely used in the Soviet Union and has been used in this country in the SNAP reactor design.)

If the temperature requirements of the LBL (we have no real criteria for analyzing them at this stage of design since we are dealing mainly with concepts) were found to exceed the limits of this system a closed coolant system utilizing a "space radiator" and a water boiler for peak loads could be used to adjust the temperature within the limits of the semiconductor heat pump. The semiconductor system would then be used for the more precise temperature regulation required within the individual packages and some of the regenerative life support systems.

## TELEMETRY

Each experimental package will be provided with approximately 64 channels for telemetered data. These channels will be multiplexed within the individual experimental packages so that the plug leaving each package will carry only one signal to be telemetered. This multiplexed signal will go into a subcarrier oscillator where frequency modulation occurs. From the oscillators all the various package signals will go into a mixer where they are incorporated into one final signal. This signal goes to the transmitter and is relayed to earth receiving stations.

The exact data-gathering instruments will vary with the experimental package involved. As long as these packages do not exceed the capacity of the LBL's system to relay information "anything goes." This is one further advantage of the central LBL concept: technological advances may take place in data gathering and instrumentation without affecting the LBL itself.

It should be added that the same plug which takes the multiplexed signal from the packages will also have the capability to relay toned control signals from earth to the individual experiments.

## POWER

Power for the LBL will be furnished by a SNAP-2 nuclear reactor. This unit, containing about five pounds of nuclear material and operating at 6% efficiency, will provide 3 kilowatts for the various systems within the LBL. This SNAP reactor would be landed near the LBL so that a cable could be run between them. An unshielded SNAP-2 would weigh approximately 1200 pounds; when shielded to a point of dosage of 2.6r at thirteen feet the total unit would weigh a little over 3000 pounds. Since it would probably not be wise to have a man move closer than this thirteen-foot limit it would probably be feasible to have a line shot from the SNAP-2 upon touchdown to some distance beyond this. The astronaut could then pull out the power cable and safely connect it to the LBL.

Auxiliary power could be provided for the time until the SNAP-2 is connected, and in case of emergencies, could be provided by either batteries or a hydrogen-oxygen fuel cell. One advantage of this last method would be that the water given off by the fuel cell reaction could be added to the regenerative life support system. This water would be absolutely pure so that no prior purification would be required before its addition to the system. Further, this fuel cell could easily be refueled by visiting astronauts if necessary so that it would be available for even later problems.

## EXPERIMENTS

Now that the basic concepts of the LBL have been shown it is probably fitting that a few experiments be suggested for use in this system. Since the main components of each package have already been mentioned it should be necessary only to give a few more details on the exact outputs desired and results expected in each experimental package. In an actual LBL mission a set of priorities would be established so that the areas of most interest could be assigned the greatest number of drawers. For our purposes it is not necessary to be so formal at the beginning.

I. Cellular studies on the lunar surface using, among others, developing frog eggs could be valuable preliminary indications of how human cells might function under similar conditions.

Fertilized eggs of Rana pipiens were used in Gemini VIII, Gemini XII, and Biosatellite spacecrafts to study the ability of the egg to divide, differentiate, and develop in the weightless or near weightless condition. As early as 1894 O. Schultze noted the response of frog eggs to disorientation with respect to gravity. Normally, the fertilized amphibian egg can rotate up to 180 degrees in the jelly capsule so that the animal pole is up and the heavier yolk mass of the vegetal pole is down. If possible the egg will reorient and establish the embryo axes. If the vegetal pole remains upward, the resulting embryos are likely to be abnormal--for example, with twin heads.

Because the results and interpretations of both earth and space frog egg experiments are still somewhat controversial a moon lab experiment based on similar procedures might answer the question of whether a normal embryo can result from an egg fertilized and allowed to develop under conditions of reduced gravity.

Although Rana pipiens normally has a seasonal reproductive capability, frogs maintained at low temperatures in a physiologically compatible medium and with antibiotic treatments can be used for this experiment any time of the year. The best experimentally determined temperature to inhibit cell division without extreme abnormalities is 43 degrees F (6 degrees C). Frogs would be kept in laboratories near the launch site at 6 degrees C.

Three days prior to launch 100 female frogs would be injected at 12-hour intervals with 3 to 5 pituitary glands each to induce ovulation. Two days later test fertilizations would be made at room temperature and the developing embryos would be observed for abnormalities in fertilization and development. From the 100 test females three donor frogs would then be chosen for the experiment and three alternates would serve as their earthly controls. Several hundred eggs would be collected and stored in petri dishes at 6 degrees C aboard the spacecraft. Also stored on board would be a sperm suspension of macerated testes (2 testes/5 cc spring water).

Shortly after landing an astronaut would strip the eggs and expose them to sperm at room temperature for 15 minutes. Then he would divide them into clusters of 10 and place them into a set of acrylic modules containing pond water (described below) and install them in the experimental package. (An alternate method for this experiment would involve packaging the eggs and sperm separately in the package on earth and have the fertilization done automatically.)

The acrylic modules would each be divided into two chambers: a 20-ml egg chamber and an 8-ml fixative chamber (as basically used in the Biosatellite II frog egg experiment). Temperature control maintains a temperature of about 70 degrees F (21 degrees C) while the experiment is in progress. Eighteen of the twenty experimental acrylic modules have in the fixative chamber a glutaraldehyde fixative in osmotically conditioned (sucrose) Sorensen phosphate buffer to give a final concentration of 2.5% glutaraldehyde after mixing with the frog eggs in pond water. A spring-loaded piston is actuated by program to mix the fixative and specimens.

The first fixation is set for the time immediately after initial placement in the LBL. The second is fixed 40 minutes later to catch the stage between the first and second cleavage. Next at 2 hours, 25 minutes for preservation of the eight cell stage. Continuous fixations would then be made until complete embryos are expected. The last two chambers would remain unfixed in hopes of returning some live embryos to earth. This entire experimental package could be picked up after the first 28 days of the LBL's lunar stay and would then be brought back to earth for histological examination.

If the results of this experiment were as most earth scientists predict we would find that reduced gravity should be adequate for normal orientation, growth, and development of the frog egg. This experiment could then be extrapolated to a human situation only as far as frog eggs can be compared to human eggs.

References:

1. G. Leoin & J.F. Saunders, "Environmental Biology," Space Science (NASA SP-155), 93-96.

2. William R. Cortiss, "Biological Experiments on Scientific Satellites," Scientific Satellites (NASA SP-133), 648-649.

3. Richard S. Young & John W. Tremor, "The Effect of Weightlessness on the Dividing Egg of Rana pipiens," Bioscience (June, 1968), 609-614.

II. An interesting correlate to the above experiment would use almost exactly the same equipment to study the effects of reduced gravity on regeneration in planaria. The planaria could be cut or sectioned as desired on earth and cooled during the lunar flight. They could then be placed in the LBL and fixed at different time intervals to see how quickly regeneration was occuring.

III. Another reproductive experiment which might be more directly applicable to man would involve use of rats or mice. The animals would be given hormone shots prior to flight and once on the lunar surface males and females would be placed together so that mating could occur. Photographic monitoring would probably be desired to observe the progress of pregnancy. After one month an astronaut could pick up litter specimens for return to earth while others would be left to grow and develop in the LBL.

IV. Since man will be working on the moon for extended periods in the future it will be desirable to learn not only the effect of prolonged reduced gravity on the muscles themselves but also the effects upon co-ordination.

In order to test the adaptation of mouse co-ordination (neuromuscular) to the 1/6 g environment of the moon and subsequent readaptation to earth's 1 g a small colony of mice would be trained on an obstacle course maze some weeks prior to launch. They would be fed regularly except during testing periods, when food dispensing would stop in order to increase motivation to cross the course in order to obtain a food reward. Each run through the course would be timed and an automatic photograph would be taken to record which mouse had made the run--only one mouse at a time would be able to make the run.

It would be expected that the mice would have difficulty doing pre-learned co-ordinated movements immediately after landing on the moon. After a few days, however, their body balance reflexes and neuromuscular co-ordination should have adapted sufficiently to 1/6 g to make "normal" co-ordinated movements possible. Upon return to earth's 1 g a similar adaptation should occur.

V. To test the oculomotor co-ordination of a monkey during prolonged reduced gravity a monkey, fitted with EEG equipment, would be trained prior to launch in some game similar to that used in the last Biosatellite. The reward for playing this game correctly would be an automatically dispensed food treat.

The actual game in this experiment begins by alerting the animal with the flashing of a cue light. One light in a 3 by 3 array then lights up, followed by some adjacent light and then the third in that line (whether straight or diagonal). The monkey would then have a given length of time (approx. 5 seconds) to press the button which continues this sequence. The game would be played in sets of 5 trials each with a short rest between each trial. About 3 sets per day might be played after the first few days in the LBL, but during those first days testing should be more intense to maximize data during the early stages of adaptation.

Initially there should be some noticeable difficulty in hand-eye co-ordination in 1/6 g for a short period; however, adaptation should soon occur and the normal co-ordination restored. Of special interest would be readaptation to earth upon recovery of the package.

VI. The degree to which mice run in a running wheel should be proportional in some way to their ease in mobility. We would expect, therefore, that as they adapted to 1/6 g their ease of mobility and subsequently their amount of running would increase. If other factors beecame involved (such as muscle atrophy) a corresponding shift in running activity might be expected. This experiment, using only one data channel to record revolutions of the running wheel, could very easily be incorporated in some other experimental package using mice.

VII. In order to determine the extent of muscular atrophy possibly indicated in the preceding experiment (as well as other such things as organ size and weight, amount of body fat, etc.) a colony of mice would probably be maintained in one of the larger drawers or in several smaller drawers. Every thirty days 2-3 of these mice would be sacrificed on the moon and stored (possibly in liquin nitrogen) for return to earth and a complete examination.

VIII. Using microorganisms experiments could be developed to test for recombination and growth rate under prolonged low-g. For the recombination experiment Escherichia coli (lactate+, arg- & lactate-, arg+) would be streaked in an X-form on a set of petri dishes containing minimal agar. They would be frozen until placed in the LBL on the lunar surface; the temperature would then be adjusted to 37 degrees C. The time lapse before growth occurred would be measured.

In a growth rate experiment E. coli would again be placed on petri dishes and placed in a LBL package. Actual collection of data in these two experiments could be accomplished by several methods--many of which have been proposed for use in missions designed for detecting extraterrestrial life.

One method would involve the use of a camera to take periodic pictures of the cultures. Contrast for these shots could be accomplished by growing the cultures on a media of eosin methylene blue (E. coli show up white on this red agar). Other methods might include gravimetric methods, a silting index, electronic particle counting, metabolic monitoring, or other optical techniques.

Depending upon the original culture size, number of cultures, and methods of measurement it is doubtful that this one experiment would take up the space of one full package. Therefore, this space and data channels could be economized by fitting another experiment into the same package.

References:

1. Edward L. Merek & Vance I. Oyama, "Analysis of Methods for Growth Detection in the Search for Extraterrestrial Life," Applied Microbiology (May, 1968), 724-731.

2. E.L. Merek & V.I. Oyama, "Integration of Experiments for the Detection of Biological Activity in Extraterrestrial Exploration," Ames Research Center.

IX. In this experiment a macaque or smaller monkey is used to determine the effect of reduced gravity on several cardiovascular parameters in primates. If isolation were found to be a crucial point in obtaining valid data two smaller monkeys might be sent instead of one larger one. In order to give the experimental animals plenty of room it might be advisable to combine two adjacent drawers into one unit. This would probably not be a difficult job from the engineering standpoint (involving a change in package design on earth and not in LBL design) and in addition to space would provide facilities for twice the power, telemetry, etc.

(a) Heart rate would be measured by an EKG hook up. Electrodes would be implanted in the region of the right arm and left leg. (It is our thought that in a long-term experiment such as this, implanted electrodes would be more preferable to avoid their removal by the animals. Further, implanted electrodes encounter less resistance and the signals meet with less interference and "noise.")

(b) Stroke volume would be determined by impedeance measurements across the heart via implanted electrodes.

(c) Displacement transducers implanted in the animal will also serve to give data on blood pressure. These measurements should be taken in such regions as: vena cava, an arm artery or the aorta, a leg vein, and the carotid artery.

With all these measurements it would probably be wise to supplement with an EEG so that we would know whether the animal was resting or active when the measurements were taken. Another valuable parameter would be the heart size and position after adaptation to 1/6 g is accomplished. This could probably be recorded after the termination of the experiment using a standard X-ray device.

Blood samples could be taken automatically via a catheter (using a heparin solution) and stored for removal by astronauts at 30-day intervals. These samples would be analyzed for changes in cell shape, white & red blood counts, clotting time, etc. Furthermore, hemocrit readings must be made to note the per cent of hemoglobin in the cells.

In the actual experimental situation it would be nice if the subjects were free to move about so that a better picture of low-g effects under "normal" working circumstances could be obtained.

However, in this case there is a distinct possibility that the animals would tinker with the instruments--the catheter might be a particularly attractive target. To minimize damage to the wires and other equipment the animal could be fitted into some suit which would restrain movements to reach the apparatus. If it were found necessary to fasten the animal in some type of chair (as in the Biosatellite program) as much freedom as possible should be left the animal and some mechanical means of exercise might even be employed.

X. Many scientists have been concerned about the possibility of bone demineralization under a prolonged weightless or low-g condition. Early manned space flights (e.g. Gemini III & IV) revealed that the astronauts experienced significant calcium ion losses, which, however, were quickly recovered upon return to earth. The results from Gemini VII and the Apollo flights, notably Apollo X, indicated that the time of flight was not the chief factor responsible for skeletal loss during space missions. Exercise and diet seem to play significantly more important roles in the rate of calcium loss from the bones.

It is not wise to become overconfident in this area, however. To date the limit of man's exposure to weightlessness at any one time has been less than a month--a Mars mission would require about 1-2 years. A moon laboratory experiment could provide some answers to the prolonged effects of reduced g forces on bone metabolism.

(a) Diet vs Calcium loss--Three rats would be placed in separate boxes and kept under similar environmental conditions except for the amount of calcium in their diets. A diet of 0.5, 1.0, 1.5 man equivalents calcium/day could be maintained. Each month a visiting astronaut could take the package to his craft and take X-ray photographs of each rat using a technique similar to the one which has been developed by Dr. Pauline Berry Mack of Texas Women's Univ. (Alternately, the rats could remain in their boxes continuously and the X-rays taken by remote control if a suitable technique could be found to insure that the rats would voluntarily place themselves in the proper position prior to each X-ray.) These X-ray photographs could then be returned to earth for comparison to those of control groups.

(b) In a similar experiment the tibia of mice, or primates, could be notched using standard laboratory techniques before launch from earth. X-ray studies would be made periodically for comparison to controls on earth.

(c) Both the above experiments, and indeed almost any animal experiment, could employ urine and fecal analysis. The urine could be collected and analyzed using a device similar to the closed system one proposed by Dr. Rho and Dr. Pace in Biosatellite III. for at least calcium, creatine, and creatinine. The feces of the subject could also be recovered for analysis on earth. Again, the necessary pre- and post-flight data and data concerning the dietary intake should be obtained to further validate any results.

References:

1. A Review of Medical Results of Gemini VII and Related Flights, Aug. 23, 1966, pp. 105, 123-124.

2. J.L. Stuart, Bioengineering in Space: The Biosatellite Urinalysis Experiment, Jet Propulsion Laboratories.

3. Lanny C. Keil, "Changes in Growth and Body Composition of Mice Exposed to Chronic Centrifugation," Growth, Vol. XXXIII, pp. 83-88

## CONCLUSION

Although this report is by no means complete it is our hope that it has served its purpose--to get across the basic concepts of the Lunar Biological Laboratory. We have avoided being specific in several areas because it would be more than slightly ridiculous for scientists of any kind to attempt to move directly from the beginning concept to the finished product.

We have tried to design the LBL around several basic principles: flexibility, efficiency and, perhaps most important from the point of view of our goals, endurance. For some time the trend in space sciences has been to "throw away" components. It has been our hope to demonstrate a reusable experimental package just as there may someday be reusable boosters.

The group which composed the various components of this paper would like to add one last note. Although the research for this paper was interesting and educational, although we enjoyed working out some of the problems involved and discussing the various aspects among ourselves, we have also sometimes felt that this project (instead of the Lunar Biological Laboratory) should be named the Biological Unmanned Lunar Laboratory Sitting High In The Sky.

PROJECT GALILEO

A Biological Lunar Laboratory

Summer Institute in Space Biology - 1969

Erle Austin
Jim McMonagle
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GALILEO

TITLE: PROJECT GALILEO

HYPOTHESIS: Through properly contolled and monitored animal experiments conducted on the lunar surface, man will be able to predict his vital capabilites for long periods of time spent on that surface.

EXPERIMENTAL DESIGN: Project Galileo has been divided into four major areas of concern . These are:

(1) Mission Profile and Lunar Operations
   a. launch sequence
   b. surface structural design
   c. surface mobility needs and designs
(2) Physiological Experimentation
   a. experiments to be conducted
   b. design configurations
(3) Life Support
(4) Power and Data Acquisition

Each of these areas will be discussed and interfaces will be outlined.

(1) MISSION PROFILE AND LUNAR OPERATIONS

a. Launch Sequence

000:00 Stage I

A large fuel cell, weighing approximately 250,000 lbs when full, and an attached Lunar Lander (LL), weighing approximately 13,000 lbs when empty, are put into a prescribed orbit by a Saturn V rocket. The LL at this point contains all the materials that are needed to construct the moon lab, the experimental animals, their life support needs for 45 days and all their experimental apparatus. In addition, in-flight life support needs for the 6 man crew, who will take the LL to the moon, and the animals contained within are stored here.

The LL vehicle consists of a descent stage with an attached section for the storage of all the above mentioned materials, and an ascent stage capable of lifting the six men, their life support needs and an additional 1000 lbs off the lunar surface and putting them on a path for the orbiting fuel cell.

001:00 Stage II

The lunar mobility vehicle is launched by the Saturn V using only the first two stages, and equipped with the necessary adaptors. It resides in a package capable of being soft-landed on the moon and comprises about the same mass as the LEM in use in the Apollo Program (32,000 lbs.).

Once launched the package is guided by remote control to a soft landing on the moon near the programmed laboratory area in the crater Censorinus. The landing site should be no farther than 1.5 miles from the proposed lunar lab site. On a signal to be given by the LL crew before their touchdown, the legs of the package, containing the lunar mobility vehicle collapsed and the side open to expose it and provide an exit ramp. A second signal initiates movement in the LMV and telemetered position readings enable ground crews to direct it to a stand-by position near the landing area.

002:00 Stage III

A Thor Agena rocket launches a capsule containing 6 men into orbit and the second stage of this assembly allows a rendevous and docking with the orbiting fuel cell and LL.

The crew launched is carefully picked and intensively trained for the mission. Some of the psychological parameters which are important considerations for maximum efficiency of the astronauts include:

1. isolation and confinement
2. sexual deprivation
3. sense of time
4. encounters with alien factors on other planets

Some physical parameters which should be considered include:

1. strength
2. coordination and reaction speed
3. dial reading
4. instrument interpretation
5. sensory acuity

Some behavioral parameters which should be considered include:

1. intelligence
2. judgement and comprehension
3. mechanical relations
4. visualization of vehicle movements
5. orientation

Some other consideration are;

1. interests
2. attitudes
3. motivation
4. personality variables
5. training of men

All the men will be cross-trained to a certain extent, but their main fields of interest and training will be as follows:

1 command pilot
1 pilot-engineer
1 astrophysicist
1 MD-physiologist
1 geologist
1 engineer-physiologist

After docking, the 6 men are transferred to the lunar lander where they check on all materials to be sent to the moon, the life support systems for themselves and the life support system and physical condition of the experimental animals. In addition, they make sure that the proper fuel levels are being maintained in the LL and that all its technical equipment is in working order.

Having accomplished this, the LL is separated form the fuel cell and 6-man capsule and begins the acceleration to escape Earth gravity. After an extended fire of the LL descent engines, injection into a lunar trajectory is completed.

005:00 Stage IV

Nearing the moon, the command pilot begins deceleration and accomplishes lunar orbit. Further critically adjusted velocity changes put the LL into position for the lunar landing. At this time also the LMV is summoned from its package and placed in the stand-by position.

The landing is made in the Crater Censorius (-0°24'0" lat. and +32°27'29" long.) in the Mare Tranquillitatis. Selection of this site was made on two main criteria. They are:

1. It is located on the visible side of the moon thus allowing constant telemetering of data from the lab to Earth. It is one of the brightest points on the whole moon and is always conspicuous.

2. It is located in an area which has been well mapped, being quite near the site of previous Apollo missions.

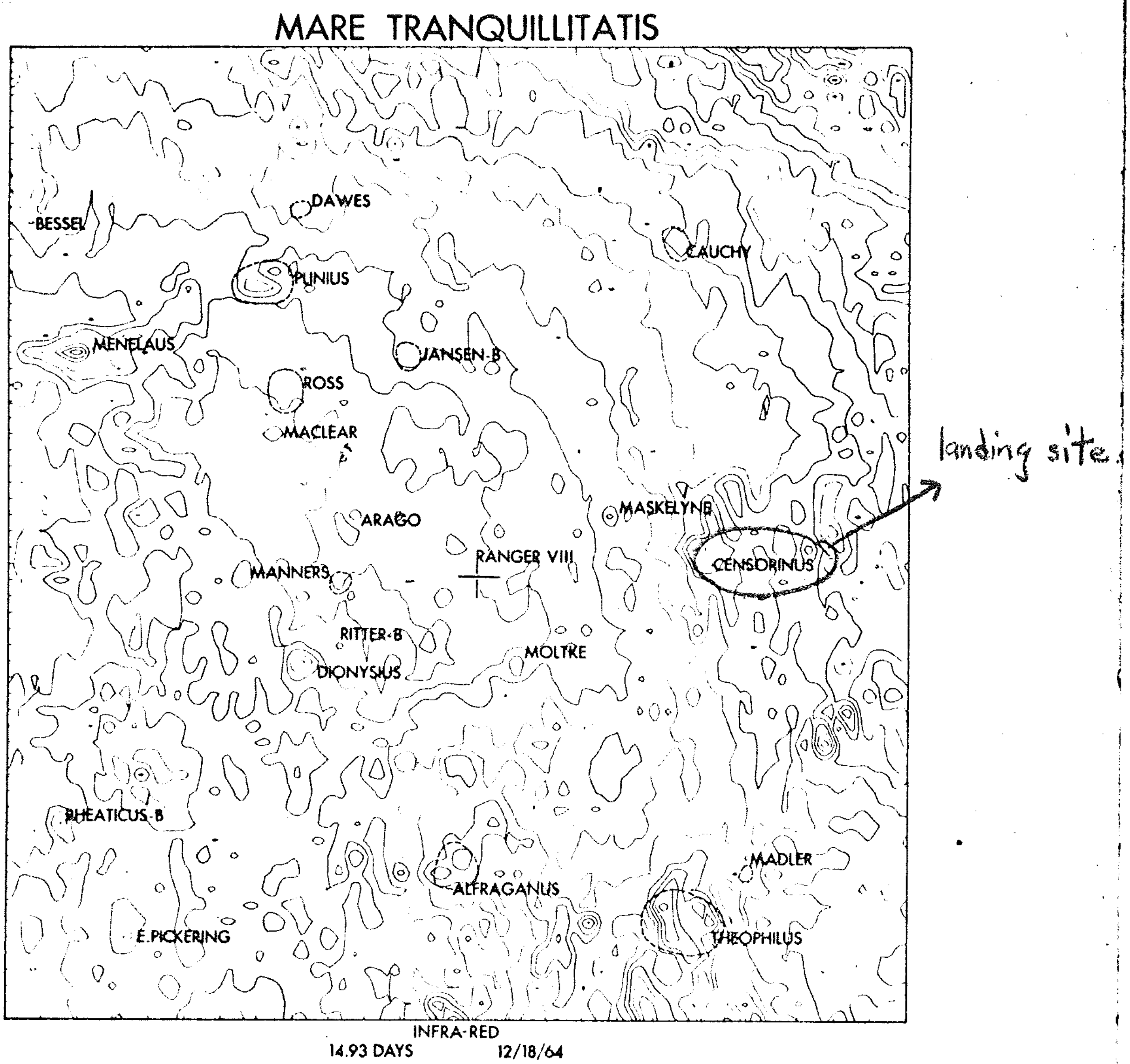
005:02 Stage V

The LL supplies are checked and put in a readiness position. The emergence ladder is unpacked and the crew lowers itself to the surface. At this time the area is examined to determine the best location of lab construction.

The LMV is brought to the LL after site selection and the material for the lunar lab is removed.

Beginning with the placement of six thermal-radiation shield-holding pillars sunk into the ground with the use of a small, electric powered dust digger, and finished with the inflation and rigidization of the laboratory structures and thermo-radiation shield protecting it, three astronauts have consummed about 2.5 hours of working time.

The other three have been engaged in the transportation of a ½ ton nuclear reactor to a position about 90 feet from the laboratory with the help of the LMV and in the digging of a hole for its placement with the same or a similar dust digger. Soon after readying the reactor, they have covered the thermo-radiation shield, itself




ISOTHERMAL CONTOURS ON THE FULL MOON

FIGURE 11-3: Isothermal contours on the full moon (phase angle −2 degrees, 16 minutes). Each tick mark on the bottom margin is separated by ten data values.

12 inches thick, with 6 to 8 inches of lunar dust. A conveyor belt assembly attached to the dust digger has aided them in this latter task.

The astronauts then implant hatch assemblies in the lunar lab wall. After sealing these, two men accomplish the interior arrangement of the lab - the laying of the aluminum grating floor and the construction of the insualted and air tight interior structure wall. Two others are involved in deploying the airlock for the laboratory, while the rest return to the LL to check on the animals and experimental apparatus and prepare them for the trip to the lab. Total time for this is about 3 hours.

After airlock construction and internal arrangement is provided for the life support system components and regualtors are transported to the lab, positioned there and called upon to adjust the internal environment to a 80% $N_2$/20% $O_2$ atmosphere of 360 mm pressure, the temperature regulating system is flushed, plugged into the power source and set to maintain 70 to 72° F internal temperatures for the laboratory.

After a reasonable interval for establisheing the proper internal environment (4 hours), the transportation of animals and equipment into the lab is begun. After completion of this phase (3.5 hours), the astronauts check all activity sites and take off 8 hours for sleep.

Awaking and taking any rations they which, the crew members break into teams to construct the experimental apparatus and to put it all into working mode. This part of Stage V last until 8 hours before the end of the fifth day, at which time all stations and functions are tested to see if information is being telemetered and monitored properly. Once assured of this, they return to the LL.

010:00 Stage VI

All systems on the LL are checked. Assured of performance optimus, the astronauts separate the ascent stage form the descent stage and ignition occurs.

After lift-off, the ascent stage powers the crew to lunar orbit and subsequently into an Earth orbit trajectory.

013:00 Stage VII

Docking with the fuel cell occurs so as to allow for automati c interim refueling of the LL ascent stage. Transfer of the crew to the original capsule occurs and separation is affected. The capsule orbits and re-enters with use of retro rocket power.

033:00, 064:00, 095:00, 126 ;00, 157 ;00
Stages VIII - XII

Thor Agena sends 3 astronauts in a capsule attached to what will become the descent stage of the LL with its lunar lab life support and equipment needs, into orbit. Docking with the fuel cell and LL is accomplished and EVA is directed at attaching the new descent stage of the LL to the ascent stage. Separation and injection into lunar trajectory occurs. After landing, the necessary equipment and life support material are removed. A five day stay during which the astronaut-scientists manintain the lab and perform experiments ends with their launch, after separation from the LL descent stage and nominal trip back to Earth. After LL docking and shut down, the crew separates and returns to Earth in their original capsule.

188:00 Stage XIII

The mission is exactly the same as VIII thru XII except for the following:

1. No lab life support materials are transported to the moon.

2. The initial crew capsule is accompanied by a smaller LL descent stage next to a beefed up LL ascent stage which provides room for materials and animals to be returned to Earth.

3. Crew members shut nuclear reactor and lab facilities down and transport animals and carefully processed waste materials back to the Earth-orbiting fuel cell. The animals and men separate and return to Earth almost immediately. The waste material is retrieved at a later date.

b. Surface Structural Design

The structures on the surface of the moon, which have been spoken of before, are discussed here.

The first requirement is that of the lunar lab. building itself. The outer walls consist of a honeycombed mesh of fiberglass strands impregnated with polyurethane resin. This structure is inflatable and, once inflated, is rigidized with a controlled release of water vapor containing 0.55% trimethyl amine. The complete process of inflation and rigidization takes 40 minutes and requires one man to do it.

Square footage ratios, collapsed to inflated, are 1:330. An air baldder protected by a buffer insures total inflation and holds in the required position during rigidization.

The honeycombed structure itself was chosen for two reasons. The first is that a porosity control is maintained so that it can be expanded fully. The second is that impregnation with the resin is made more complete.

The attractive features of the polyurethane resin are:

1. A high degree of control in impregnation.

2. Degree of chemical cross linking can be controlled.

3. The strong inter-molecular forces that result from the urea and urethane likages.

4. The material is nontoxic.

5. The urethane foam is a good protection against meterites.

Another factor which makes this lab a reasonable option is that the same catalyst vapors that are used to rigidize the structure can be used to inflate the air bladder.

Now to the overall structure of the lab. It will inflate in the shape of a hexagon. Three factors made the structure of that shape appealing. The first is that the hexagon is a stable structure with good lead carrying capabilities. The second is that square footage in it is at reasonably high values in relation to its perimeter measurement. Finally, interfaces with other structures needed or wanted in the future can be easily and efficiently arranged. The lab will have the operational configuration shown on the following page.

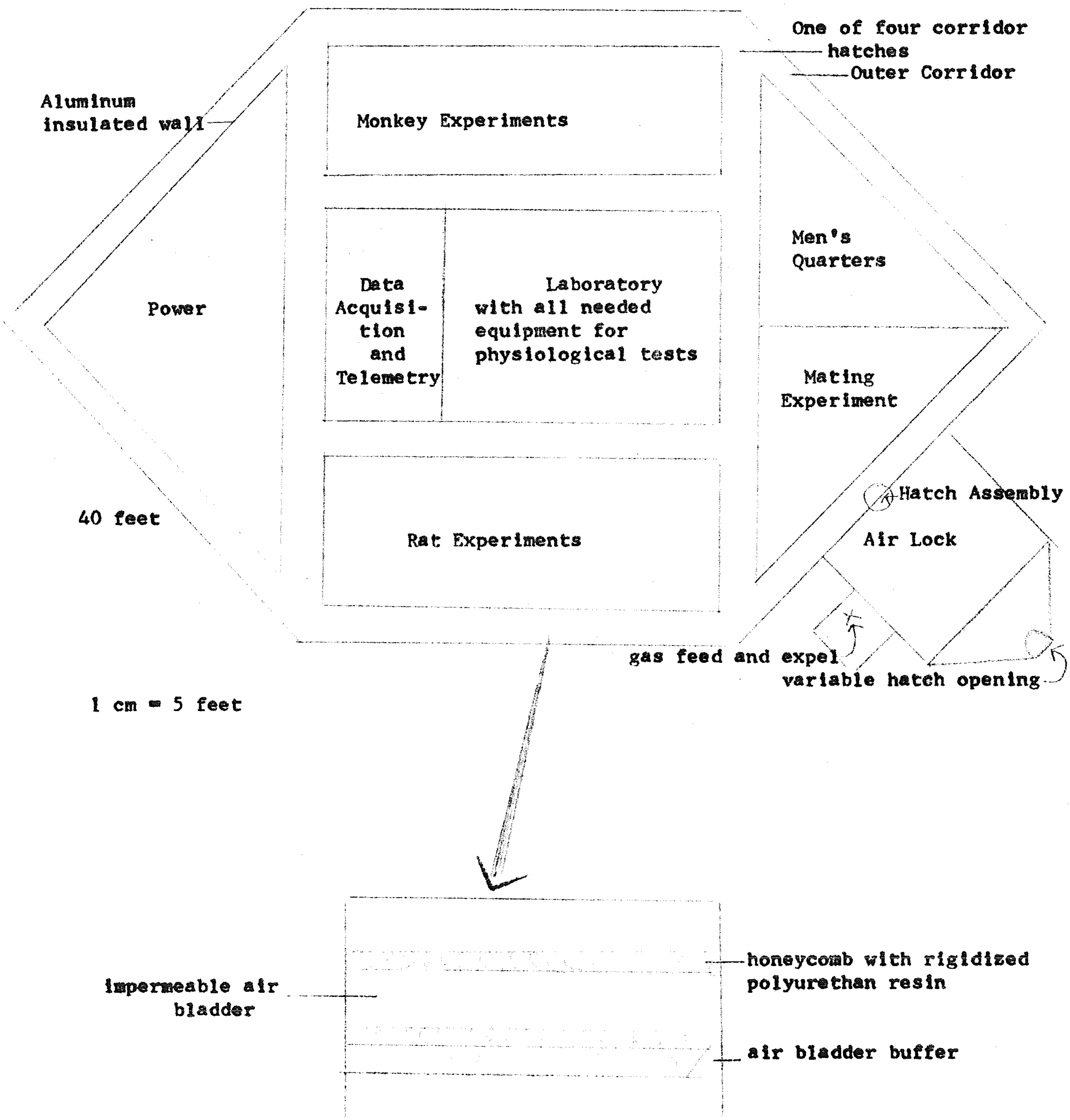
The floor is of aluminum grating. ABout 3040 sq. ft. will be needed. Each edge of the hexagon is 40 feet. The height of the strucutre is 8 feet. The size of the deflated structure in canister transfer is approximately 1 ft.X3 ft. X3.1 ft.

The airlock is made of the same material and is carefully sealed to the side of the laboratory. The external hatch opening is variable in that a hatch within a hatch is present. This will allow both large and small loads selectively. The air lock is not thermally protected but otherwise is supplied much as is the lunar lab.

The pillars spoken of before are 4 feet on an edge and are square in configuration. They too are constructed of the same material as the lab. Their arrangement is at the points of the hexagon. After sinking them 3 feet down below the lunar surface their height is reduced to 14 feet. They are rigidized and filled with lunar dust.

The shield referred to is a square 80 feet on an edge. With the 6 to 8 inches of lunar dust it receives, this shield provides effective micrometeoroid and thermal protection for the lab, and limits radiation dosages to those able to be hazarded by animals and men. It does, in

LUNAR LABORATORY



effect, bury the station a few feet below the lunar surface without the dust movement and structural limitations imposed by that sort of program.

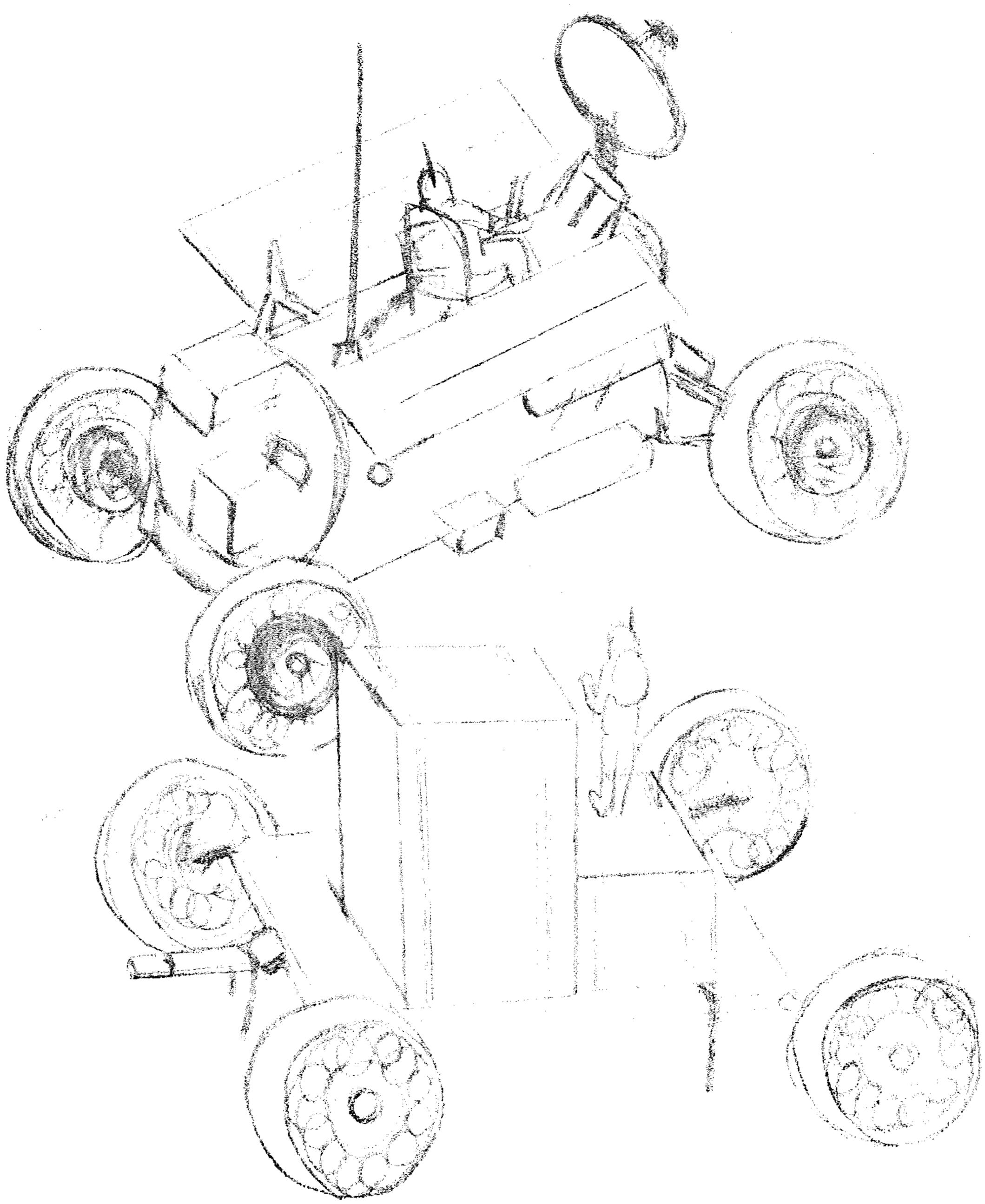
In case of future interface with other structures, the shield is easily trimmed and united with other similar structures.

c. Surface Mobility Needs and Designs

It will be necessary to carry large amounts of material between the LL and the lab. To accomplish this we have decided to use a vehicle known as a Prime Mover (with a trailer of ROBB) which has been developed by the Bendix Corp. and named the Lunar Mobility Vehicle (LMV) by us. It has a carrying capacity of about 3000 kg and can be manned or directed by remote control. Running on rechargeable batteries it could easily last out our lunar mission's time duration. It has a 15 km range and a maximum speed of 8 km/hr. The wheels consist of elastic metal rims supported by spokes of a similar material, and are driven by individual electric motors and transmissions. The method used to transfer the vehicle from Earth and to introduce it into the laboratory area has been explained. The picture on the following page shows the LMV.

The only other automated extra-laboratory vehicles is the dust digger equipped with conveyor extension. It can be operated by remote control and has a range with a radius of 1.5 km. The wheels are similar to those used on the LMV and the power source is a rechargeable battery. The conveyor boom is long enough to permit complete coverage of the thermo-radiation shield.

LUNAR MOBILITY VEHICLE
(LMV)



(2) PHYSIOLOGICAL EXPERIMENTATION

The primary objective of our studies is to determine man's ability to live and function satisfactorily for extended periods in a low gravity environment. We have thus avoided, for the moment, questions of more general biological interest. It seems more important to us to first focus on the possibility of man living in a 1/6 G environment. If such an environment proves favorable for man, further studies of a more general biological nature could easily be pursued. We thus propose to subject for a six month period certain laboratory animals to the moon's gravity, monitoring vital physiological parameters as frequently as is safe and practical.

Due to man's predominantly erect stature and resulting need to transport blood for some distance against Earth gravity, one must first consider the effects of reduced gravity on cardiovascular dynamics. Since man is the only truly erect animal, choosing an experimental animal purely to study orthostatic tolerance is a difficult problem. The giraffe would indeed provide an interesting study , but moon trips for giraffes seem to be a hell of an engineeering problem. We have decided to study the cardiovascular dynamics in the monkey <u>Macaca mulatta</u>. This entails a considerable extrapolation to man, but we feel that the present state of physiological knowledge of primates is greatest for the monkey.

Three monkeys will be surgically implanted prior to flight with telemetry devices capable of measuring and transmitting body temperature, EKG, blood pressure in right ventricle, left ventricle, and aorta. Three other monkeys will be surgically implanted with telemetry for EEG, EOG, and brain temperature. The well-healed animals will be carefully restrained only during transport to and from the moon. In the moon laboratory the six monkeys will each be placed in separate cages (36 X 36 X 48 inches) arranged in a circular pattern around a large center cage (48" radius; 84" ht.) into which each cage has an entrance. All seven cages have an inner structure of stainless steel bars.An outside layer of plexiglass with appropriately placed hatches permits the use of only one life support system for all six animals while allowing complete individual isolation in case of death or need for quarantine. Each of the outside cages is equipped with a monitored water and food supply. In addition there is a retractable "Skinner" lever to which the animal is trained to respond upon a light cue. The lever is specially designed to increase regularly the tension required to present a food pellet. Thus after a sixteen hour starvation every three days, the number of times the animal is able to pull the lever to feed himself will provide a measure of his muscle strength. Waste products will not be assayed constantly in these animals, and instead will be allowed to pass through coarse grating and conveyed to a waste disposal area.

The center cage is provided to allow all six animals more freedom of movement as in a zoo environment. Each animal is, however, trained to enter and leave the cage upon a specific auditory cue. In addition, the bottom of this cage can be turned into a treadmill for the sake of periodically measuring cardiovascular work capacity. Finally, the cages are provided with a closed circuit TV for making basic visual obsetvation of the animals' performances. This entire seven-cage set-up is then isolated in one particular room of the moon lab and is initially set for a 12/12 day/night cycle.

Under these conditions, the basic pattern for monitoring the six monkeys is as follows:

<u>Three Cardiovascular Monkeys</u>

DAY/NIGHT CYCLE

light: 8AM to 8PM

FEEDING

day 1 8AM and 4PM
day 2 8AM and 4PM
day 3 8AM present lever and cue, and 4PM
etc.

TEMPERATURE

daily, once every hour

OTHER

daily: EKG, bp 10 AM to 2PM
exercise 12 noon to 1PM, 20 minutes each
10 PM to 11 PM

<u>Three EEG Monkeys</u>

DAY/NIGHT CYCLE

light: 8AM to 8PM

FEEDING

same as above

TEMPERATURE

same as above

EEG, EOG

10 to 12 PM every night
8 PM to 8 AM for one monkey each night

Due to size and urine collection considerations, rats were chosen as our primary subjects for monitoring mass, mineral metabolism, fluid balance, and ventilatory gas exchange. Seven rats surgically telemetered for body temperature are placed in seven separate sealed plexiglass chambers (18 X 18 X 18 inches) arranged in a circle similar to the monkey cages, each chamber leading into a center "weighing" chamber of the same size. A slanted metal tray beneath each rat funnels urine into a glass burette from which 20 lambda samples are taken every 6 hours and transferred to a urine auto-analyzer to determine concentrations of calcium, creatine, catechol-amines, and SMA. Each chamber has its separate, specially designed life support system that maintains a constant $O_2$ concentration, monitoring $O_2$ uptake. A $CO_2$ electrode also monitors the partial pressure and triggers a flushing out and restoration of the chambers' atmospheres at a specific $CO_2$ concentration. Relative humidity is also monitored in each cage to determine the amount of water expired.

The center chamber is primarily used for weighing the animals. The rats are sequentially allowed to enter the chamber, registering a mass reading. Return to the home chamber triggers resealing and opens the next chamber to the scales. Body mass will be measured once every other morning.

Bone density in each rat will be measured weekly by a fluoroscope. The fluoroscope is mounted on a circular tract running above the circular arrangement of the cages. The scope stops at each chamber, swings down, triggers a food switch to orient the animal, then takes a picture.

The experimental set-ups presented above provide fairly constant information regarding the physiological states of the experimental animals and do not require the presence of man more than once a month. At this time, aside form some general maintenance procedures, the three men should conduct a series of basic medical tests on selected laboratory animals.

Since all the animals monitored above are predominantly unrestrained, blood collection during the unmanned part of each month is most difficult. Thus thorough studies of blood chemistry and hematology should be made each time the lab is manned. Basic hematology tests should be run on each of the animals mentioned above: rbc, wbc, hematocrit, hemoglobin, and differential counts. General hemostasis tests should also be run on each animal: platelet counts, bleeding time, clotting time, and plasma prothrombin time. Blood chemistries should include glucose, $Ca^{++}$, pH, $pO_2$, $pCO_2$, total and free cholesterol, thymol turbidity. An autoanalyzer can easily be set up to analyze each of these parameters, in addition, extra blood samples should be frozen and stored to return to Earth for assesment of such blood components as ACTH, GH, etc.

A series of more formal structured tests should also be performed. Glucose tolerance tests should be run on each monkey. Measurement of total blood value and total and extracellular body water should be made on the six monkeys and 7 rats. Also, pulmonary function should be measured in each monkey by subjecting the monkey to different percentages of $O_2$ and measuring the resulting values of $pO_2$, $pCO_2$, and pH in the blood. Cardiovascular effects of 1/6 G can be studied with the three monitored monkeys using both tilt-table tests and a small centrifuge, returning the monkeys to a 1 G or greater gravity field.

In addition to the seven closely monitored rats, thirty-eight other rats are to be brought to the moon lab. Among these, three should be females in the early stages of pregnancy to be separated from the other rats and supplied with food, water, and necessary nesting materials. Hopefully, these females will provide offspring that will have never known a 1 G environment. In addition, 7 females and 5 males will be included in an area capable of maintaining a small colony of rats. This set should provide us information on the effects of 1/6 G on conception and on reproductive patterns. A monthly check on the progress of this colony should at first be sufficient, but allowances for TV monitoring should be made in case more frequent checks are indicated.

Twenty-three rats thus remain to be caged separately and used as replacements or for specific monthly tests of otolith and semicircular canal sensitivity. For otolith sensitivity the rat is placed in a large barrel allowed to spin at a relatively low speed. The object of this test is to see how readily the rat can maintain the lowest position in the barrel. In addition, it may also be possible to have several rats, in which micro-electrodes have been specifically implanted, to measure the rate of the firing of the efferent nerves of the otoliths. This same micro electrode technique can be used to monitor semicircular canal sensitivity. By placing the animal in different orientations, it will be possible to detect the long term effects of 1/6 G on these two sensitivities.

As a final test of the effect of the moon's gravity on orientation, basic psychomotor tests should be performed on several of the monkeys each month. Prior to flight, each monkey is taught to distinguish among four or five different symbols and is taught to match a presented symbol to the appropriate symbol on a small panel. Each month, the monkeys are tested with respect to recall, time to retrain, and the effects of auditory and visual cues. A careful experimenter can use these test methods to study higher mental processes such as vigilance, attention, memory, and problem solving.

We feel that in order to obtain the most meaningful results from our moon laboratory, a control situation, identical in every respect but gravity to our moon lab, should be set up on Earth. Initiating the Earth "moon" laboratory several months prior to the lunar laboratory will help foresee any unexpected technical or biological problems that an unmanned laboratory may pose as well as provide more meaningful controls for the sake of comparison.

It is our basic understanding that the three areas of most concern in a low gravity environment are blood pressure lability, musculoskeletal deterioration, and disorientation.

We feel that the above experiments sufficiently cover this area. One must not assume, however, that an unexpected effect of low gravity will not show itself in a long term situation. It is to this end that other experiments basically of a general medical diagnostic nature, are proposed.

We are confident that the physiological problems imposed by a long term 1/6 G situation can be surmounted by the many homeostatic mechanisms inherent in man. We feel, however, that such confidence should be substantiated by sufficient preliminary testing with experimental animals. The lunar laboratory delineated above is how we propose to obtain this evidence.

(3) LIFE SUPPORT

To minimize the häzards of fire, it has been suggested that a two gas mixture of $N_2$ (pp 160 torr) and $O_2$ (pp 190 torr) be used. Five tests using pure oxygen at 3.8 to 7.4 psi were run on six subjects. It was found that such an atmosphere could be tolerated for periods of up to fourteen days. However, minor physiological alterations were noted in each case. A pure oxygen atmosphere can be used for the pressure suits of our astronauts for periods of less than 14 days.

Acceptable pressure ranges in the inhabited area vary between 285 and 362 torr. A low pressure level of 196-260 torr is to be used in the space suit because of the pure oxygen atmosphere.

The oxygen is supplied by the electrolysis of water. This water input comes from metabolic wastes as well as the water produced by the hydrogenation of metabolic $CO_2$.

The $CO_2$ is removed from the laboratory atmosphere by means of a regenerable zolite molecular sieve. The carbon dioxide is processed to reclaim the bound $O_2$. The sieve has an affinity for both $H_2O$ and $CO_2$. This affinity is stronger for the water, so the air stream must be dried before passing through the sieve. This is accomplished by the use of a bed of silica gel. Both the molecular sieve and silica gel are regenerable, therefore two parallel paths are included to provide for the continuous removal of $CO_2$ and the periodic regeneration of necessary materials. The Sabatier reaction involving the hydrogenation of $CO_2$ to $H_2O$ and $CH_4$ is utilized. The reaction is exothermic and heat must be removed in order to maintain a constant reactor temperature. The reaction takes place in two steps:

(1) $CO_2 + H_2 \longrightarrow CH_4 + H_2O$

(2) The $H_2O$ vapor is collected, condensed, and electrolyzed to produce usable $O_2$.

The $O_2$ is dried and supplied to the laboratory. The $H_2$ is then mixed with the $CO_2$ output from the regenrating sieve and reacted with a catalyst to form more $H_2O$ and $CH_4$. The water is then consensed and transported to the $H_2O$ management subsystems for purification.

For the Lunar Lander, LiOH is used for $CO_2$ removal. It reacts chemically with the $CO_2$ in the presence of $H_2O$ vapor as a catalyst to produce $LiCO_3$ and $H_2O$. The humidity of the cabin air is suitable as a catalyst and the reaction is exothermic.

The temperature control of inhabited areas is accomplished by removing the heat as required from the lab air. The air is recirculated through a glycol heat exchanger. The heat is then ejected into space by means of a radiator. Major components of the temperature control subsystem include glycol to arrange the heat exchanger, recirculating blowers and pumps, distribution ducting, valving, controls, and radiators.

The humidity control subsystem removes water vapor from the air stream coming from the lab. The air humidity is removed by passing the airstream through a liquid-gas heat exchanger in which it is cooled by ethylene glycol to a temperature below the dew point of water. Moisture condenses out of the airstream. It is then collected by a wick-like material within the heat exchanger and transported to the water management subsystem where it is purified for reuse.

The trace contminant system removes odors, particulate matter, and toxic gases from the cabin atmosphere, and controls the growth of bacteria, virus, and fungi. Air is removed from the lab and passed through a chamber in which it is exposed to ultra violet irradiation. This controls microorganism growth. However, this process must be examined for efficiency and for the amount of ozone produced. From this process the air passes through an activated charcoal filter which absorbs most of the odors and high molecualr weight contaminants. 0.1 pounds/man day of charcoal is required.

The low molecular weight contaminants are controlled by passing a portion of the flow through a regulator and heater into a combustion chamber. It is oxidized in the presence of a hopcalite catalyst ( a mixture of Cu and Mn oxides) and returned to the lab.

Vapor compression distillation is used for the water management. The operation is performed in batches processing approximately 30 lbs of water per cycle. Urine and waste water are collected in plastic bags and placed in a evaporator chamber. The compressor creates a partial vacuum over the contents of the evaporator causing the waste water to boil at about 0.5 psi at the cabin temperature. The compressed vapor is removed from the evaporation chamber and raised to a temperature of 90° F, and these vapors are used to heat the remaining contents of the vapor. The vapors are condensed and the final purification is performed by forcing the distillate through a millipore filter, ion exchange filter, and a filter of activated charcoal. The noncondensing gases are vented into space. The residue remaining in the still is removed after each batch operation and discarded.

Included in the waste management subsystem are toilets for the men and open bottom cages with a moving conveyor belt for the removal of wastes for the animals. The feces are sampled and stored until a suitable time when they are incinerated or shipped back to Earth for further analysis.

# STATISTICS FOR LIFE SUPPORT SYSTEM

| | |
|---|---|
| DAYS | 168 days |
| ENVIRONMENT | shirtsleeves |
| ATMOSPHERE | |
| Composition | $O_2$ and $N_2$ |
| $O_2$pp | 190 mm Hg |
| $N_2$pp | 160 mm Hg |
| total pp | 362 mm Hg |
| $CO_2$pp | 57.6 mm Hg |
| TEMPERATURE | 70° F |
| RELATIVE HUMIDITY | 50-60% |
| MATERIALS REQUIRED BY MAN | |
| Oxygen | 2.0 lb/man day |
| Water | |
| drink and food | 6.6 lb/ man day |
| utility | 3.3 lb/man day |
| Food | 1.4 lb/man day |
| DIET CALORIC REQUIREMENT | 2820 cal/ manday |
| METABOLIC OUTPUT | |
| Liquid Waste | |
| urine | 4.0lb/man day |
| fecal $H_2O$ | 0.2 lb/man day |
| respiration and perspiration | 2.2 lb/man day |
| Solid Waste | 0.5 lb/man day |
| $CO_2$ Production | 2.25 lb/ man day |

FOOD AND WATER REQUIREMENTS

MONKEY

20 pellets X 2.5g/ pellet day X 6 monkeys X 168 days = 111 lbs.

500g $H_2O$ X 6 monkeys X 168 days = 1109 lbs.

RATS

10 pellets X 2.5g/pellet day X 45 rats X 168 days = 416 lbs.

100g $H_2O$ X 45 rats X 168 days = 1663 lbs.

MAN

1.4 lbs/day X 3 men X 30 days = 126 lbs. food
9.9 lbs/day X 3 men X 30 days = 891 lbs. water

TOTAL FOOD REQUIREMENT FOR MISSION = 4,316 lbs. food and water

An additional 339 lbs of food and water will be brought to sustain the men while the moon lab is being built.

The total requirement for life support will be about:

13,300 lbs.

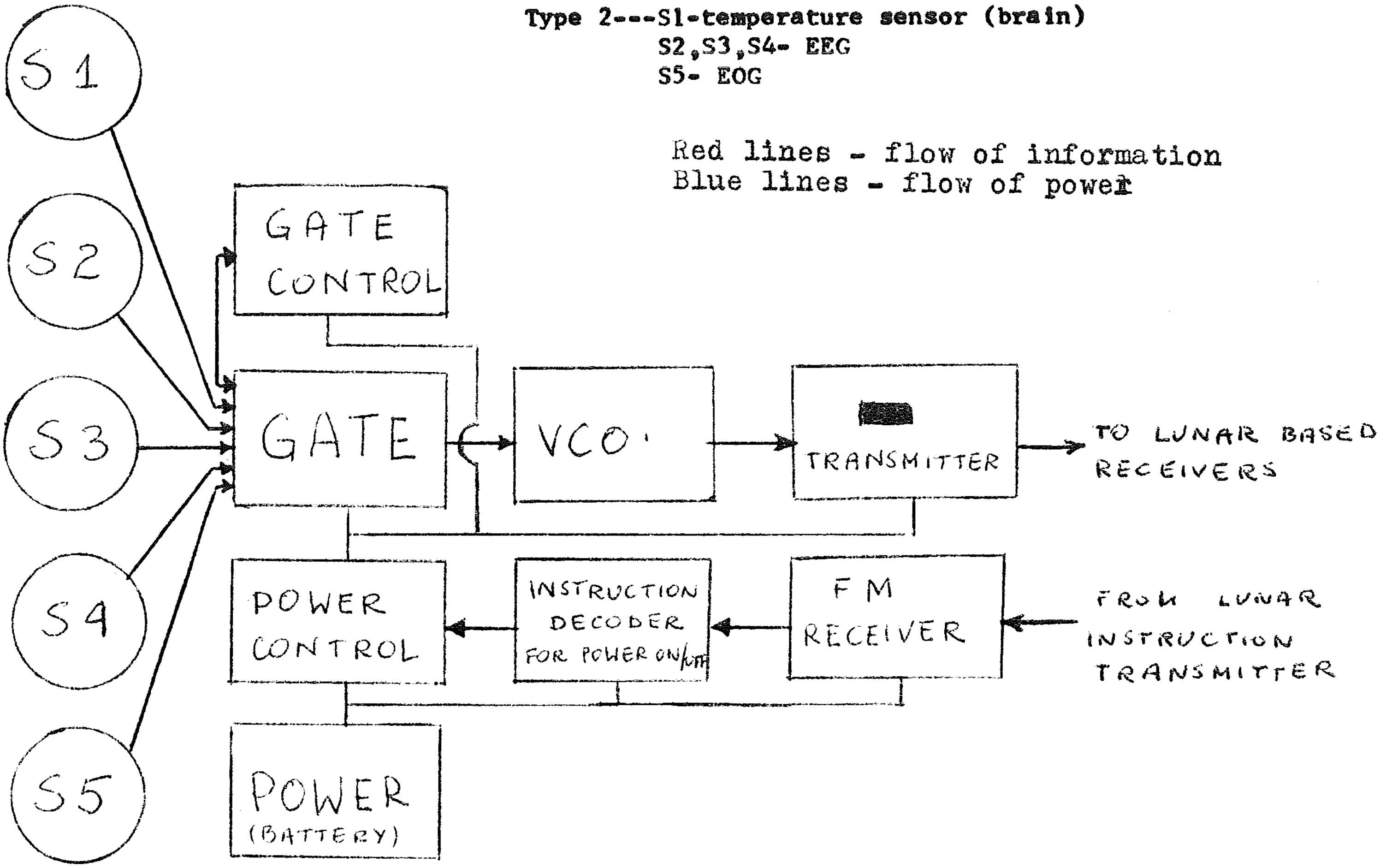
## (4) POWER AND DATA ACQUISITION

**Implanted animal package for collecting of medical data in monkeys**

**Type 1--S1-temperature sensor**
**S2-EKG**
**S3-blood pressure in right ventricle**
**S4-blood pressure in left ventricle**
**S5-blood pressure in aorta**

**Type 2---S1-temperature sensor (brain)**
**S2,S3,S4- EEG**
**S5- EOG**

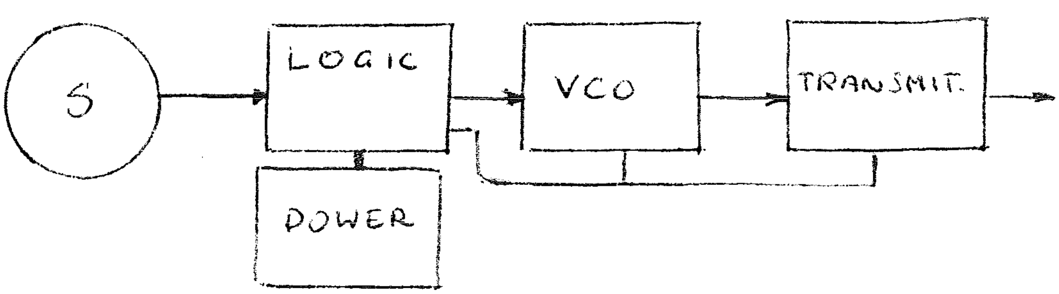
Red lines - flow of information
Blue lines - flow of power




**Gate control provides timed identification signal(different for each package) and controls action of the commutator(gate).Output of the gate controls VCO providing FM transmission of data to a moon based receiver device which further processes and sends data to Earth. The FM receiver in this packg will obtain instructions to turn the devices on and off so that batteries will last longer.Note that the only constant drain is caused by the receiver and instruction decoder which are always on.**

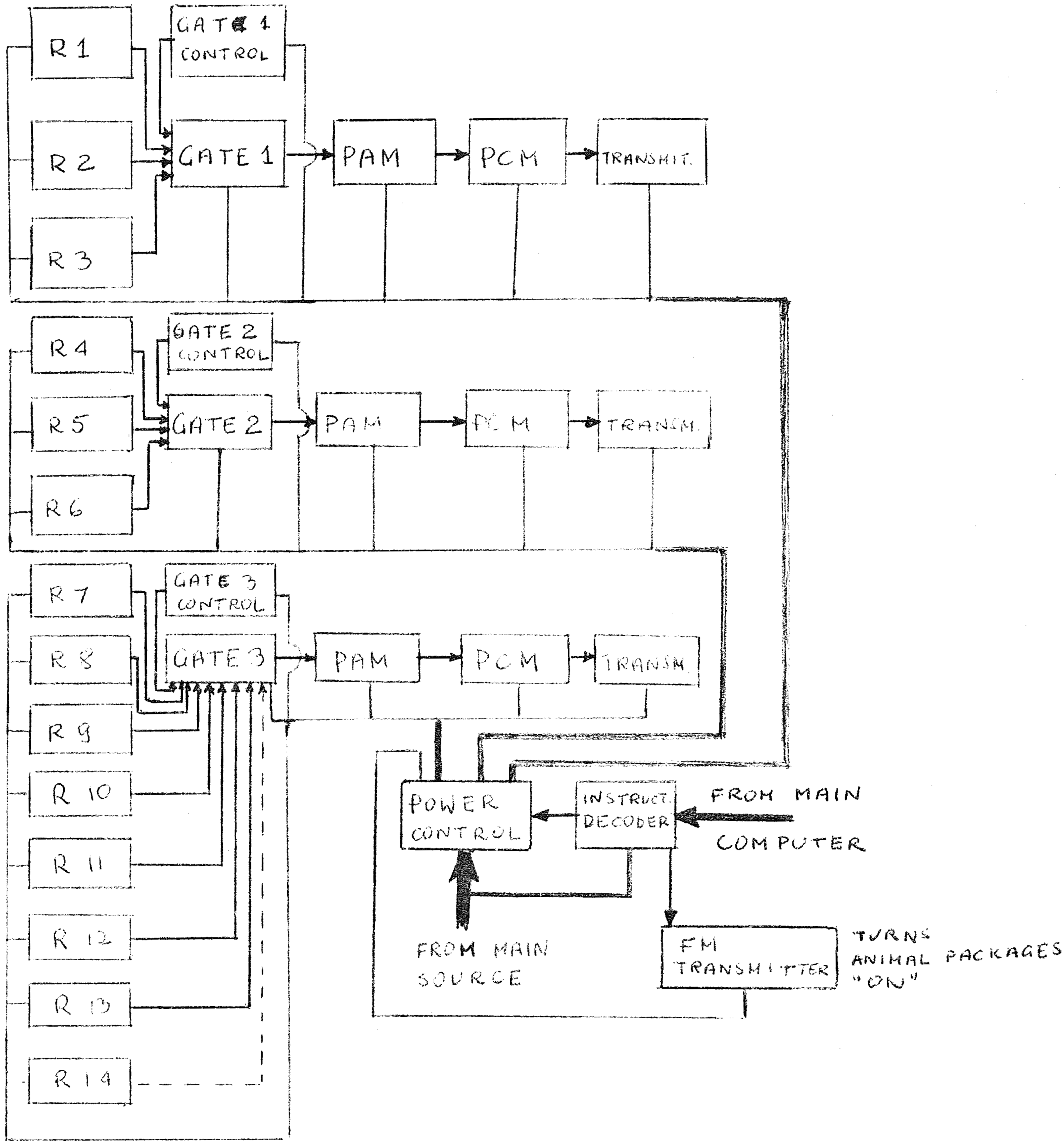
**Implanted animal package for rats**

**This consists of only one temperature sensor,logic module allowing timed collection of temperature,VCO and FM transmitter,small battery.( The logic provides rat identification)** [redacted]

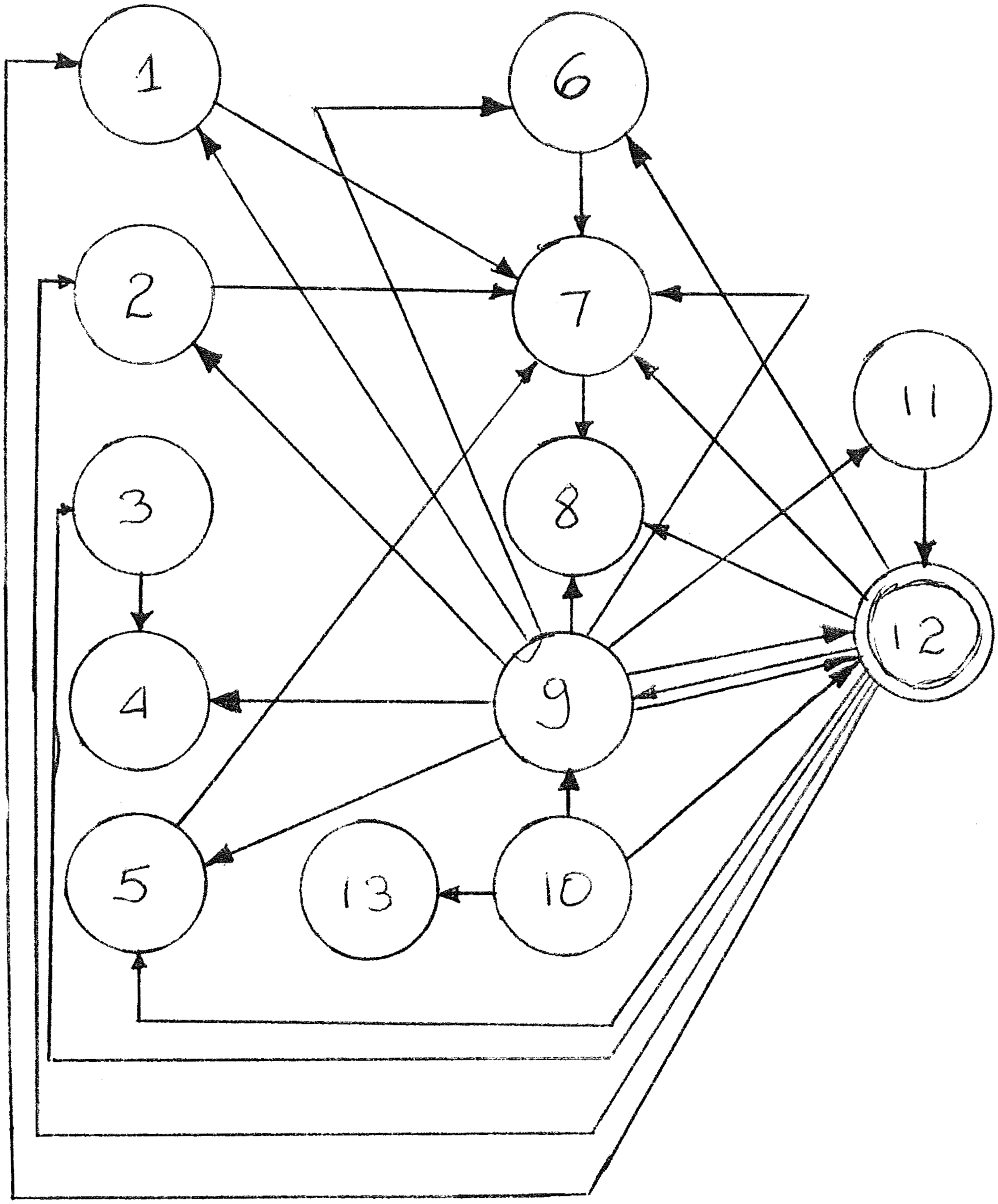


This system recovers signals from implanted telemetry packages, processes them and transmits to Earth.

Red lines - flow of information
Blue lines - flow of power



Moon base telemetry system




This diagram illustrates the relationships between subsystems.Red lines indicate flow of information (data and instructions) while black shows flow of electrical power. Circles indicate general subsystems and are:

1 - all life support,external data monitoring,experiment controls -monkeys cages
2 - same as above but for rats
3 - internal telemetry for all animals
4 - transmitting system (to Earth)
5 - general life support
6 - scientific and engineering data collection
7 - transmission control
8 - transmitting system (to Earth)
9 -power distribution control
10-main and emergency power supplies
11-instruction receiving
12-main computer
13-two way communication link for Moon-Earth and Moon base to off-base communication

R1 - R2 - R3 each is an independet (frequency wise) FM receiver and demodulator which obtains signals from devices implanted in three monkeys (cardiovascular) and provides output equivalent to that obtained from gate output in the animal. The output of R1, R2, R3 goes to GATE1 (commutator). The output of GATE1 is composed of three components, one after another. Each component provides animal identification and five data signals. We can see that this provides for time sharing on one channel by three animals , each animal monitored for five variables. Thid data is Pulse Amplitude and Pulse Code (binary) Modulated and transmitted to Earth via separate transmitter.
R4 - R5 - R6 provide identical functions for other three monkeys.
R7 to R13 receive temperature information from seven rats. R14 is an extra.
The value of the system is due to accurate coding for transmission to Earth and in independent status of subsystem for each animal group. Each group can be monitored independently of each other at the same time or one at a time, at any desired time. This is due to having separate receiving and transmitting facilities for each group and to having power control run from a main computer. Power control also provides for power savings as the system can be shut off (with exception of instruction decoder) when not in use.
The main computer will thus turn on or turn off the animal implanted packages and lunar based telemetry system.

All functions different than animal internal functions will be monitored by collection of data with appropriate sensors, PAM and PCM and transmission to earth. There will not be an intermediate lunar stage for recovery of original data as had to be the case with data collected from within the animals which require freedom of movement.

All systems with exception of main power supply (which has own control system) will be controlled by main computer with some instructions stored in memory and some instructions obtained from Earth.

An independent communication link for Moon-Earth and lunar base-off base is provided for use by men.

Main power supply is a DC generating plant driven by a small (I/2 ton) nuclear reactor provided with own control and fail-safe system. In case of main generator failure the emergency power supply (batteries) will automatically take over. The emergency power supply will be able to mantain all lunar functions long enough to allow for arrival of repair crew from Earth before total failure. The use of DC power eliminates need for elaborate AC to DC power supplies in lunar equipment, problems of 60 Hz noise which would otherwise require use of filters and so on.

All subsystems will be assembled on Earth and bulk of the task done by set-up crew will consist of interconnecting them by use of lines prepared also on Earth. It will simply be plugging in numbered cables in corresponding sockets.

## EXPECTED RESULTS

It is our opinion that information gathered at our lunar laboratory will significantly add to man's realization of the vital capabilities for Earth life in other than Earth environments. We feel that extrapolations from our data will support the idea that man can exist on the lunar surface for extended periods of time.

# LUNAR LAB PROJECT

Group II

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HL

Proposed Moon Lab Experiments on *Macaca mulatta* (Rhesus monkeys) to Test the Physiological Effects of $\frac{1}{6}$ G on CVS and CNS

## Introduction and General Considerations

We have chosen Rhesus monkeys for these experiments on the cardiovascular ~~sys~~ and central nervous system because the physiological structure of monkeys is fairly similar to man's. Consequently, if our experiments demonstrate that the $\frac{1}{6}$ G environment on the moon significantly affects the physiology of the CVS and CNS in the monkeys, we can predict with somewhat more confidence that man's physiology also would be altered in a $\frac{1}{6}$ G environment than if our experimental animals were rats or other species whose physiological systems do not closely resemble man's.

The only variable in these experiments will be the $\frac{1}{6}$ G environment (except in those experiments in which drugs are specifically introduced). Therefore, atmospheric, humidity, and temperature conditions must be similar to those the monkeys would normally experience on earth while in the captive state. The absence of a magnetic field on the moon will probably not add any significant error to the results ~~since~~ because the earth has a very low magnetic field and past experiments involving small changes in the surrounding magnetic field do not seem to affect CVS or CNS function. Of much greater importance is that the design of the experiments must not prevent the monkeys from leading a normal life—given the one restraint of captivity. Any techniques such as long-term catheterization would ~~sub~~ induce substantial

Provide $\vec{E}$ field?

stress and introduce another variable into the experiment. Consequently, our experiments will be designed so that the monkeys will have sufficient mobility even though such a design prevents us from collecting daily urinalyses and blood tests. We are limiting ourselves in this respect with the desire that our data will be more applicable ~~for application~~ to man.

The monkeys will be young males - age 24 months and average weight about 2300 grams. Ideally 4 monkeys would be taken to the moon, each housed in a separate cage. The experiments can be carried out with a minimum of ~~3~~ 2 monkeys housed in separate cages.

~~Experiment 4~~

Hypothesis and Purpose

The moon lab experiments will be pioneering a new field in science because neither man nor animals have spent a ~~substantial~~ prolonged amount of time in an environment less than 1G but substantially greater than the weightless state. Experiments in ~~water~~ water immersion may approximate reduced G states, but they also introduce other variables such as the enclosure of the body by a fluid. A large unanswered question is whether there is a continuous line of environmental influence from the 1G to the weightless situation ~~or whether there is a~~ (as there is from 1G to increased G levels for many physiological systems) or whether there is a discontinuity so that changes from 1G to weightlessness do not have any long-term effects on the CVS and CNS until environmental conditions reach a near-weightless state.

Certainly one test at the $\frac{1}{6}$ G level will not be able to answer the above question conclusively. However, if there are no significant effects at $\frac{1}{6}$ G, then the "discontinuity" theory may be more promising. If there are significant effects, then either the discontinuity level is higher, i.e., $\frac{1}{6}$ G can be regarded as near-weightlessness, or the "continuity" theory ~~seems~~ is more adequate in describing gravitational effects on ~~the~~ CVS and CNS. Looking to the future (the far-future), a Mars biological laboratory ~~may~~ would give added information with regard to this subject.

Given the fact that we do not have any data on below 1G but above 0G environments, we are not proposing a hypothesis for these experiments. We are, however, proposing a purpose for each of the experiments which is to examine the above question and determine whether $\frac{1}{6}$ G affects certain aspects of ~~central~~ nervous and cardiovascular behavior in Rhesus monkeys. Our hope is that the data and conclusions can be used for extrapolation to man.

Experiment #1

In this experiment brain waves and eye movements will be monitored continuously if possible, although only periodic information will be sent to the earth for immediate analysis. [See section on data collection] As well as being an experiment in itself and giving evidence of the monkey's behavior throughout the day and night, the EEG's and EOG's will be used to determine CNS behavior during other experiments.

[of each animal] Nine pairs of electrodes will be implanted in the brain at the following locations: left and right frontal, left and right occipital, left & right parietal and left and right temporal lobes. A pair of ground electrodes will be placed at the front center of the head. The electrodes will be rigidly connected to a head mantle attached to the top of the head. The mantle will contain a transmitter capable of transmitting the 8 channels of EEG 100 ~~ft~~ feet to a near-by pickup device [See data collection section]. The transmitter will be powered by a plutonium battery.

In addition a pair of electrodes will be implanted in the muscles on either side of an eye in the socket. Each eye will be monitored in this way.

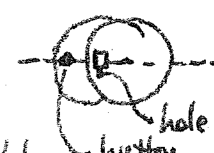
These electrodes will provide information regarding the animals' sleep habits, its state of alertness, during the day, and other factors relating to brain activity. Such information may help indicate whether $\frac{1}{6}$ G has any influence on CNS behavior

Experiment #2

A small apparatus containing a lever, automatically-controlled light and timer and pellet dispenser will form part of the lower rear wall of the animal's cage. The animals will be trained on earth to go to this apparatus at the sound of a fairly high-pitched bell. The light will flash for 2 seconds. If the animal pulls the lever within 10 seconds after the light flashes, the dispenser will give him a pellet of food. A total of 15 pellets will be offered in this manner. The experiment will be performed every day at 0300 and will also constitute the animal's breakfast. A wide-angle television camera equipped with a zoom lens which is normally used to monitor the monkey's activities in the cage will zoom in and " his performance in this conditioned-response test. The test will determine his ability to remain attentive at $\frac{1}{6}$ G. [Experiment adapted from biosatellite project.]

Experiment #3

An eye-hand co-ordination test will be performed daily to determine whether $\frac{1}{6}$ G alters the monkey's ability to co-ordinate muscle and eye movements [Experiment also adapted from ~~biosatellit~~ biosatellite project.] At 0700 a high-pitched sound will call the animal to a second piece of apparatus at the rear of his cage. The apparatus will consist of a pellet dispenser and two rotating disks – the front one with a hole in the periphery of the disk, the back one with a button the same distance from the center of the disk as the hole in the first disk.




The front disk rotates at 80 rpm (has a 15 cm diameter); the rear disk rotates in the same direction slightly faster (81 rpm). The monkeys are trained to push the button and receive a pellet of food every time the hole and button are in a alignment which occurs about once every 60 seconds Again, 15 pellets will be offered.

Experiment #4

The purpose of this experiment is to determine whether the interaction of $\frac{1}{6}$ G with the cerebral spinal fluid has any pathological long-term effects on the brain. Animals accustomed to a 1G environment may develop differential pressures between the brain and CSF in $\frac{1}{6}$ G conditions.

The experiment will be carried out once every four weeks during the manned portion of the laboratory. A CSF tap will be made in the lumbar region of the spine and the CSF will be sealed in a ~~bottle~~ capsule and eventually sent to earth for analysis.

Experiment #5

Drug experiments - See Jerry's write-up.

Controls for CNS experiments

Each monkey will perform the same experiments (note exceptions in drug experiments); they will have been trained to do these experiments on Earth in similar cages and a similar environment. They will not be sent to the moon until the lab has been constructed and is ready for use. Consequently, the time lapse between their launch from earth and their installation on the moon will not be so long that they will forget the learned experiments [Condition-response and eye-hand coordination tests can also be set up on the trip to the moon.]

Other Rhesus monkeys which have undergone the same training procedure will perform identical experiments on the earth. These will be the actual control monkeys at 1G.

Experiment #6

The purpose of this experiment is to determine whether $\frac{1}{6}$ G causes any changes in the cardiovascular system, specifically heart rate, blood pressures and blood volume. Special attention will be paid toward the possibility of blood pooling in the large veins of the arms and legs and in the venous areas close to the heart and the possibility of loss in blood volume — conditions which all occurred with astronauts in weightlessness.

A battery-powered (plutonium) sensory device will be implanted under the breast bone of the monkeys and will continuously measure the heart rate (EKG) aortic pressure, central venous pressure and blood flow (through the aorta). A second sensory device implanted in the neck will measure carotid pressure.

Experiment #7

During the manned periods, a blood sample will be taken once every month and a ~~urinalysis~~ urine sample will be obtained. The urine will be obtained by placing the monkey in a separate small cage which has a wire-mesh filter under the cage to allow urine to pass through but not feces. If this method of urine collection proves unfeasible because of contamination of the urine by fecal material, then the urinanalysis will have to be abandoned.

The blood tests will enable scientists on earth to determine much vital information about the monkeys; for example, red cell level, blood sugar level, calcium level in the blood. Blood ~~tests~~ samples will also be taken from the animals prior to lift-off to the moon for comparative purposes.

The urinanalysis will also be compared with pre-flight tests. Although the fact that the urine will be collected at monthly intervals may ~~[illegible]~~ invalidate most findings; we would expect that calcium, creatin, and creatinine levels would be high if bone degeneration continues to occur. Such information may be helpful in trying to determine whether man would experience bone degeneration only to a certain extent at $\frac{1}{6}$ G and then adapt or whether he would experience continuous bone degeneration.

Controls for CVS experiments

Again, the same experiments will be run on earth under the same conditions.

Other monitoring systems

Two thermistors will be installed – one in the brain and one in the body ~~to~~ to measure temperature.

A pressure sensing device will be installed near each lung to measure respiration.

Environmental data

The monkeys will be fed about 90-100 grams of food everyday in pellets weighing 2½ grams each. In addition to the feedings at 0300 and 0700, 20 pellets of food will be given to the monkeys at 1200.

Room temperature will be kept constant at 70 ± 2°F and humidity will be kept constant at ? %. (Check out with Ron or Molly.). The monkeys will be kept in a 12 hour light / 12 hour dark environment synchronous with what they experienced on earth.

DRUG STUDY

Any future prolonged space flight must without doubt provide for the extended medical well being of the astronauts involved. On recent short trips minor use of drugs as decongestants, analgesics, and fatigue eliminators has been attempted. The need for further research on effect as well as change in structural and chemical properties cannot be over emphasized. Environmental conditions including the complex of flight factors (vibration, acceleration, isolation, and weightlessness) have now geen more closely defined and allow for a more precise delineation of drug on individual systems which can be controlled separately as to their specific space response. Man and animal have only certain capabilities and since their organ systems are subject to both chronis and acute alterations under Earth conditions, there is every reason to expect that these, as well as new ailments will also occur in space.

There are three main areas of pharmacology which can be studied:
therapeutics--concerned with the use of drugs in the treatment or prevention of disease,
toxicology--the study of poisons or other agents with undesirable actions in the body, and
pharmacodynamics--concerned with the mechanisms of drug actions.
Due to the desire to keep the animals alive, study their behavior, and monitor their physiological systems, the study of drugs will be confined to the five day manned periods each month.

Experiment 1. Even minor alterations in the configuration of a drug molecule can cause significant changes in the response of an organism to a given dose. For this reason the stability of all drugs proposed for space use must be determined. The space conditions can be created on Earth or samples of the drugs can be taken into space on earlier missions and analyzed.

Experiment 2. The effect of aspirin on rats. We propose to use the Ercoli-Lewis method to estimate changes in potencies of aspirin under weight reduced conditions (1/6 G). In the Ercoli-Lewis method, the rat's back is shaved and a heat source applied to produce pain. The end point is the twitching of the skin 4-5 seconds after heat application. The threshhold is constant over months and is not affected by temperature, diet, or other environmental conditions. The effectiveness of aspirin can be determined by this method at different doses and compared with results under 1 G conditions.

Experiment 3. The effect of amphetamines on monkeys. The main use of amphetamines is to reduce fatigue. By applying varying doses in an attempt to measure the effective doses, we can observe the monkey's ability to effectively go about normal activity for prolonged periods of time as well as getting a picture of his alertness through electrode recordings in the reticular formation of the brain.

Another study is suggested by the use of amphetamines. Under reduced gravity conditions organisms tend to eat less food. This decreases the carbohysrate energy reservoir of the animal. By the use of amphetamines the animal's systems are stretched beyond normal capacity thus increasing total daily metabolism. Thus, an incresed metabolism couples with a reduced energy source may lead to hypoglycemia. Testing of blood sugar continuosly during amphetamine administration will thus be performed.

Experiment 4. Tranquilizers and their effects on monkeys. Tranquilizers such as secorbitol sodium will be used on monkeys to determine their effects under reduced weight conditions. After establishing Earth conditions for normal dosage, varying dosages will be given to the lunar monkeys to get a comparison. The monkeys will be monitored by EEG for cortical activity and depression of the normal EEG, and by reticular formation electrodes for general alertness.

It has been found that pilots often show reduced judgment even with the weakest non-sedating tranquilizers. To test judgment, the hand--eye co-ordination tests with the rotating discs (described earlier) will be performed.

Experiment 5. Drugs for hypertension. By monitoring cardiovascular function, the effectiveness of drugs (such as chlorothiazide diuretic) to relieve hypertension can be determined. If the monkeys are not already hypertensive, they can be made so by altering their normal routine.

GROWTH AND DEVELOPMENT UNDER CONDITIONS OF MOON GRAVITY (1/6G)

INTRODUCTION: Eventual colonization of the moon requires that man be able to produce and rear offspring in the lunar setting. To this date there have been no studies to indicate whether fertilization, embryogenesis, and normal growth will be possible under the conditions of reduced gravitational stress characteristic of the moon. For this reason, it is proposed that an extended study of growth and development of a mammalian animal be included in the lunar biological experiment series.

EXPERIMENTAL TECHNIQUE: A group of female rats ( Rattus norvegieus) will be allowed to mate freely with several young males of the same species while living in the lunar environment. After mating, each female will be retained individually in a breeding cage, given adequate life support, and allowed to produce a litter of pups. From those animals born approximately five will be randomly selected and allowed to develop in the lunar environment (1/6 G). Careful measurements of weight, body size and more subjective determinations of health are to be made during each manned period. At the termination of the lunar experiment these animals will be sacrificied for extensive anatomical studies. Data obtained will be compared to normal growth curves for earth controls.

BONE AND WOUND HEALING UNDER CONDITIONS OF MOON GRAVITY (1/6 G)

INTRODUCTION: Establishment of long-term lunar bases necesitates that men be able to function in the lunar environment for extended periods of time. Almost certainly injuries will occur and, for reasons of expediency and safety, these injuries may have to be treated in the lunar setting. Previous work sought to determine whether an increased gravitational stress can affect the healing of bone and skin. ( see C.C.Conley). It is the purpose of this experiment then to use similar techniques to determine parameters for the healing of bone and skin under conditions of 1/6 earth gravity.

EXPERIMENTAL TECHNIQUE: Essentially, the experiment will proceed as follows. Skin wounds and fractures are to be experimentally induced in rats (Rattus norvegieus) during lunar habitation. The course of healing will then be followed over a period of 5-6 lunar months. The healing process will be observed thru periodic histological studies of both skin and bone wounds and densitometric measurement of the bone. Data obtained will then be compared to the results obtained from an experimental control located on earth ( 1G).

1. Young male rats are to be carefully selected and matched according to body size, growth rate, etc.

to allow close approximation between the fourteen animals used in the lunar experiment and the fourteen animals which will serve as controls on earth.

2. At the onset of the experiment tibial lesions will be produced in the right tibia of each animal. Since the tibia is a superficial bone one overcomes the problems of soft tissue overlay and approximation of the reference wedge for densitometry.

3. The lesion produced will be a uniform notch on the surface of the tibia. By notching, one allows the remaining bone to serve as a natural splint. The procedure is to be carried out under sterile conditions in order to minimize the risk of infection which would disrupt the normal regeneration process.

4. The wounding procedure is to be carried out sequentially. On day one four animals should be treated (group A); on day two, three animals (B); day three, four animals (C); and day four, three animals (D). This type of time distribution will give some indication of daily changes since x-ray and growth measurements can only be made periodically (every 23-28 days).

5. After the animal has been wounded, weight and body size should be recorded, and the animal's leg x-rayed. The densitometric techniques proposed are those developed by P. B. Mack, in which a reference wedge is placed near the bone, x-ray produced, and amount of calcification related to a point on the reference wedge. (see P.B.Mack)

6. Upon completion of the surgical procedure and preliminary measurement, each animal is to be placed in a separate cage. Food and water are to be supplied to each cage via automatic systems. A modified pair-feeding technique is required to minimize dietary differences between experimental and control groups. When the investigator is able to return to the lunar lab at the start of the next 5-day period, each animal should be weighed, size measurements made, and the leg x-rayed in the same manner that the preliminary data was collected. Two rats are then selected for the histologic studies. It is suggested that in this first period one rat each from groups A and C be sacrificed. The subsequent period would select one each from groups B and D; these alternations carried on until termination of experiment. Selection, however, may have to be modified according to unexpected variables (death, etc.)

The rats selected for sacrifice are to be immersed in liquid nitrogen to effect quick death and to preserve all body tissues. The actual histologic studies can then be carried out upon return to the base laboratory, i.e., the earth or an orbiting space station.

7. The same procedure is to be carried out during each 5-day period available to the investigator. In addition, data collection from the controls on earth

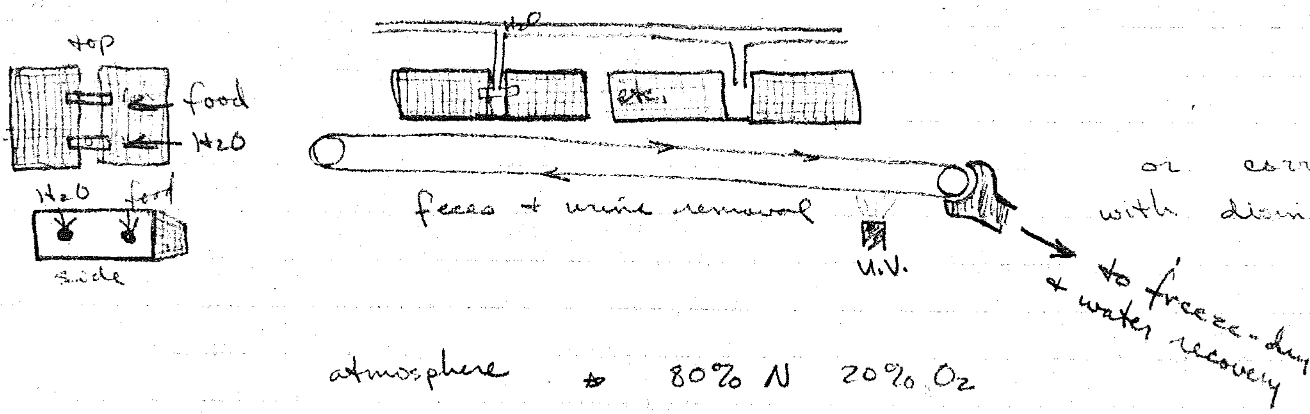
should approximate the lunar portion of the experiment.

8. At the conclusion of the experiment, data will be analyzed to determine effect of 1/6 G environment. The data obtained may also be correlated with that obtained in previous work which measured effects of increased gravitational stress.

RN3 Life Support Requirements for Rats (Notes)

gangway 1.3 – 1.5 m between wall + cages for men

① cages thermostable plastic (as light as possible but strong)
10 mm mesh interconnecting
total 28 cage size 15 cm (h) x 15 cm (w) x 30 cm (l)




X
or corrugated absorbant with disinfectant

atmosphere 80% N 20% $O_2$

② temperature + ventilation (a) ambient temp 70 ± 2 °F (20–21°C)

(b) (downward ventil) 6 air changes / hr (every part of room)
incoming air: microfiltration
(c) pressure should be slightly hier than in corridors so that leakage is always outwards + there is less chance of airborne infection being sucked in

[In general, overheating is more damaging than cooling]

③ humidity: should not go below 50% ; hier relative humidity up to about 80% OK

'Rats + mice accomodated at reasonable density will produce every 24 hrs a volume of water vapor, from exhaled air and evapration of urine, corresponding to a litre of $H_2O$ for every sq. meter of floor area'

common experience indicates 6 changes / hr. best, with air introduced at low level at one or several points + removed at hi level at diagonally opposite side of room

④ Illumination 12 hrs lite 12 hrs dark
too intense a general illumination should be avoided. Provision should be made for more local + intense illumination for examination of animals using mobile lamps

Physical Structure of the Moon Lab

In order to carry through the proposed experiments, it will be necessary to provide a physical structure on the lunar surface. Materials for such a moon laboratory can be transported from Earth to an orbiting Earth station and from there into lunar orbit. A shuttle system can then be utilized for transportation to the moon's surface. XXXX

It is proposed that the laboratory be manned five days out of each lunar month. During this five day period, the craft transporting the men to the lunar surface will serve as living quarters for all but one of the men. The laboratory will provide accomodations for the remaining crew member.

The laboratory will be constructed on the lunar surface. An inflatable structure utilizing airlocks for passage in and out has been proposed. Such a structure could be reinforced on the inside by supporting materials. Radiation protection provides a problem due to the lack of atmosphere on the moon. Protection can be provided by piling lunar surface material (rock, dust, etc.) about the structure to a depth sufficient to act as a shield. At present, information does not seem to indicate a lunar surface suitable for an underground structure. The proposed inflatable laboratory may be constructed so that it can be temporarily attached to the lunar landing craft during the five day manned periods. This would facilitate movement of men and supplies between the lab and the craft.

It will be necessary within this laboratory to house two monkeys and a maximum of twenty to fifty rats and their life support systems. The lab must also provide adequate working space and housing for one man. To accomodate these facilities, the following structure specifications are proposed:

A,B: monkey facilities

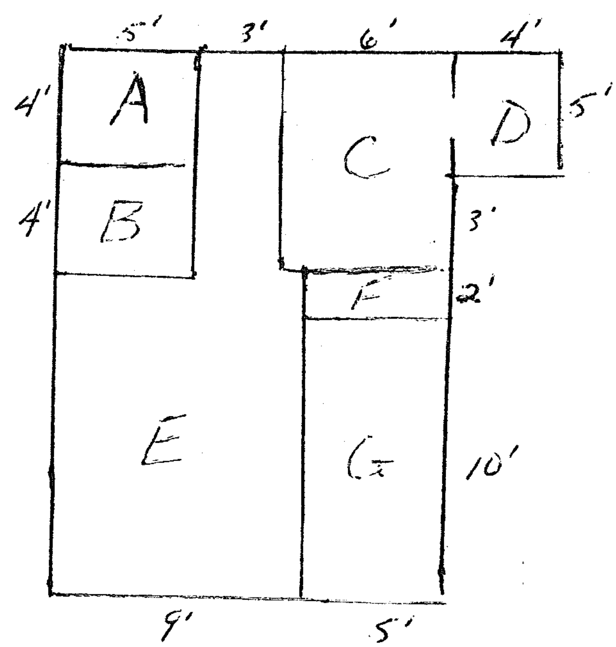
C: Rat facilities

D: Breeding rats and storage

E: Work space & life support

F: Storage

G: Living Quarters



# Life Support

The life support system of a prolonged space flight which consists of living organisms includes protection from a hostile environment, provision of oxygen, food and water, and removal of waste products. If the space flight is indeed long enough, the advantages of a regenerative life support system are maximized. This life support system is for the animals (monkeys and rats) needed for the proposed experiments. The men that monitor the laboratory for five days out of every twenty eight day period will supply their own life support. Also they will be capable of replenishing certain unregenerable necessities in the laboratory.

To diminish the possibilities of a fire hazard a mixed atmosphere of nitrogen and oxygen is suggested. Also results of long exposure to a pure oxygen atmosphere are not known. Due to inadequate engineering there is a certain pressure loss due to the leakage of the spacecraft.

There are two basic types of life support systems. The first system provides for the removal of $CO_2$ by the hydrogen method and $O_2$ regeneration by the electrolysis of water. Because of the loss of gases by leakage, oxygen is stored as water. Nitrogen is carried as a gas because very little is needed. An air-glycol heat exchanger is used to remove all heat generated. When the special radiator system becomes inoperable, a water boiler heater is used. A cryogenic refrigerator using liquid urine, $H_2$, and wash water is used to house food and wastes.

The electrolysis of water supplies the needed oxygen. The atmosphere of the vehicle provides the source for the carbon dioxide. The carbon dioxide is processed to reclaim the oxygen. The hydrogenation of $CO_2$ to $H_2O$ and $CH_4$ is used. To maintain a constant reactor temperature heat must be removed. There are two steps to the reaction. Products from each step are utilized. In the first step water is liberated. This is put through the procedures of electrolysis to produce oxygen, which is supplied to the inhabited areas, and hydrogen which is mixed with $CO_2$ to form $CH_4$ and $H_2O$. The water is transferred to the central water system to be purified.

A glycol heat exchanger recirculates the air to remove the heat. A radiator is employed to radiate the heat into space. The major components of the temperature control system consist of glycol, circulating blowers and pumps, distributional ducking, valving, controls and radiators.

Carbon dioxide is absorbed by a molecular sieve. This is a very effective means except that the sieve has a higher affinity for water than carbon dioxide. Thus the air must be dried before being passed through the sieve. A double parallel path of silica gel and a molecular sieve is used for the absorption of carbon dioxide. While one path is being used, the other path is being regenerated. By passing hot air from path one through the silica gel of path two, the silica gel of path two is regenerated. Afterwards the air is reused by the monkeys and rats. Heat is also added to the molecular sieve.

A subsystem for the removal of contamination is also included. Contamination is considered to be odors, small particles, toxic gases, bacteria, virus, and fungi. Ultra violet light is used to control the growth rate of bacteria, fungi, and virus. A certain amount of $O_3$ is produced. For this reason the method may not be efficient. An activated charcoal filter is used to absorb the odors and the high molecular weight contaminants. A combustion chamber is used to remove the low molecular weight contaminants.

Water management is maintained by vapor compression distillation. The urine and waste water are collected on a moving conveyor belt. They are collected and placed automatically in plastic bags. The materials are placed in an evaporating chamber. The waste water is boiled, and the vapor is compressed. The temperature of the vapor is raised to a sufficient degree so that it heats the remaining solution in the chamber. The solution is passed through several filters, millipore, ion exchange, and activated charcoal. The unwanted gases are vented to outdoor containers which will be returned to earth. The residue of the shell is removed after each process.

This paper is not a specific analysis of the life support system, nor was it meant to be. It is a general analysis of the main ideas involving a life support system. The system will depend upon the experiments and life involved. Also the space that is available for the life support equipment is of great importance.

PROPOSAL FOR LUNAR LAB:

A STUDY OF THE COMBINED EFFECTS OF

RADIATION AND LOW GRAVITY ON WHITE RATS

UCLA 1969 Summer Institute in Space Biology

August 25, 1969

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Introduction

The general purpose of the experimental Moon laboratory will be to answer basic questions concerning reactions of mammalian tissue and integrated biological systems to the space environment. For the sake of practicality, only those experiments dependent on a reduced gravitational field will be included; other aspects of the space environment can be simulated at much less expense on earth. Synergistic effects of reduced gravitation and radiation will be studied because of evidence of a complex interrelationship between the two, gathered in experimemts from Biosatellite II.

The selection of experimental animals, the design of experimental apparatus and the selection of experiments were all made within the limits of present day capabilities and national motivation. In light of recent flights with highly instrumented animals and complex interactions of experimental systems, there was a feeling that there was a need for more reliable data from reactions of mammalian tissue and fundamental systems.

In line with this reasoning, the rat was selected as the chief experimental animal. The chief advantage arising from use of the rat is the redundancy of the biological systems under investigation. Such redundancy allows for more reliability of the data collected. Larger more sophisticated organisms such as primates were ruled out for a number of reasons besides the limited number that could be supported in a moon lab with present capabilities. Problems of restraint have brought the serviceability of primates as experimental animals in space into doubt. The lack of experimental data on the normal functioning of primate systems in the earth environment also points away from their use in space. The wealth of experimental data on the laboratory rat eliminates this problem of comparison when the rat is the object of experimentation.

The chief argument for the use of a primate revolves around investigation of orthostasis. This argument is valid only when the animal is restrained because the primate spends less than 20% of his time in an upright position if unhindered. The proposed six month duration of the experiment makes restraint of the animal impractical.

. Catherization for urine collection or other methods of sampling that might be expected to become blocked or become sites of infection are also rendered impractical by the long duration of the experiment.

The use of rats in fairly large numbers allows examination of a sampling of the population each month to allow plotting of experimental data against time spent in the lunar environment. The plan for removing and examining rats from the moon will be eight after each of the first two months, twelve after the third, fourth, and fifth months and twenty after the final experimental period. The increase in numbers will provide a safety factor in the event that some of the rats die before termination of experiment. Such premature deaths are anticipated and provisions have been made in the experimental apparatus for removing and preserving the dead rats until the next monthly service period.

## Launch and Recovery

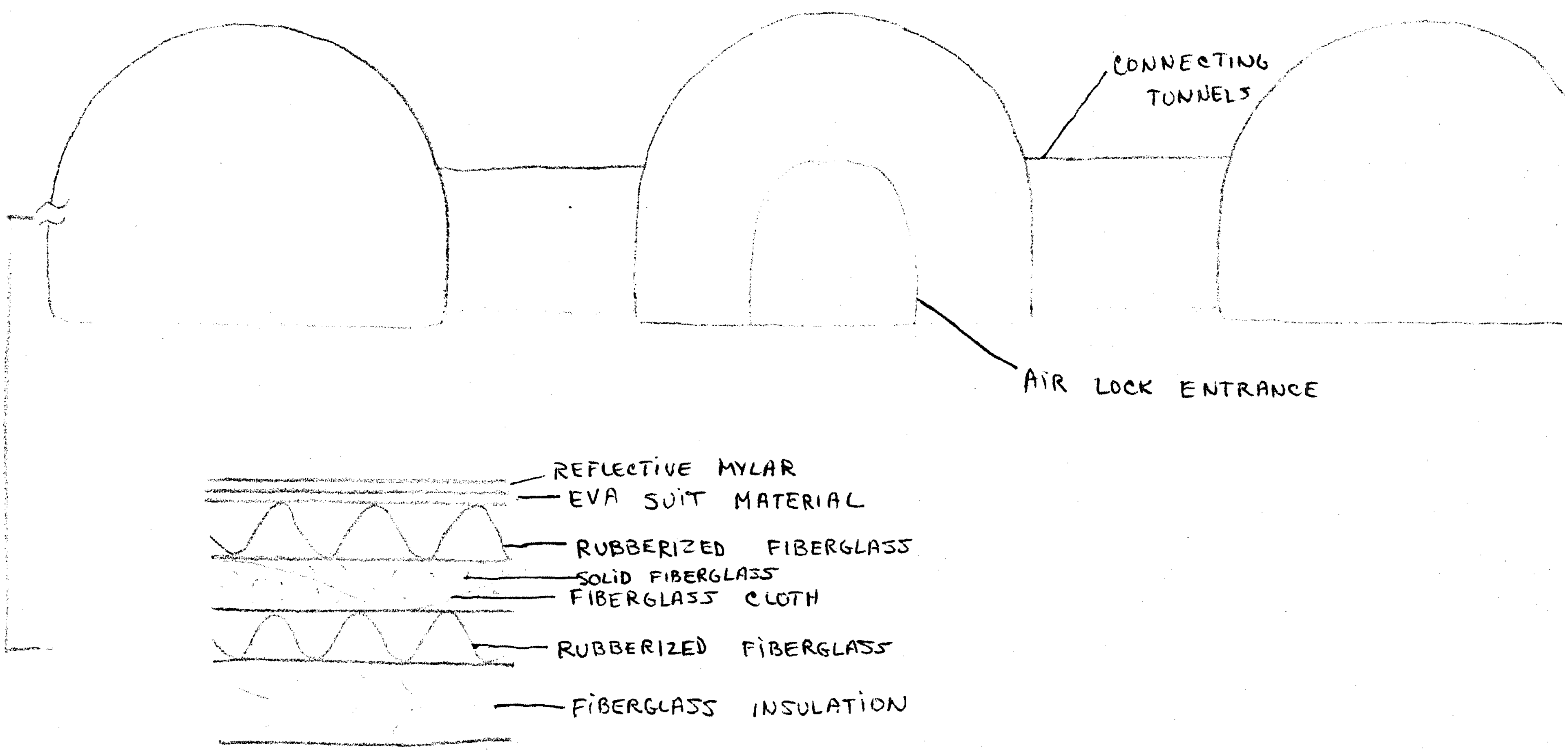
We intend the Moon Lab experiment to be compatible with current ability and technology to largely eliminate the delay and cost of developing new systems and special equipment. Transportation will utilize only slightly modified Apollo systems. The primary modification is an increased payload capability. Unmanned Apollo-type rocket systems will be remote landed by previously landed astronauts. These rockets will carry the components too large and/or heavy to put on the manned mission. By this method, the only additional payload required would be the guidance and control package for the unmanned supply rocket. Only the approach to the landing site would be controlled from the Moon and control would be similar to that on Apollo with the addition of a radio beacon previously placed on the desired landing site. This remote landing system could also be used for subsequent landings as the only equipment which is not reusable is the beacon which would be destroyed by the rocket blast upon landing.

General Lab Configuration

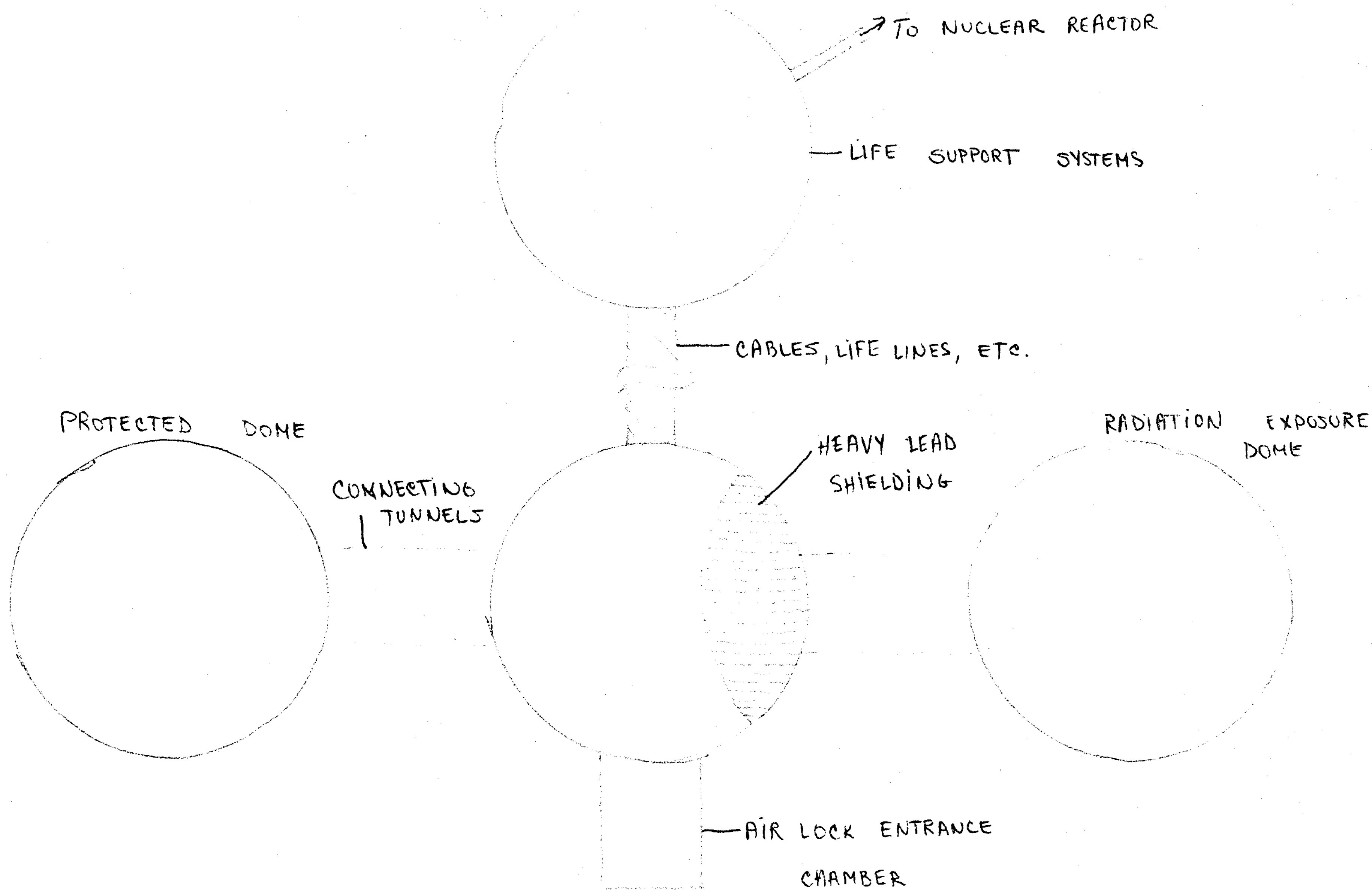
The lab will consist of three identical domes, interconnecting tunnels and power supply dome. The domes are double walled and floored with synthetic rubber coated fiberglass cloth. The outer dome is also covered with the meteorite and radiation shielding material used in the Apollo space suits. Loosely attached between the layers is another layer of fiberglass cloth. To erect the structure, the inner dome is inflated and then the outer dome is separated from the inner by additional pressure. The area between the layers of the floor (same construction as walls) is filled with fiberglass with a pressure feed system which automatically mixes the catalyst. The inflating gas is bled into the lunar environment so that a constant pressure is maintained between the walls. When hardened the floor is level and anchored to the lunar surface. The area between the walls is then similarly treated. After setting the temporary half-seal is removed and replaced by the permanent pressure seal and hatch. The tunnels and other domes are erected sequentially in the same manner as the first.

Two levels of shielding from radiation are planned. One experiment dome will be shielding in the same manner as the Apollo space suits. The central dome and other experiment domes will be shielded more effectively. In addition to having built in suit level shielding, the central dome will be shielded in parts to provide emergency protection from solar flares. for the astronauts. The second experiment dome will be shielded with the stored drinking water and further lead shielded to provide no more than one-thousandth the exposure of the other experiment domes. Lunar soil may be used for part of the shielding.

DIAGRAMMATIC SKETCH OF MOON LAB STRUCTURE



DIAGRAMMATIC SKETCH OF
LAB CONSTRUCTION
(NOT TO SCALE)



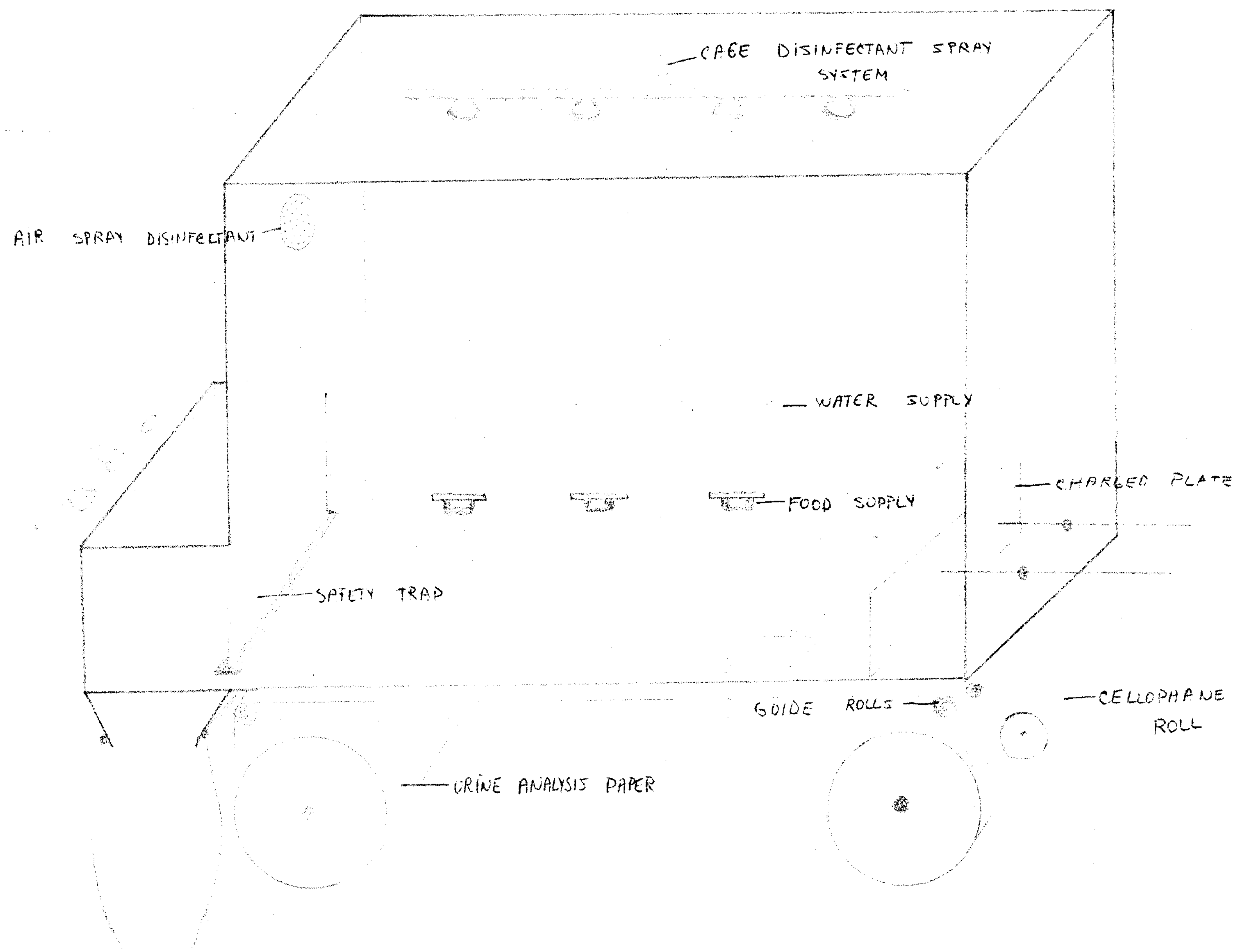
Experimental rat cage

The primary experiment involves housing 72 rats in two groups. Housing will be in groups of twelve in special cages. Because the cages will have no maintainance except during the service period, automatic methods will have to be used. A commercial product such as Lysol will be sprayed every two or three days to wash down and disinfect the cages (see sketches of cages for this and below). The cage floor will be wire so that urine some feces and pieces of rat pellets can fall through. They will fall onto a plastic backed absorbent paper roll which passes under the cage. At the take up roll another layer of plastic will be added. The paper will be prenumbered to aid in later analysis.

Cage sweeping and removal of dead rats will be accomplished by a moving barrier and trapdoor system. On detection of a dead rat (by television monitor) or during the cleaning process, the barrier is charged and begins moving across the cage. The rats have been previously conditioned to jump over the barrier to avoid being shocked or trapped at the end of the cage. Dead rats are pushed to the end of the cage and wipers on the bottom of the barrier clean the cage floor (the wires in the bottom of the cage are not crossed but run only parallel to the direction of motion to avoid catching anything). On reaching the end of the cage, a trapdoor opening into a small end section of the cage opens and the debris and/or dead rat is pushed in. The barrier then retracts and the trapdoor closes. The door in the bottom then opens and solid material drops into a bag formed from a periodically sealed soft plastic cylinder. Material stuck to the cleaning area is washed into the bag with disinfectant spray. The bag top is then sealed and moved into position for the next cycle.

Food and water are delivered as taken by the rats with a preset limit on the maximum number of pellets which may be taken in any one day. Atmosphere is circulated over the cages by blowers. Lighting is by overhead flourescent lamps and red lights, cycled for twelve hours each. Heating and cooling are done by a mechanical heat exchanger on a full-dome basis. Heat or cold is transferred using the Moon as a heat sink. A reflective coated Mylar layer on the surface of the structure reduces heating caused by absorbed radiation. An inner layer of spun fiberglas sealed into plastic (stored and transported compressed) forms a "dead-air space" to futher reduce unwanted heat transfer.

Diagrammatic Sketch of Rat Cage



Telemetry and communication

The prime user of the system bandwidth is the television unit. Several cameras are switched and scanned to send pictures of the interiors of the experiment cages. Commercial resolution camera images are digitized and transmitted in FM mode with the high power transmitter (see below). Unless otherwise commanded, a short segment of each hour will be allocated to a sequential scan of the cages. The scan may be interupted from Earth at which time it returns to a position which compensates for time lag overshoot.

Other information will be monitored on a multiplex basis or when requested from Earth. Continuously sampled information will include channels allocated to the implanted dogs, internal and external temper-ature, humidity radiation levels, oxygen and water consumption from each experiment dome, power supply output and status and life support status. Requested information will include food consumption, water removed from environment and extra television information.

Control of food and water, power supply and life support can be controlled from the ground. Transmission and reception are on separate channels to allow simultaneous operation. In addition to the telemetry information, voice channels will be available for on-site observation and communication. The main transmitter and antenna will be designed to provide wide angle, continuous contact with Earth. A lower-powered, high gain system will provide back-up communications.

Power supply

A small nuclear reactor driving a frequency-regulated alternator system will be the primary power source. Estimated power consumption will be well under ten kilowatts except for peak loads when all systems are functioning at once. Nickel-cadmium batteries will be used to store power for peak loads and emergencies. Emergency power will also be derived from compressed-gas driven tubine-alternator combinations. These will come on automatically in the event of a main system failure or they can be activated from Earth. Solid-state inverters will convert the stored dc from the batteries to the required ac levels. Synchronization with extant power, if any, will be done electronically.

The reactor will be located in the first service rocket (unmanned) and will be connected to the experimental area by interconnecting cables. The batteries and other power supply apparatus will be stored in the power supply dome. If practical (depending on soil conditions), all outside cables will be buried to minimize possible meteorite damage.

Space suit requirements

For the work required to establish and maintain the Moon Lab to be practical and not exhausting, the current EVA suits will be replaced by hard shell types currently undergoing tests. The back pack for construction work will be smaller and will be connected by umbilical cord to the capsule. Although the cords may be a nuisance, we feel the reduced mass will be more than compensatory. Additional cooling will also be supplied via cold water from the capsule. The larger, self-contained back packs will be used only for longer excursions. In the lab, the suits will be left in the central dome where the astronauts will don clean suits (coveralls and caps) to minimize contamination. After entering an experiment dome through a tunnel and air lock, the astronaut will breathe through a two-hose mask connected to the capsule to minimize cross contamination via airborne organisms. Breathing gas in the tunnels and central dome will be one-third atmosphere oxygen and will be independent of the two experiment domes' environment.

Environment

Breathing atmosphere inside the domes will be maintained at 72$^{o}$ F., 40% humidity and will be oxygen at five p.s.i. Carbon dioxide will be absorbed by lithium hydroxide which will be replaced or recycled as required on a monthly basis. A commercial product such as Ozium will be injected at the circulation blowers to control odors and destroy bacteria. Humidity will be controlled by extraction with cooling fins. As the natural tendency of the environment is to raise the humidity, no special effort to add water vapor will be made. Buried cooling fins will provide the heat sink for both the cooling unit and humidifier (humidified air differs from cooled only in that it is rewarmed after passing the fins). When in either of the experiment chambers the astronauts will be linked to their capsule by a two hose mask system. In addition to reducing the chances of transmitting airborne bacteria, a smaller life support system can be used since no men will be supported by it. In an emergency the large size of the chambers would allow the astronauts several hours to return to the capsule or to repair the malfunction.

Food and water rations for the rats are 100 ml/day/rat of water and 10 pellets/day/rat of food. For the six month, 72 rat experiment, this leads to 1,220 liters of water and 30.5 kilograms (@ 2.5 g/pellet) of food. These supplies with safety excess will be brought monthly as required. Additional supplies for other experiments will be stored in the central chamber when they are brought up.

Telemetry data will enable earth control to monitor the environment. Internal and external temperature, humidity, oxygen consumption, water consumption, radiatin level will be sampled and transmitted. Food consumption will be transmitted only on change.

Experiment 1. Experiments on the Musculoskeletal System: The Effects of Prolonged Exposure to a Low-Gravity Environment on the Musculoskeletal System of White Rats.

Purpose: To determine the effects of a reduced gravity environment for periods of one month to six months on the constitution of the muscles and their functions in white rats.

Introduction: Data on the effects of weightlessness on muscle metabolism is very limited and the subjects involved were under a variety of diets and in-flight stresses. Data from Gemini VII indicated a negative change in the calcium balance which means a loss of calcium from the bones. After the fourteen-day mission X ray evidence showed bone demineralization, per cent change in density, in the _os calcis_ (heel bone) and the second phalanx of the small finger. Bed rest studies are used as simulation of weightlessness. Studies by Mack, Texas Women's University, on bed rest and immobilization show a loss of skeletal mineral and an increased excretion of calcium in the urine. Studies indicate that isometric exercises reduced the loss of bone mineral during bed rest. None of the space flights have resulted in a lack of muscular coordination or muscular atrophy but atrophy is expected after exposure to longer duration weightlessness.

Procedure: A total of sixty-four rats will be used for the experiment, thirty-two of which will be exposed to both radiation and low gravity and the other half of which will be exposed to reduced gravity only. X rays will be taken of the bones of two legs of each rat prior to the trip to the moon. Each month during the five-day service period the astronauts will take X rays of the legs. A number of rats will also be brought back to earth for more extensive bone density studies. The rats will be tagged with numbers to differentiate them. The loss of calcium determined from urine collection will be compared to the X rays of bone density of those rats brought back from the lunar environment. After each five-day service period the rats returned to earth will be extensively tested and observed for adaptation to increased gravity of the earth. The rats will be watched during the periods of activity in order to identify any muscle weakening or incoordination. The control rats on earth will undergo the same series of testing and evaluation.

A group of eight rats will be subjected to surgical fractures on earth and taken to the moon to observe the effects of low-gravity on bone healing. This experiment will be commenced during the second experimental month.

Expected Results: Though not subjects to weightlessness on the moon, the rats will experience a very low force of gravity. Therefore the X rays should show some change in bone density especially during the first month or two. In subsequent months, after adjustment to the new environment the calcium in the bones which determine the density of the bones should come to an equilibrium level. This level of calcium in the bones will be the characteristic amount required of the animal for muscular functioning in the low-gravity lunar environment.

It is possible that there will be a continual decrease in the bone density and, therefore, a continual loss of calcium. This would be detected through the amount of calcium excreted with urine. If this should happen muscle atrophy will occur to a marked extent and the rats may die. A constant loss of bone mineral will also eliminate the ability of the rats to readapt to the increased gravity of the earth since the bones will be so deteriorated. Therefore, these two possibilities should be examined.

On return to earth, the rats should be seen to have some muscle atrophy due to calcium loss and decreased activity on the moon. Muscular incoordination should be more marked with the rats that have been in the lunar environment the longest - the four, five, and six month periods. There should be readaptation to the increased gravity force of the earth which may be a slow process of calcium build-up in the bones.

Experiment 2: Effects of Radiation on the White Rat in a Reduced Gravity Environment.

Purpose: To determine the synergistic effects of radiation and 1/6 g on mammalian systems and to provide information concerning proposed shielding techniques.

Introduction: To a large extent, the hazard of high energy radiation in space can be simulated on earth with linear acceleration and cyclotron techniques. Such studies have generally involved a short term, high dose exposure: consequently extensive literature dealing with cumulative efforts of exposure to highly ionizing particles is lacking. Earthbound studies are unable to answer questions concerning the influence of reduced gravity on the reaction of tissue to ionizing radiation. Results of experiments performed in Biosatellite II indicate important synergistic aspects of tissue reaction to reduced gravity and radiation. For these reasons, and also for the elucidation of questions in the engineering of protective shielding, an experimental investigation of radiation effects on rats protected with variable amounts of shielding is planned.

Experimental Design: The population of experimental rats will be evenly divided into two groups designated group S and group E. The cases of those in group S will be heavily shielded with maximum practical shielding for a permanent manned installation on the moon, group E will be housed in identical cages shielded with EVA space suit radiation shielding.

At the end of the first, second and third months, four rats will be taken from each group. Two of these from each group will be sacrificed on the moon by immersion in liquid Nitrogen. The remaining four rats (2 S and 2 E) will be prepared for return to earth.

The amount of radiation received by rats in either group will be continuously monitored by radiation dosimeter. Provision will be made for an automized increase in shielding of one of the E group cages to prevent death of all exposed rats as a result of unexpectedly high doses of radiation.

Control groups on earth will be irradiated with doses corresponding to those recorded by the dosimeters monitoring each of the groups. Control exposure need not be simultaneous time elapsed experiments with appropriately adjusted sacrifice time will be satisfactory.

As the number of rats returned to earth at the end of each month increases (12 after both 4th and 5th months and the 16 remaining at the terminations of the experiment), the proportion of rats from groups S and E will remain 1:1. The number of rats immediately sacrificed in $N_2$(L) will be kept at 2, all remaining animals returned to earth alive.

Analytical Technique:

The emphasis of analytical techniques will be on determining somatic effects of long term exposure as influenced by reduced gravity. Consequently, techniques will be, for the most part, limited to chemical and histochemical procedures. Both red blood cell and white blood cell counts will be made as part of the blood analysis. Assays will be made to determine extent of possible carcinogenic induction including leukemia. Examination of eye tissue will be made in anticipation of possible cataracts.

Histochemical and chemical analysis of brain tissue will be carried out extensively. For investigation of blood-brain barrier mechanism following exposure, one milliliter 10% solution of sodium fluorescien in buffered saline will be injected into one of the live rats returned to earth, twenty-four hours before sacrifice by decapitation. After brain removal, coronally sectioned blocks can be observed in a dark room under ultraviolet light. Histochemical analysis of glycogen accumulation can be made using the Schiff procedure involving PAS staining.

Chemical analysis will be performed on irridated and nonirridated lunar and control rats that have been sacrificed by immersion in liquid nitrogen.

Glycogen can be isolated by standard techniques and analyzed with the use of glucose oxidase. Lactic acid analysis can be carried out after homogenization in 10% TCA.

## Expected Results

Group E will be relatively well protected against electromagnetic components of radiation including ultraviolet, X ray and gamma radiation. This reduces the chief experimental variable to exposure to or shielding from high energy components (mostly protons,alpha particles). Studies of several species have indicated that for a total body dose, such high energy components are prone to damage the gastrointestinal system. This is in contrast to the predominant damage to the hemoporetic system resulting from exposure to X or gamma radiation.

Hemorrhagic phenomena are likewise more common following proton irradiation than following exposure to X rays.

The design of the experiment, specifically the number of animals involved precludes the meaningful study of genetic or life shortening effects (reported to be one to one and a half per cent per one hundred rem in the rat. Such statistical phenomena, based on population studies would be better investigated in a Drosophila experiment.

BBB disturbance, increase in glycogen accumulation and an increase in lactic acid level can be expected as a generalized response to irradiation of the brain. The increase in glycogen accumulation and concurrent increase in size of astrocytes can be explained by any of three hypothesis: 1. the liberation of carbohydrates in the injured tissue and subsequent uptake of them by glial cells; 2. increase in permeability of the BBB membrane to glucose; 3. inhibition of glycolysis.

Investigations of tissue reaction to radiation at the cellular level have indicated that aside from the direct effect of atomic collision, radiation generates strong oxidizing agents such as hydrogen peroxide in the biological fluids causing cell destruction. For this reason antioxidant drugs such as ascorbic acid or butyl hydroxytoluene have been used experimentally to lower tissue oxygen levels thereby reducing the number of damaging free radicals. The problem of using these drugs is compounded by the fact that they must be administered just before exposure if they are to be maximally effective. Introduction of such anti-radiation drugs to a liquid food supply of a limited number of exposed and control rats may provide significant data.

Comparison of histological data of both groups of lunar rats with the earthbound controls will form the crux of the radiation experiment. Indications from Biosatellite II that cell metabolism is slowed down in reduced gravity have been used as an explanation for increased recovery rates, postulating that the slowdown enables the cell to repair damage. A conflicting hypothesis might be based on the theory that radiation recovery depends on elimination and replacement of damaged cells. Such a conflict, based on present data, indicates the need for more data concerning synergistic effects of low gravity and radiation. Present theories are chiefly speculative.

Experiment 3: Urinalysis

Purpose: The purpose of this analysis is to provide a means for daily evaluation of the general state of the experimental animals, particularly with respect to electrolyte balance and calcium excretion.

Experimental Design: The general procedure to be followed will be the collection of the urine from each cage on an absorbent paper, the drying of the urine on the paper, the measuring of humidity to determine volume of urine excreted, and the evaluation of the chemical data obtained from paper.

The absorbent paper used for urine collection will be an ion free filter paper backed with a water repellent plastic sheet. The paper will be on rolls, and will be advanced daily, dried, and rerolled. The drying process will be done by passing air over the system and perhaps subjecting the paper to a final drying stage by subjecting it to a blast of warm air. The sheet will be impregnated with an anti-bacterial agent to prevent the growth of bacteria and/or loss of quantities sought. During the service period the paper will be recovered and returned to earth for analysis.
Note that this procedure is based on the assumption that each rat will have an excretion within certain limits and that little will be lost by considering the entire cage population instead of the individual animals. Catherization was ruled out because of the size of the animals and the irritations and possible infections resulting from catherization.

Evaluation of Urine Paper: On return to earth the paper will be divided into daily sections. Each piece will be eluted with ion-free distilled water and tested using the usual clinical procedures. According to Dr. Adey if the urine is dried thoroughly in space, the constituents retain their form, i.e., are not degraded, and the usual gamut of tests may be run. The tests which will be performed include the determination of sodium and potassium (flame photometry), chloride determination (chloridometer), calcium determination (atomic absorption spectroscopy), VMA, catecholamine, and 17-hydroxysteroids, proteins, and perhaps a determination to detect red blood cells or other sedimentary material in the urine.

Expected Results: From reports of space flights a decrease in body fluids and thus an increased urine output occurs in low-gravity situations. Thus one might expect an increased output from the lunar rats at least during the initial few weeks. The levels of electrolytes in the urine might show some change but the exact nature of this change can not be easily predicted. In order to maintain homeostasis it would be assumed that a concentration of electrolytes would be excreted so that internal electrolyte concentration would remain normal, inspite of lower body fluid. Because of loss of bone density, one might expect the level of calcium excretion to be high during the initial few weeks and then to level off to a normal or a "lunar normal" value. The creatinine level would be low because or one would expect muscle atrophy (disuse). The VMA, catecholamine, and 17 hydroxysteroids would give an indicate of endocrine activity and would thus be expected to be increased during the initial weeks while the rats are in a condition of relative stress. Blood sediment, urine protein, and other forms of urine sediment may give indications of distress in the kidney, perhaps resulting from cardiovascular system disturbances. However, no change is expected unless the animals go into a condition of deterioration.

In summary, one might expect to find increased urinary output, increased calcium excretion, decreased creatinine excretion, and increased VMA, catecholamine, and 17-hydroxysteroids, particularly during the first few weeks in the lunar environment. If these levels persist however, i.e., if they do not stabilize or return to an earth normal, the animals may go into a state of slow deterioration and thus show the inability of the animals to adapt to the lunar environment.

Experiment 4. Blood analysis of rats exposed to the lunar environment for prolonged durations both exposed and protected from radiation.

Purpose: To screen the animals kept in the lunar environment for durations of varying length. To examine the blood of protected rats and rats exposed to the radiation incident upon the lunar surface.

Procedure: A 1cc sample of blood will be attained caudally from each of the rats during the five day service period. From this sample a minimal amount will be used for hematology procedures. The remaining amount will be spun down immediately at 2000rpm for 10 minutes. The serum can then be separated from the solid material, frozen, and stored until it can be analyzed at the earth laboratory.

The usual clinical procedures for hematology and blood analysis will be employed. The hematology examination will take place in the lunar laboratory. The astronauts will take a red blood cell count, white blood cell count, an d a platelet count. The clinical procedures for the determination of electrolytes, calcium, creatinine, bilirubin , and cholesterol in microtechnical form.

Expected Results: From previous manned space flights in which a decrease in the red blood cell count was noted one might be led to expect that there will be a decrease in the red bllod cell count of the rats subjected to low gravitational effects for extended periods of time. The white blood cell count may increase because of lowered resistances and increased susceptibility to infections. No change is expected in the platelet count, however should such a change be evident, concern would arise over the clotting mechanisms.

Creatinine, a product of muscle contraction, may be found in ever decreasing concentrations if any appreciable muscle atrophy takes place. Likewise, an increase in the calcium concentration may be found due to a decrease in the bone density.

Because the literature indicates a decrease in the red blood cell count an increase may be expected in the bilirubin concentration since this substance is the result of red blood cell break-down. No change is expected to be evident in the electrolyte concentration.

A test will be made for cholesterol to determine the possibility of the animal being in a state of hyperlipidemia. Should this occur along with proteinuria there would be rather strong evidence that there has been some structural alteration in the renal filtering system. A change in the glomerular basement membrane could be the result of the changes occurring in the cardiovascular system. The interdependence of these systems makes it imperative that these systems be examined in relation to the other~~e~~s.

Monthly Maintenance

In accordance with designated time schedules for manned operations the moon laboratory will be serviced every twenty-eight days for a period of five days. The service periods have been chosen to coincide with the daylight cycles of the lunar month. At these times the service crew will have the most favorable lunar temperature environment and provision will not have to be made to provide for the cold lunar night.

The tasks which will be performed by the service crew will involve data accumulation, testing, and equipment servicing.

I. Landing procedure: The service craft will land within a fifty yard radius of the lunar laboratory stations. The proximity of the crafts will allow the astronauts to leave their module without the inconvenience of the life support back pack, being joined with their craft by life line tethers. However, outside the radius the suitable back pack will be provided for such situations.

II. Experiment Servicing Duties: The experiments and data accumulation which have been running for a month previous will require servicing.

a)) Urine Collection: Timed automatic control of the paper-advance will allow for the removal of the roll of urine analysis paper. The rolls which are under all groups will then be replaced with new rolls and the advance mechanism will be activated. This change provides enough paper to last another month.

b)) X-ray Films: The X rays taken of the rats to indicate bone healing and spine curvature will be removed and replaced with unexposed X-ray plates. The exposed plate will be flown to earth lab for analysis.*

c)) Blood Collection: On the first of the five day service period a 1 cc sample of blood will be collected by caudal dissection. It shall be noted on the fifth day if the tail is healed.

d)) Systems Check: A thorough check will be made on the functioning of life systems and environmental controls. The mechanisms involved with experimental procedures can be also examined for operational efficiency.

e)) Radiation Group ;Rats: Because of the necessity of preserving the brain without change in order to perform an accurate analysis of glycogen content, a specific number of rats will be quick frozen in liquid nitrogen and kept in the frozen state until accurate cross-sections and stain can reveal the glycogen content.

In addition rats will be returned to the main laboratory for histological, anatomical, physiological, and morphological studies.

*Special consideration must be given the bone healing and densitometry experiments. Since we do not want the X-ray procedure to interfere with the radiation studies, a special selected isolated group of rats will be provided for this study. These rats will not be introduced to the lunar environment until the second month and will replace the group being returned to earth after one month. These rats will be protected from solar radiation.

Monthly Experimentation

At monthly interals a determined number of rats will be removed. Provision has been made to allow for the disengagement of the entire cage. The space provided can then be used for this introduction of a compartment housing a cardiovascularly telemerized dog.

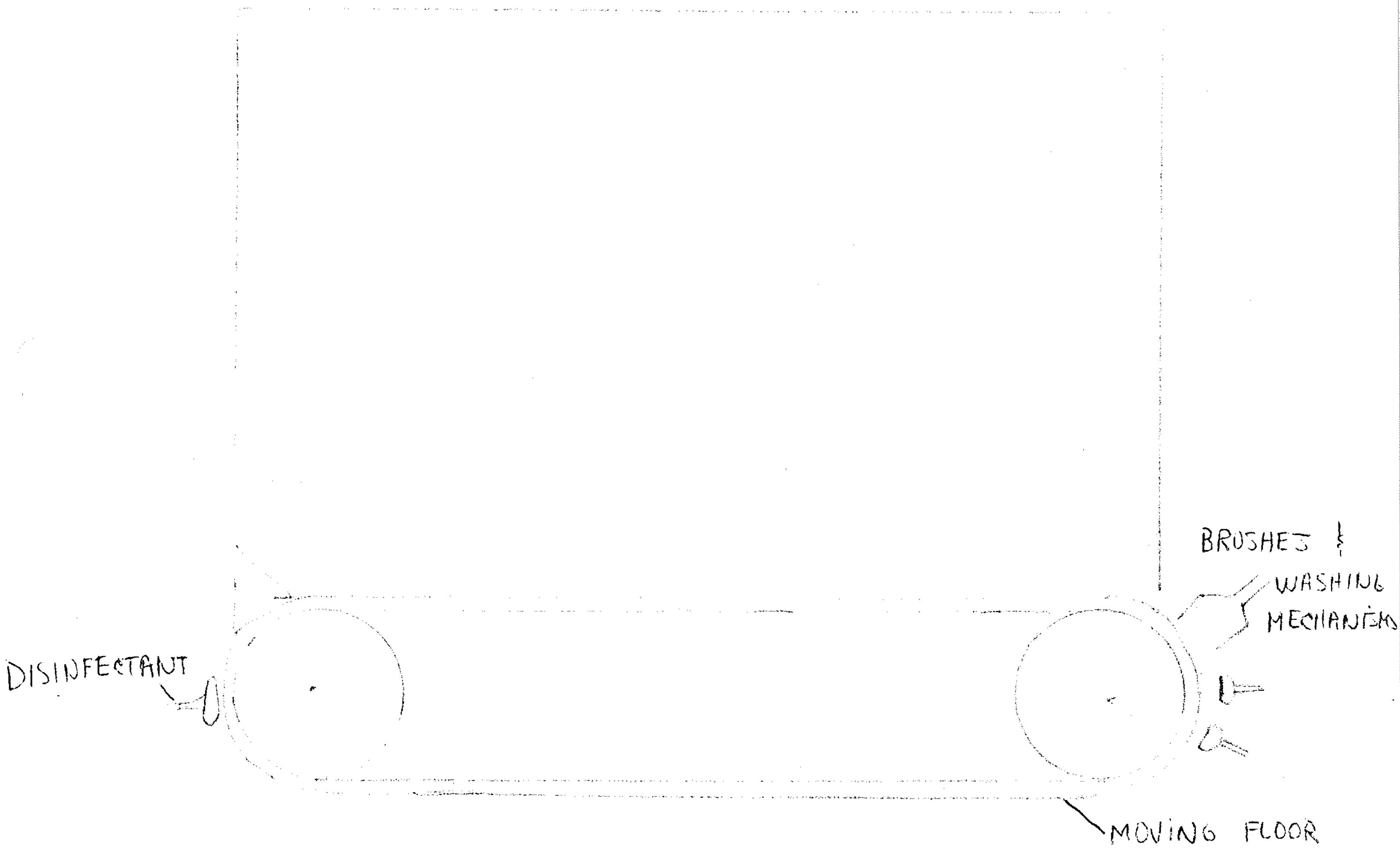
Because of the wealth of knowledge on the cardiovascular system of the dog it was decided that a dog would be the best subject for this study.

In order to study the cardiovascular system in the reduced gravity environment of the moon, catheters are surgically implanted at four sites for blood pressure measurement. Additional measurements are EKG readings and respiration rate. To prevent clotting of the blood due to the implanted catheters, heparin-saline solution is added to the bloodstream at the rate of 5 ul/ min.

Primary interest will center upon the effects of pooling in the thoracic cavity, blood pressures, mean heart rate, resistance to blood flow.

The cage design for the dogs is quite similar to the rat cage. The floor is connected with a treadmill mechanism which moves at designated times in order to clean the cage and clear it of waste products. The dog is kept in a radiation protected environment identical to the rat environment.

DIAGRAMMATIC SKETCH OF
DOG CAGE



Presented to

Mr. Pierre Hahn

<u>Moon Lab Experiment</u>

Presented by

Joseph Bonventre

Alice Hemingway

Eric Hilgeford

Michael Karbowski

Mary Ann Kelling

Neil Kesselman

Hypothesis:

The moon is an ideal station for a manned science lab for a number of reasons: first of all, from an astronomical point of view the moon does not have an atmosphere to inhibit visibility. More important, however, are studies pertaining to radio astronomy. Whisperings of radio waves from space have given us a vast amount of knowledge in recent years; however our atmosphere, as well as man-made radio signals, have made it very difficult to study the faint emmissions from afar. Observations on the far side of the moon would be shielded from such interference, as well as provide a scan of the entire universe in the course of a month.

A permanent science lab on the moon could provide many other experiments that are not possible on the earth, such as first-hand geological studies.

Besides science labs, industries may find lunar factories beneficial to man; products requiring a deep vacuum for construction would be an example, as well as products making use of the lunar natural resources itself.

But the lunar environment is hostile to man, and long term visits may prove fatal, or too expensive in protecting him.

This project is concerned in determining if man could stay for long term durations on the moon; likewise, it seeks to determine how the lunar surface material could best be utilized in protecting life from radiation and broad temperature ranges.

We propose to establish life stations consisting of one type of animal, one type of plant, and one type of bacteria, with the stations covered with lunar gravel to various depths.

Important parameters to be studied will be radiation, gravity, and temperature; radiation will vary according to depth, gravity will be constant at 1/6 g, and each level will have three groups of different temperatures. All other parameters will be controlled to earth conditions.

Since the required power will be less than 10 kilowatts the method of power generation we will use is to generate heat by radioactive decay.

## Preexperimental Tests:

Previous to sending the living organisms to the moon for study, several physical properties of the lunar surface will be studied. By a conveyor type apparatus, a cone ten feet tall will be built; the conveyor will scrape only the loose surface gravel and will be fitted with a sieve that will eliminate rocks over $\frac{1}{2}$ inches in diameter. This will eliminate air gaps and other inconsistencies that larger rocks may produce.

Through the center of the cone, GM tubes, scintillation detectors, and thermocouples will be set at two foot intervals. Besides radiation counts and temperatures at various depths, the natural slope of the cone will be taken by measuring the cone's dimensions. Men will supervise the building of the mound and take the physical dimensions, as well as a series of photographs of the cone; radiation counts and temperature readings will be telemetered automatically every hour for a month, throughout the night and day cycle.

This study will give scientists and engineers information on the radiation absorption co-efficient of the lunar surface; they will also be able to determine the temperature "buffering" of insulation that the lunar material provides. These critical factors will be important in determining the dimensions of the later cone that will support life.

Experimental Design:

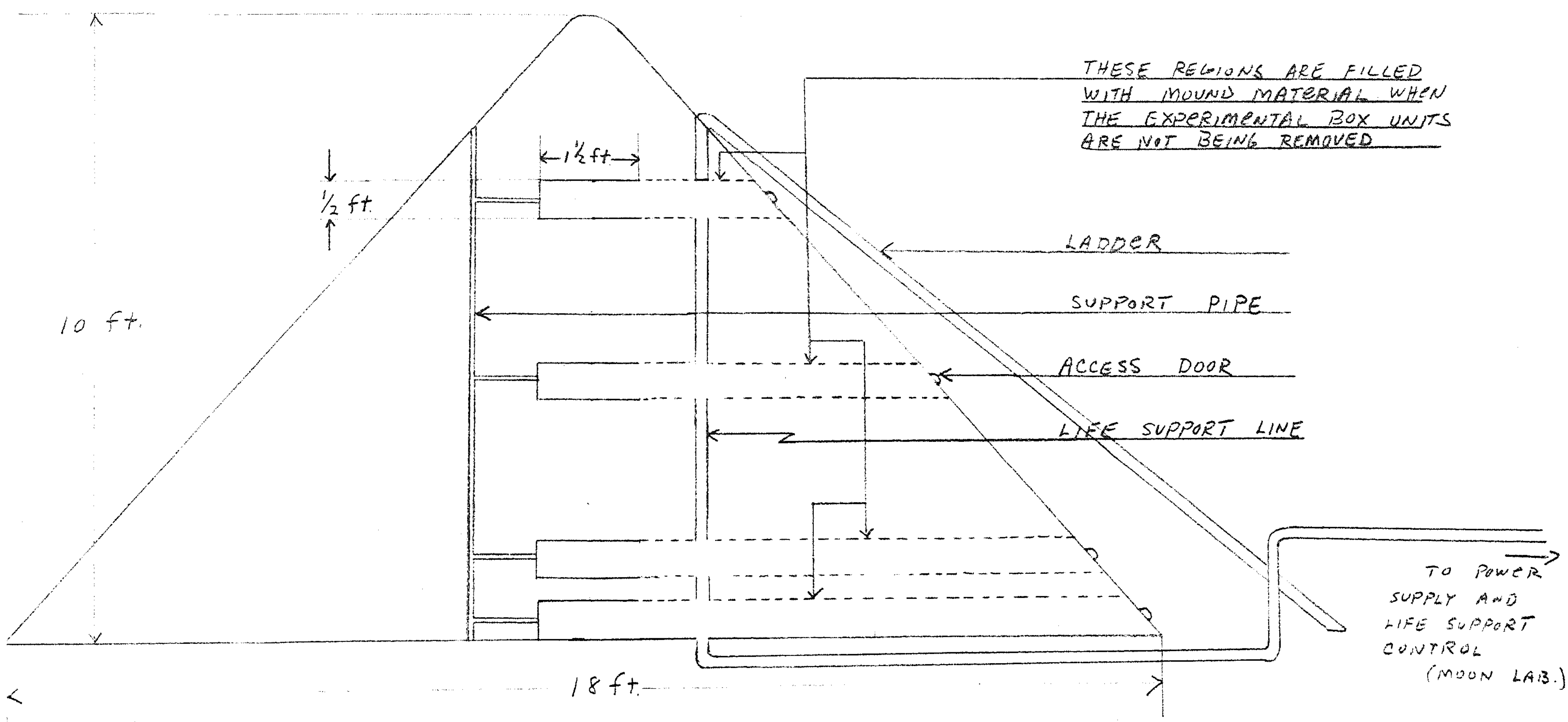
A cone is once again constructed as before with dimensions determined by previous radiation counts; the height will be such that there will be substantial differences in radiation counts from level to level. Packages with supported life will be buried within the cone at three different levels (see figure 2). They will be set such that the volume of lunar material above each level is twice that of the level directly above. Hollow tubes will lead from each package to the outer surface of the cone for servicing, so that each life package can be brought to the scientist-astronauts by a conveyor belt. Tubes from each level will also lead to a common life support system located outside the cone for easy servicing.

Each package will contain three compartments, identicle except for the temperature settings; temperatures will be set at 20°C, 25°C, and 37°C. This is true for all levels.

To insure that the cone will retain its shape throughout the entire six months, and that it will be the same in proportions as that determined by the first cone, the second cone will be covered with a thin plastic fence. The fence will be strong enough to provide support, yet thin enough such that its radiation shielding effects are negligible; it will be of such a material as to withstand the broad temperature range of the moon, as well as being flexible enough that it could be folded for the trip to the moon.

The cone will be inspected and serviced every 14 days from a lunar orbiting space station, from which the living organisms have been selected and where a control set of organisms is contained.

# CROSS-SECTIONAL VIEW OF EXPERIMENTAL MOUND



EXPERIMENTS WITH DROSOPHILA:

This part of the proposal deals with *Drosophila* experiments. There are two basic experiments, and each will be treated individgally. The two are: 1) longevity, 2) hatchability, viability, and adult mutations.

I TITLE: LONGEVITY IN MALE AND FEMALE *Drosophila melanogaster* UNDER 1/6 EARTH GRAVITY, VARIOUS AMBIENT TEMPERATURES, AND VARIOUS RADIATION EXPOSURES

HYPOTHESIS: Reduced gravity, various degrees of radiation exposure, and different ambient temperatures interact in ~~a~~ complex way to change longevity.

EXPERIMENTAL DESIGN: ONe can only expect enough time for two runs of the longevity experiment because the average life expectancy for *Drosophila* is 68 days and some always live longer. True the life spans can be expected to be shorter, but with exceptional flies one must plan for a long study. There being 168 days, it is possible three studies could be completed. The first study will deal entirely with males, and the second entirely with females. At each of the three levels in the mound there will be placed three vials of 50 flies each freshly delivered from Earth and thus less than 3 days old. There will be one vial each in compartments maintained at 37°C, 25°C, and 20°C. They will be fed a standard agar media ~~XXXXXXX~~. On each visit the astromauts will check for deaths and transfer them to fresh containers. The containers will be cyllindrical with 2 inch porous sides and 3 inch clear glass bases.. A further modification will be discussed in a few lines. Daily monitoring of deaths will be accomplished in two ways: 1) photographs thréugh the top, 2) a suction counter described in an included article by P. Cuperus. The suction will be light, and a light will be used to help attract the living flies. The light-dark cycle will be maintained constant so as not to disrupt any circadian rhythms. If the counting was begun just at the beginning of the light , it would certainly facilitate counting. The counting technique will involve transferring the fruit flies back and forth from day to day between two containers. To fulfill requirements for this suction counting technique the container mentioned earlier will have to have an inverted funnel on one of the top corners to lead to the counter and through which the suction is applied. One counter will be used at each level, and a system of valves used to enable the counting of all the containers. The camera arrangement is similar. One will be used at each level for all the experiments, and mirrors used to bring the images to the camera. On each lunar visit the astronauts replace the film. Once all the flies from the first part are dead, they will be replaced by 50 fresh females from Earth which will be less than 3 days old.

EXPECTED RESULTS: WE expect good longevity curves which will indicate the combined effects of reduced gravity, different degrees of radiation exposure, and different ambient temperatures. The curves are expected to show that reduced gravity increases longevity , while radiation reduces longevity. The total result represents a complex interaction. Temperature is expected to be seen to have a more complicated effect. Reduced temperature is expected to both decrease the effect of radiation and thus longevity, and to increase longevity directly. When the temperature is raised above 25°C the inverse is expected.

Controls for this experiment we assume to have been or will be run on Earth and in near-earth orbit. We suggest that small centrifuges be used in a similar experiment within our mounds to simulate Earth gravity. This could be done at a latter date.

If eggs of the same developmental stage are needed, the first hour harvest is discarded; it contains many eggs which were retained during starvation and which are thus at very variable stages. The eggs laid after the preliminary period are very homogeneous: their real age corresponds to the moment of oviposition, as shown by the unimodal and narrow-shaped eclosion curve in figure 2, which describes the hatching of larvae from 100 eggs collected during 20 minutes after a preliminary period of one hour (Urbana wild stock).

Our system seems to be very simple and rapid: forty bottles can be handled within 10 minutes without difficulty, and twenty thousand eggs of the same age can easily be obtained from young flies during half an hour following the preliminary first hour.

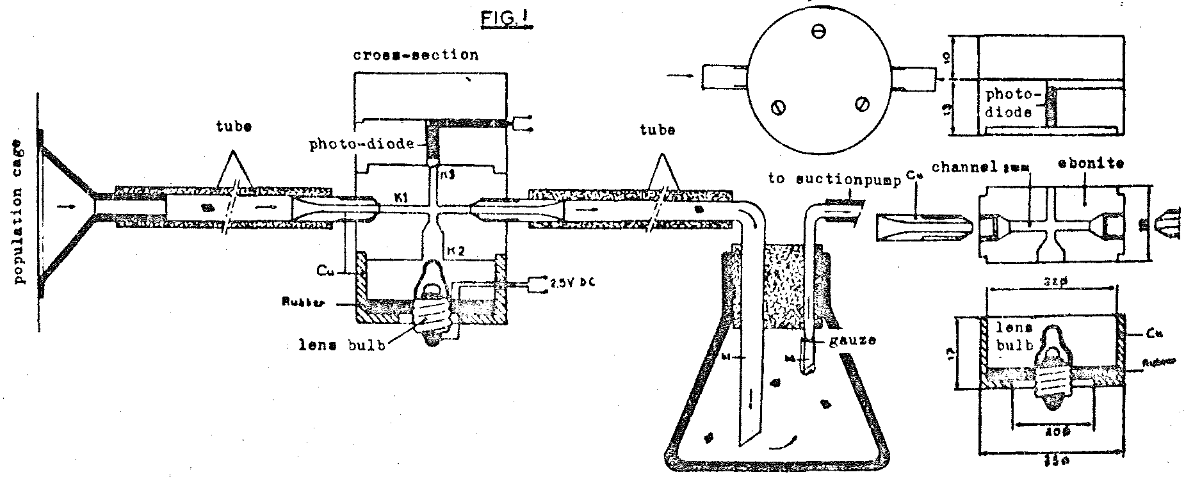
*100 cc water, 3 g agar-agar, 2.5 cc ethylic alcohol, 1.5 cc acetic acid.

Cuperus, P., J. A. Beardmore and W. van Delden. Central Electronics Service and Genetics Institute, University of Groningen, Haren (Gr.), The Netherlands. An electronic fly-counter.

The size of cage populations of Drosophila melanogaster can easily be determined, without etherizing the flies, with the aid of the electronic fly-counter described below. The flies are sucked out of the cage by means of a suction pump, pass through a counting head and are then stored in a bottle. To prevent flies from entering the pump, the opening of the tube from the bottle to the pump is covered with fine gauze.

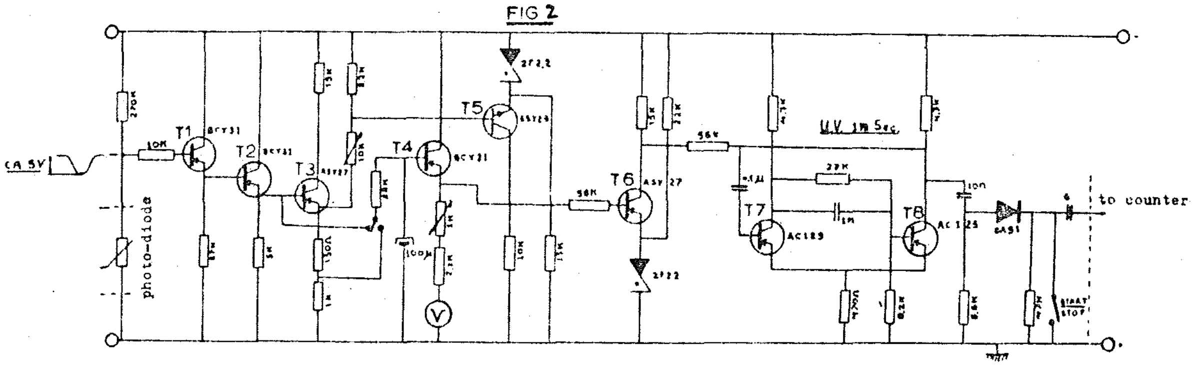
The counting head (figure 1) possesses two perpendicular intersecting channels; the flies are carried through channel $k_1$ with a tapered entrance leading to a straight section with a diameter of 2 mm*. The other channel ($k_2k_3$) is the counting channel and has a lens bulb L (2.2 V - 0.25 A, Philips) fed by D.C. at the end of $k_2$. A photodiode (Philips OAP-12) is fitted opposite to L at the end of $k_3$. The flies moving through $k_1$ interrupt part of the beam of light falling on the photodiode.

FIG. I




In the amplifier-discriminator and pulse-shaper, (fig. 2), the photodiode is connected in series with a resistance of 270 k σ connected to the -15 V. supply. The flies moving through $k_1$ cause a negative impulse of about 5 V over the photodiode. The pulse width depends on the velocity of the fly. These impulses are fed to $T_3$ via two emittor followers $T_1$ and $T_2$. The emittor voltage of $T_3$ can be adjusted from 1.5 V to about 5 V by means of the 10 k σ adjustable resistance. This ensures that the impulse to $T_3$ causes an impulse by the transistor only if it reaches a critical value. The adjustment must be such that only whole flies are counted and smaller parts cannot cause a current impulse by $T_3$. The $T_3$ base and emittor voltages can be measured by means of transistor $T_4$ and voltmeter V. The voltage impulses, which are developed across the collector resistance $T_3$ are fed to the saturated amplifier which consists of $T_5$ and $T_6$. The output of this amplifier steers a univibrator ($T_7$ and $T_8$), with a 1 msec. metastable condition. This time span is longer than the time during which the light beam is interrupted by the flies. The univibrator is coupled to a conventional counter, which registers the number of flies passing.

FIG 2




By means of this fly-counter a population of many thousands of flies can be counted within ten minutes with an error < 0.5%.

*This measurement would need to be correspondingly altered for species appreciably larger or smaller than D. melanogaster.

## TEACHING NOTES

Moree, Ray and Donald T. Grahn. Washington State University, Pullman, Washington. Demonstration of intra- and inter-chromosomal effects of inversions on crossing over.

The following experiment must be in use in many teaching laboratories, yet I do not recall any mention of it during conversation. It may therefore be worth a note since it adds an interesting contrast to the types of experiments traditionally in use. Using the stocks y w, In(1)y,In(1)w (see DIS 35:7), Cy/Pm;D/Sb, and any wild type stock, $F_1$ females of the following four types are produced: (1) y w/++;+/+;+/+ (2) In(1)y,In(1)w/++;+/+;+/+, (3) y w/++; Cy/+;D/+, and (4) In(1)y,In(1)w/++;Cy/+;D/+. These females are then crossed to y w males. As carried out by the class the crosses have given, respectively, the following percentages of crossing-over between y and w: 1.5, 0.3, 8.1, and 2.4. Some students often fail to identify D in selecting $F_1$ females, so the maximum enhancing effect is probably greater than that obtained. Results are clear cut and can be appreciated without resort to a statistical test. The experiments are easily performed and yet introduce an aspect of genetics quite novel to beginning students. That no satisfactory explanation exists for the increase in crossing-over is disappointing to some students but intriguing to others.

II TITLE: THE EFFECT OF 1/6 EARTH GRAVITY, DIFFERENT RADIATION EXPOSURES, AND DIFFERENT
ON
AMBIENT TEMPERATURES ON HATCHABILITY, LARVAL, PUPAL, AND EARLY ADULT VIABILITY, AND ON ADULT MUTATIONS

HYPOTHESIS: Hatchability, as well as larval, pupal, and early adult viability, as well as adult mutation rates are effected by reduced gravity, radiation, and ambient temperature.

EXPERIMENTAL DESIGN: 8 normal males and 4 normal females are placed in the mound early on the first day spent on the moon. This is done at all three levels of the mound and for the 20°C, 25°C, and 37°C compartments. On the third day before leaving the moon the bottles are removed for a short period and 50 eggs removed and placed in bottles ~~xxxxxx~~ prepared in the way described by R.H. Richardson in the include article. The bottles of eggs are then placed in the mound where they were removed ~~fsom~~ from earlier. Photograph are to be taken once daily to monitor hatchability and viability. Since the eggs take a day to hatch, the larval stages 4 days, and the pupal 4 days for a total of 9 days, and since they will have developed for ~~around~~ ABOUT 1 day before the astronauts leave, they will emerge as adults 8 days after the astronauts leave. Thus they will have been adults for 4-5 days when the astronauts again return. These figures will be slightly changed due to the extreme conditions, but any changes will not greatly effect the experiment. On returning they will remove the film for processing on earth and check the bottles for unhatched eggs, dead larvae, dead pupae, and dead adults to supplement the photographs. They will also check for mutants in the dead and surviving adults, and prepare for the next phase of the experiment. From the adults they find normal they will choose 8 males and 4 females and follow the same procedure used ~~xx~~ during the first experimental period. (NOTE: it is important to keep all flies from the different levels and different temperatures seperate and have them returned to where they were removed.) This will be done for each of the remaining ~~XXXX~~ 2 and 1/2 day~~xx~~ experimental periods.

EXPECTED RESULTS: Data will have been collected from 11 generations of flies on the hatchability of eggs, viability of larvae, pupae, and young adults(4-5 days).. Data will have also been collected on the percentage of mutants in each ~~xxxxxxxxx~~ succeeding generation resulting from apparently normal adults. The cumulative effect is also expected to reduce viability in general. Results are expected to show that 1/6 earth gravity has adverse effects on developing organisms, and these effects are compounded by radiation. The combined result representing a complex interaction. Data is ~~xxxx~~ also expected to show that temperature plays a complicated role in which lowering the temperature reduces the effects of radiation, but raising or lowering the temperature much above or below 25°C is also expected to have adverse effects of its own.

Drosophila Information Service

41 Jan. 1966



If the distance between well centers is made 8 mm and the well diameter 4 mm, the reactants may be delivered in 3 doses of 0.01 ml at approximately 2-hour intervals. If the well geometry is increased to 10 or 13 mm to allow for a well diameter of 6 mm, the complete 0.03 ml of reactants may be delivered at one time.

When precipitation is complete the slide is washed in tap water to remove excess protein from the wells. Unprecipitated protein is eluted by soaking the slide in buffered saline for 24 hours, followed by 2 rinses of 1/2 hour each in distilled water. Slides are stained for 20-30 minutes in Crowle's triple stain (Immunodiffusion, 1961, Academic Press) or in dilute water-soluble nigrosin, destained in 1% acetic acid, and air dried to a film. The finished slide may be used directly in the photographic enlarger to prepare prints, and is in itself a convenient permanent record of the test.

Richardson, R. H. University of Texas. An improved technique for fecundity and hatchability tests.

A new technique of collecting eggs for fecundity or hatchability tests has been devised, which has the following advantages: homeogeneous egg laying surface resulting in uniform egg distribution, rapidly and easily dispensed medium, medium lacking extraneous food components (such as charcoal), transparent medium allowing scoring of burrowing larvae, and easily cleaned and reused equipment.

The medium consists of 1 g. Bacto-agar, 100 ml. water and 15 ml. white Karo syrup, which is dispensed with an automatic syringe while hot. This medium is then sprayed with a water suspension of bakers yeast immediately before use.

The equipment consists of two variations on the same theme. One variation supplies a black background to facilitate counting. The other presents a transparent background, which allows visual examination of eggs without the removal of the cap from the test bottle.

The test bottles are constructed from 40 dram Plastainer bottles (ca. 2" x 3 1/4") available from Owens-Illinois Glass Co., Toledo, Ohio, at a cost of about $5 per carton (6 dozen). Extra caps are available at about $20 per thousand. The screw caps are made of Teflon and the bottle of clear plastic. A hole is punched in the cap top with a die about 1 1/4" in diameter, and then a piece of plexiglass 1/16" thick is glued to the outer surface of the cap over the hole. The plexiglass may be either black or transparent, giving the two varieties of background. A critical factor in construction is the cement for glueing the cap and the plexiglass. The most satisfactory one tried was Eastman 910 adhesive, available from the Tennessee Eastman Company, Kingsport, Tennessee, at a cost of $8 per bottle. One bottle is sufficient to glue about 400 caps. Also the surface of the cap must be roughened with hardware cloth or a file before glueing. The glue is spread in a very thin band completely around the hole in order to get a water-tight seal. Leaks may be sealed with a band of Duco cement around the external cap-plexiglass junction.

Counting is easily accomplished by marking the agar surface into regions with a blunt needle under about 40X magnification or less. Eggs or larvae may be conveniently transferred to food bottles by transferring agar and eggs or larvae with a small spatula (eg., No. 19240, Curtin Cat. 40) bent at a convenient angle to work inside the cap. Larvae may crawl off the agar surface, but for caps changed every 24 hours or so, it is not a serious problem. Empty egg cases are easily distinguished from unhatched eggs.

An additional advantage of this technique is the practicality of a permanent photographic record of the egg production or hatchability, especially since the eggs are well spread over the surface. The quickest technique using the transparent plexiglass caps in a "contact print" of the cap on photographic paper (available in bulk rolls about 4 1/4" wide) where the shadow of the egg is recorded. Enlargement prints are possible by placing the cap in the film plane of a darkroom enlarger. More detailed records may be made by microfilming the black plexiglass caps with a 35 mm. camera. Examination of the negative either in a microfilm reader or under a dissecting scope allows easy egg counts, hatch scores, or even some egg development scores. It appears counts could even be made by visual scanners in use by automatic data processing systems.

## EXPERIMENTS WITH NEUROSPORA

The purpose of this experiment is to study the effects of reduced gravity and radiation on the growth, development, and genetic characteristics of plants. Radiation-protecting chemicals and their interactions with the above factors are to be examined. Biosatellite II employed *Tradescantia* in radiation studies as its blue petals turn pink when irradiated. Because of the life support conditions required by this plant, *Neurospora*, a fungi, was substituted for this part of the experiment.

*Neurospora* has long been used in genetic studies relating mutations to enzyme function. Data of a wide variety is available for this organism making data evaluation somewhat easier.

## PROCEDURE

The general procedure of this experiment includes growing a culture of *Neurospora* on a maximal medium containing all nutrients necessary for growth and metabolism. After exposure to a mutagenic agent, the *Neurospora* is inoculated into minimal medium cultures of varying types. These cultures lack all or most all of the amino acids required by *Neurospora*. In this manner, it is possible to determine specific mutations and the percentage of mutations.

Before conducting this experiment in the lunar laboratory it will be necessary to determine the concentrations of the radiation-protecting chemicals tolerable to the organism. After the concentration levels have been determined, the experiment is ready for the lunar laboratory.

### Specific Procedures

A total of twelve experiments are to be run using six drugs and controls. The only difference between the medium used in the drug and control experiments is the addition of a pre-determined amount of drug.

SCHEDULE OF EXPERIMENTS

| Experiment Number | Drug | Drug Number |
|---|---|---|
| 1 | Cystamine dichlorhydrate | 1 |
| 2 | Dihydrobromide amino-ethyl-isotiuronium (AET) | 2 |
| 3 | Serotonicreatin-sulfate | 3 |
| 4 | 5-methoxytryptamine chlorhydrate | 4 |
| 5 | Tryptamine chlorhydrate | 5 |
| 6 | 5-oxytryptophan | 6 |
| 7 | Cystamine dichlorhydrate | 1 |
| 8 | Dihydrobromide amino-ethyl-isotiuronium (AET) | 2 |
| 9 | Serotonicreatin-sulfate | 3 |
| 10 | 5-methoxytryptamine chlorhydrate | 4 |
| 11 | Tryptamine chlorhydrate | 5 |
| 12 | 5-oxytryptophan | 6 |

Microconidia, instead of macroconidia, are to be used becuase of their longer incubation period. One drop of microconidial suspension pe, fl strain (Y8743m,L) (FGSC#867) Baylis & De Busk, 1965, is used to inoculate two Erlenmeyer flasks, 125 ml, containing 40 ml of complete medium (1l. of 1x Vogel's medium containing 20 g. sucrose, 1 g. yeast extract, 1. g. malt extract, 0.1 g. liver extract, and 2% w/v agar) Baylis & De Busk, 1965. To retard any bacterial growth, 500 ug. of chloramphenicol per milliter of medium. One flask is labelled control with the experiment. To the other flask is added the drug to be tested and this flask is labelled with the drug number and the experiment number.

These cultures are to be grown in the same areas of the moon lab as th e *E. coli* and *Drosophila*. The temperature is to be maintained at 20°C. to insure the incubation period of 15 days. The atmosphere is also to be maintained at a constant value. Controls are to be run on earth with the same temperature and atmosphere so that comparisons can be made. The varying mutation rates will be due to the combined effects of reduced gravity, radiation, drugs, and lunar shielding.

During the 2½ day visitation to the moon lab, the astronaut is to remove the cultures and replace them with new cultures from supplies aboard the moon lab. The schedule of experiments provided is to be followed.

In the orbiting moon lab the astronaut is to analyze the cultures. The microconidia are collected by adding 25 ml ofwater to each flask and shaking for 15 minutes by either hand or rotary shaker. The suspension is poured from the flask and filtered through cheesecloth and glass wool to remove mucelia and clumps of conidia. The viability should run from 10% - 20% on minimal medium (1 l. of Vogel's 1x, 0.5 g. fructose, 0.5 g. glucose, 20 g. sorbose, 2% w/v agar) Baylis & De Busk, 1965.

Vogel's Minimum Medium N - 50 x Stock Solution

| | |
|---|---|
| $Na_3$ citrate • $2H_2O$ | 125 g. |
| $KH_2PO_4$ anhyd. | 250 g. |
| $NH_4NO_3$ anhyd. | 100 g. |
| $MgSO_4$ • $7H_2O$ | 10 g. |
| $CaCl_2$ • $2H_2O$ | 5 g. |
| Biotin solution (0.1 mg/ml) | 2.5 ml. |
| Trace elements solution | 5 ml. |

Trace Elements Solution

| | |
|---|---|
| Distilled water | 95 ml. |
| Citric acid • $1H_2O$ | 5 g. |
| $ZnSO_4$ • $7H_2O$ | 5 g. |
| $Fe(NH_4)_2(SO_4)_2$ • $6H_2O$ | 1 g. |
| $CuSO_4$ • $5H_2O$ | 0.25 g. |
| $MnSO_4$ • $1H_2O$ | 0.05 g. |
| $H_3BO_3$ | 0.05 g. |
| $Na_2MoO_4$ • $2H_2O$ | 0.05 g. |

Taken from
Neuorspora Newsletter, Number 10, December 1966, p. 34.

Moon lab--Bacteria experiment

The opportunity to return to the moon at monthly or bi-monthly inter
intervals offers a unique opportunity to perform some ~~beautiful~~ UNIQUE experiments on E. Coli. The first few times that the astronaut sets foot on the moon he can set the way for subsequent experiments and in the later experiements he can use the results of the previous experiments to plan more extensive studies.
Bacteria offer ~~the~~ an advantage in experimentation in space for a number of reasons including their small size allowing great numbers to be transported, their short generation time, the small amount of material necessary for life support, the ease off experimentation with them.

The astronaut will return to the moon base every two weeks during a six month period and he will stay at the base or near it for a period of five days EACH MONTH. He will return every two weeks because along with his duties concerning the bacteria experime nt, he will also have to perform other experiments, and specifically, as we are suggesting, take care of the Drosophila which will be located at the moon base. The Drosophila will probably need attention every two weeks or so. The experiments with the E. coli will be done while the astronaut is on the moon. They will not be performed during the period he is away. Bacteria multiply very rapidly and their cultures would stagnate if someone were not there to provide them with fresh nutrients. Beside, the short generation time of the bacteria will make it possible to study many generations of the organism in the ~~five~~ 2 1/2 day period when the astronaut is at the base. The experiment will be done during his ~~five day~~ stay but the data may be analyzed while he is on his way to earth or in a lunar orbiting laboratory.

Purpose:

The problem we propose to investigate is what are the effects of reduced gravity on the reproduction rate and mutation rate of a microorganism, what are the effects of constant ~~gxxxxx~~ high levels of radiation on the organism, how do~~xx~~ different temperatures ~~affxxxx~~ modify the effects of the reduced gravity and high radiation, what amount of lunar material is adequate to shield the organisms from the high levels of radiation. Each experiment will be relatively easy to perform and this will permit the results of early experiments to be applied to later experiments.

Hypotheses:

Earlier biosatellite missions showed that the weightless state affected the generation time of E. coli and that the mutation rate was changed in the weightless state. Much the same results are expected in this experiment. Because of reduced downward acceleration, the bacteria should be able to metabolize more quickly, excrete wastes more quickly, synthesis new genetic material more quickly, and have a reduced generation time. In addition, the different lunar temperatures we plan to subject the organism to should modify these ~~xxxxxxxxxxxxxx~~ generation times. The high flux of radiation normally encountered on the lunar surface will probably be lethal to most of the organisms, but with adequate shielding, this hazard can probably be reduced.

Materials:

In the first few experiments we will be concerned with those bacteria that can grow on a minimal medium (water, buffers, glucose) This can be provided in either liquid medium in an Erlenmeyer flask or in agar. The agar will be handy for the weightless state but it would be advantageous to use liquid on the moon because one of the proposed experiments will be a turbidity experiment. In addition tb the mutrients ~~will~~ which can be stored in a powdered form before dissoving in water, petri dishes (plastic) will be used. Plastic petri dishes are very light and small. Instead of Erlenmeyer flasks, plastic bags could probabby be used. This would save space and weight on the journey to the moon. In addition, ~~felt~~ pdeces of felt will be used to assay the bacteria by way of the "replica plating technique"commonly used in bacterial experiments on earth. Thus, the supplies are simple and will not occupy more than a few cubic feet of cabin space. The bacteria will be transported on aggar plates to the moon lab and them transplanted to liquid medium. Life support will consist of shielding from radiation pwovided by lunar material in the shape of a cone piled a few feet high on the lunar surface. Temperature control will be provided and the chambers which will be used to house the Drosophila experiemtns will be used for this experiment too.

Experimental procedure:

There will be about twelve opportunities to perform ~~five~~ 2½ days experiments on the lunar surface during the six month period. The first one will be spent(as described in another part of this report) taking experimental data (radiation counts, temperature, etc) from inside an experimental mound of earth similar to the one which will be used for the biological parts of the experiment. The information can be telemetered back to the orbiting lunar laboratory or to experimenters on earth who can use the information to plan for the next phase of the experiment.

The bacteria will be cultured on the lunar orbiter and those which have not undergone mutations will be used in the early experiments. (wild type). These are easy to find because the mutants will not be able to grow on minimal agar medium. When the astronaut arrives on the moon base, he will again sort out the bacteria to make sure the ones he is using are wild type. The first set of experiments he does will be concerned solely with generation time. This can be found by using a light scattering technique and reading the turbidity of the solution as a function of time. Since the turbidity is directly proortional to the population in the solution, if the initial concentration is known, then the concentration at any subsequent time can be determined. From this information, it is a simple matter to determine the generation time. This experiment will be done at 37°C., 30°C., and 25°C. Assay of the orginial amount of bacteria present will be done on agar plates. The experiment is very easy and can be performed easily within a few hours. The experimenter will perform the experiment at the three temperatures indicated at each of the three levels in the mound.( see description of experimental setup.) He should do the experiment twice so that the prodedure will be followed 18 times. This should not be any problem and may take a total of eight hours during the ~~five~~ 2½ days that he is there. If the experimenter runs into any problems, the exxperiment can be repeated easily. In addition he will also have time to perform specific tasks concerning the Drosophila cultures. Meanwhile, on earth & in the moon orbiter a a set of control experiments will be performed.

The next time the astronaut goes to the moon, he will perform experiments which will use both liquid media and agar plates. This time he will be concerned with the mutation rate in E. coli which can be expected on the moon's surface with different shielding provided. The procedure will be similar to the one of Luria&Delbruck and subsequent experimenters. From cultures of known concentration, plates on agar will be made and the number of mutations will be counted(the plates will be minimal agar and the mutants will not clone). This experiment will allow the determination of the rate of mutation for <u>any</u> type of mutation. We will not be looking forx specific mutations yet.

The replica plates for this and subsequent experiments will have to be shielded from the radiation ~~will~~ while assays are being performed as well as possible. The bottom of the mound will be an appropriate place and if this is not convenient, the plates can be taken back into the living quarters of the astronaut so they will be shielded from the radiation as wellx as possible.

The next time the astronaut goes to the moon he will be using lysogenic bacteria. These bacteria have viral DNA integrated in their own DNA and radiation can be used to cause these bacteria to liberate this viral DNA. When this occurs, the bacteria lyse and virus pariticles are released. The effect of reduced gravity and constant radiation at different temperatures can be studied. The procedure will follow much the same pattern as before. Unmutated ~~mix~~ lysogenic bacteria will be utilized and the rate of ~~the~~ lysis will be studied.

In subsequent 2½ day periods, specific mutations can be studied utilyzing much the same techniques which are useful on the earth. Information about radiations effect on the replication ~~and~~ of the genetic material can be easily obtained.

Conclusion:

The small amount of space necessary for bacterial experiments and the ease of performing the experi ments make them ideals for a lunar mission. The effects of radiation, differing temperatures, and reduced gravity can be easily studied by an experimenter who will have 2½ days every two weeks to experiment.

# THE

# MARS

# MISSION

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# PROPOSED MARS MISSION - Psychological aspects

## Stress and Emergency Conditions

### Fatigue

Although of only relatively minor significance in short duration space flights, fatigue could become a major problem in long term flights. Such factors as the disruption of the circadian rhythm, the mental stress of high performance requirements, the need to perform monotonous tasks, personality, and others all interact to produce the complex phenomenon known as fatigue. The need to minimize, if not eliminate, fatigue is necessary for the success of the mission, since fatigue, boredom, and lowered morale are all interdependent and will determine to a large extent the mission's success.

There are several ways to approach the problem. First and probably most important are the methods of selection and training of the astronauts. The selection screening should look for not only physically fit individuals with high physiological reserves[1], but also psychologically and sociologically well-adjusted people. The latter become very important here since mental attitude and motivation determine largely the amount of fatigue the astronaut experiences.

A second way to attack the problem is to put GSR and EEG leads on the astronauts with monitors both in the

[1] See Borisov's Life in Space, Aug., 1964, p. 235 for further detaisl.

spacecraft and back at mission control. By looking at the data from these, especially the former, the astronaut himself and/or mission control could tell when he is fatigued and devise activies to combat it. The reliability of the EEG and GSR data are at present limited but will probably be perfected by the time such a flight occurs. However, it should be remembered that this technique measures only the state of arousal of the individual and not fatigue directly.[2] For this reason it is of only secondary importance.

Finally, the astronauts' environvent must be strictly controlled to prevent fatigue. The physical, as well as psychological, surroundings must be such[3] as to eliminate (or at least minimize) the fatigue-enhanceing factors of hypoxia, confinement, isolation, and boredom. For instance, Frequent voice contact with mission control should be maintained in order to maintain high morale as well as to provide information.

To review, the problem of fatigue on a long duration space flight, although serious, can be minimized by carefully selecting and training the astronauts before flight and constantly evaluating by both voice communication and telemetered GSR in flight their physical and psychological (as well as possible) states.

[2] Techniques of Physiological Monitoring, Vol. 1, Sept. 1962, pp. 71-72.

[3] To provide for a healthy social and psychological, as well as physiological, climate, women should perhaps be included in the crew.

PSYCHOLOGICAL TESTS

A Mars flyby mission will require the selection of an exceptional group of men. The intensity of the various stresses presented to them during flight will be considerably heightened by the 500 plus days they will be required to spend in the space environment. It is the realization of this fact which calls upon us to require that extremely demanding standards be met by those who would participate in such an endeavor.

With some variation, we expect the average individual chosen to be between the ages of 25 and 38, to be in excellent physical condition, to have completed at least a bachelor's degree in a biologial or physical science or in engineering.

On the basis of the potential stability offered to the individual we would expect a good number of the most acceptable candidates to be married. We will not require any specific alignment of the crew structure on the basis of past or present military affiliation, feeling this to possess negligible importance for crew cohesion and morale.

The necessity of selecting "men for the job" will make it necessaty to add to the list of basic requirements, special training and/or educational requirements which will suit the men for their projected tasks. In essence we will ne d to select a group of experts capable of performing adequately in several dissimilar disciplinary contexts. The need for extensive cross training has therefore been introduced.

The crew size has been set at six. We believe that larger crews will occur only when large construction or full scale technical programs are conducted, and that exploratory programs will invariably involve smaller crews. The composition of the crew is as follows:

1 Command Pilot - Engineer
1 Vice Command Pilot - Astronomer
1 Physician - Engineer
1 Exobiologist - Physician
1 Astrophysicist- Pilot
1 Geophysicist - Pilot

An extensive amount of cross training is obvious. The benefit of this comes in the possibility for accomplishment of missions of a more comprehensive and scientifically valid nature in addition to extensive back-up capabilities in case of an accident or unforseen debilitating experience.

Like all previous manned space flight selection teams, our Mars Mission team must select men or, maybe more appropriately, a crew which is composed of men extremely likely to complete the mission and do it without physical or mental impairment.

As a help in evaluation of a candidate's ability to cope with the problems of extended space flight, the selection team should avail itself of information from intensive physical and psychological inquiries , and from the medical history of the individual. Laboratory tests and performance studies under stressful and non-stressful conditions will be used in the physical evaluation of the subject, while extensive psychological testing and interview procedures must be utilized to give a reasonable evaluation in that area.

Use of the word "evaluation" must not lead one to the conception of a certain separateness in the physical and psychological areas of concern.

Evaluation in most areas are considered as parts of the overall medical evaluation.

We will now concern ourselves with the psychological portion of the selection program. The purpose of this is to assess the merit of the candidate in terms of those psychological characteristics which are considered most importdat for adaptability to space flight. This requires that the examiners understand the job requirements for space missions, that they formulate the psychological characteristics which would seemingly contribute most to effective job performance, and that the candidates be assessed for those characteristics.

The personality areas that are deemed most important to the mission's success, and therefore the ones which are of special interest to us, can be catagorized as follows:

1. General emotional stability: absence of neurotic or psychotic symptoms, and freedom from problems in the social, marital or financial spheres; ability to tolerate stress and frustration without significant emotional symptomatology or impaired performance.

2. High motivation and energy level: demonstrated ability to pursue realistic and mature goals with determination and initiative; capacity to think in a creative and flexible manner when unforseen events occur.

3. Adequate self-concept: strong confidence in self and capacity to give opinions and make independent decisions without overconcern; at the same time, ability to depend on judgement of others when the missions warrents.

4. Interpersonal relationships: ability to form satisfactory and productive relationships with supervisors, peers, and subordinates, but not be overly dependent on people for satisfaction; capacity to function as a team member in any role.

To uncover data which would bear productively on these general cateories of the evaluation framework, an extensive psychiatric and psychological evaluation of each candidate is made. Each applicant is assessed by a variety of the interviews and test procedures given by several examiners. The assessment program consists of:

1. Psychiatric interviews
2. Clinical Psychological testing
3. Performance stress testing

During the psychiatric evaluation each evaluee is interviewed by two psychiatrists. The first interview which is two hours in length; the second, one hour in length, is the final procedure in the psychiatric and psychological assessment. A psychiatrist also observes the subject's performance during the performance test to be described later. Although the interviews are nondirective, each examiner attempts to assess certain areas which have been agreed upon. These areas include:

1. Review of flying career and experiences: the subject's original and current motivation; his adaptability during training; major goals and reasons for changes; evidence of outstanding or ineffective performance; reaction to frustrating experiences; the quality of his relationships with co-workers and supervisors; and his reaction to competition and failure.

2. Motivation for space flight: the subject's expectations; realistic vs. unrealistic, the quality and quantity of motivation; his current job satisfactions; and his alternate goals.

3. Marital history: the subject's marital adjustment; his wife's attitude toward his job; his current situational problems; the family's adaptability to past transfers and separations; causes for marital

discord, and response to them.

4. Developmental history: the subject's early relationship with parents and siblings; causes of intrafamily tensions and applicant's response or participation; his early education history; his academic achievements; his social and sexual adjustment during and after adolescence; and his avocational interests.

5. Psychiatric history: hospitalization or consultations; symptom review; and use of alcohol.

6. Current situation: the family relationships of the subject; his social and recreational interests; and his interpersonal relationships.

general psych. criteria for any job

One aim of these interviews is to screen out any individuals with personal or interpersonal adjustment difficulties which interfere significantly with performance. Beyond this, an attempt is make to assess the intellectual and personality characteristics whcih would affect the applicant's over all adaptability and effectiveness in a space program.

Each psychiatrist tries to subjectively evaluate the personality characteristics of each candidate in terms of the job requirements which had been formulated. Less weight is given to emotional conflicts which seem unrelated to job performance and effectiveness. Emotional conflicts whcih are only partially resolved, and are considered to represent areas of emotional vulnerability even though overt behavior is well-controlled, might cause an applicant to be recommended with reservation. In addition, the influence that intrafamily problems of any nature might be expected to have on participation in a program is considered, even though the problems may not be related to the applicant's personality or emotional stability.

An attempt is also made to identify positive attributes which indicate a capacity for unusually effective behavior and performance. One of the most important of these is the ability to perform despite physical and psychological stress. In addition, high motivation and and persistence are considered important for a program which will be highly technical and intellectually demanding. High energy level, aggressive pursuit of job oriented goals, and an enthusiastic approach to work in geneeal is also regarded as highly desirable, as is the ability to work smoothly and cooperatively with others.

Each psychiatrist objectively rates a number of personality variables. Definitions of each of the variables are developed, and used as a guide by all of the psychiatrists.It is desirable to make some systematic descriptive statements about the candidates in this manner.

A six point rating is used. Each scale is positioned on the form so that the hypothetical optimal quantity of each characteristic will yield a straight line; that is, the most adaptive individual would have ratings which form a straight line on the rating form. The first group consists of certain conceptualized drives or motivations which are reflected in interpersonal behavior. The second group of variables reflects the individual's self-system andffeelings about himself. The third group includes his accustomed defense mechanisms; It is here that unconscious factors which affect behavior are reflected in the ratings. These variables are as follows:

1. Needs: affiliation; dependency; dominance; sexuality; hostility.
2. Ego system: self-concept; emotional control; adequacy.
3. Ego defenses against: dependency; sexuality; hostility; lowered self-esteem
4. Pathologic defenses: anxiety; somatization; depression; symbolisation; regression; and behavior deviations.

A job oriented rating is made of factors which are considered to be particularly important to the specific characteristics of the job. The following items are rated: Motivation, Independence-assertiveness, Interpersonal relationships, Emotional stability, Absence of neurotic symptoms, Personal affairs, and Past achievement. The final evaluation is based upon clinical information obtained during the interview.

These ratings are of some value in helping the examiners to consider the applicant's major personality attributes in a systematic manner. Their primary usefulness will be in a later comparison of the individual's performance in a space program with an objective description of personality variables.

Clinical Psychological Tests:

1. Wechsler Adult Intelligence Scale is an individually administered measure of intelligence, consisting of eleven separate Verbal and Performance sub-tests; a well standardized instrument commonly used in clinical evaluation of flying personnel. It provides measurement of a broad spectrum of behavior and adequate though not outstanding discrimination at the upper ranges of intelligence.

2. Miller Analogies Test is a timed group test correlating highly with general intelligence and verbal achievement measures. This test consists of 100 multiple choice paired analogies. It is a well standardized test with comparable norms available, permitting differentiation for verbal abilities at a very high level.

3. Doppelt Mathematical Reasoning Test is a timed group test consisting of 50 multiple choice problems requiring the identification of complex mathematical principles. It is another well standardized instrument whose published norms enable high level differentiation.

4. Minnesota Engineering Analogies Test is a 50 item high level objective measure of specific engineering knowledge, combining features of

an abstract reasoning test with those of engineering achievement. Excellent standardization allows for good separation among candidates at high levels.

2 personality tests 5. Rorschach Inkblot Test is a projective test consisting of ten ambiguous inkblots of various shades and colors to which the subject is asked to respond in an unstructured manner. It is the oldest and perhaps most stable of all the projective multi-dimensional tests. Though re research findings about this measure are equivocal, its multi-faceted contribution to the assessment profile plus the considerable experience of the evaluation team using this instrument with comparable populations resulted in its inclusion.

6. Thematic Apperception Test is a projective test consisting of a series of pictures depicting ambiguous, usually interpersonal situations about which the subject is unstructed to make up a story. Multi-dimensional analysis is possible. This is the second most widely used personality test and one for which a great deal of comparable data is available.

7. Draw-A-Person Test is a brief projective test. The subject is asked to draw a figure of a person and then one of the opposite sex. From these drawings inferences about self-concept, ego boundaries, and possible conflict areas can be made. While the data from this test are not always contributory to an assessment in each case, the drawings frequently enable significant personality differentiations to be made when other evidence is equivocal.

8. Bender Visual Motor Gestalt Test consists of nine designs, reproduced one at a time by the subject on a plain 8 x 11 piece of paper. Later in the testing the candidate is asded to reproduce the forms from memory. This test has been demonstrated to be useful both as a neurological screening device and as a projective technique.

9. Gordon Personal Profile Test is a self administered personality

inventory consisting of 18 tetrads of descriptive phrases. It provides a quick assessment of five traits: Ascendancy, Responsibility, Emotional Stability, Sociability, and overall Self-evaluation. The main virtues of this test are the small amount of time required for its administration and the availability of comparable Air Force norms.

10. Edwards Personal Preference Schedule is a 247 item personality inventory in which the candidate must choose between two descriptive phrases as being more like himself. The test is then scored for 15 manifest needs, similar to those described by Murray, and a consistency score which is a measure of profile stability. This test has the virtue of focusing on the relative strengths of normal personality variables rather than concentrating on pathology. Comparable Air Force norms are available.

11. The complex behavior simulator performance test is a test in which a complex task is used to simulate the job characteristics of systems operators tasks. It utilizes a Complex Behaviour Simulator in combination with an information-processing task. The information-processing task requires a continuous auditory monitoring and processing of signals by presenting single-letter Morse code signal in random order at a rate of one letter every five seconds. The subject's task is to monitior the different code letters being presented and to signal, by means of a push-button swotch corresponding to each code letter, whenever he has heard a specified number of a particular letter. In this particular application the subject monitored three code letters and reported whenever he had received three of any one of them. Due to the small amount of practice time available, the subjects were given a mnemonic aid for monitoring the signals.

This stress-testing was allocated one hour per subject. The subject received standardized instructions and practice on the task. Practice sessions were carefully monitored to insure adequate performance by the subject with coaching where indicated. Criterion for satisfactory AUDIT performance was 100% signal recognition and five successively correct identifications of randomly sequenced three-signal series.

Performanc̶e on the Complex Behavior Simulator was evaluated in relation to the scores of an "ideal" subject. Measures of profiency (based on response time) and efficiency (based on the number of signals processed) were derived for each subject. On the average, this special group showed a decrease of 23% in efficiency and an increase of 16% in proficiency, values generally like that demonstrated by the "ideal" subject.

In addition, an auditory tracking task is administered in conjunction with the hypoxia procedure during EEG studies. Each candidate breathes an oxygen-nitrogen mixture containing approximately 8% $O_2$ for four minutes. The combination of procedural factors such as nose clamps, a mouth piece, and other attachments, together with the physiologic stress of relative hypoxia produced a situation in which stress-tolerance could be assessed.

The tracking test is administered as follows: Subjects are fitted with an earphone through which was fed a 600 Hz tone varying in intensity in a sinusiodal fashion at the rate of 30 cycles per minute. Their task is to rotate a potentiometer mounted on a bracket placed close to the subject in phase with the signal in order to cancel the variation in signal intensity. Perfect performance produced a barely detectable steady tone.

Average error per cycle for each 30 second period is computed from the error record. The tracking rating record is arrived at subjectively by considering error scores and the apparent extent of physiologic insult, based on the amount of slow wave activity in the EEG record.

A) selection of train crews for extended isolation situations,
B) detection of psychosis in crew members

N. Marilou Okano
Mars Project

# EMERGENCY STRESS CONDITIONS: RAPID DECOMPRESSION

I. Introduction
  A. General responses to physiologically stressing conditions
    1. Sources or causes of the stress
      a. Low pressure
      b. Temperature extremes
      c. Gravitational extremes
      d. Immobilization
      e. Nutritional and fluid lack
      f. Reduced caloric intake
      g. Toxic chemicals
      h. Ionizing radiation
      i. Disruption of Circadian rhythms
      j. Illness
      k. Emotional distress
    2. Possible effects
      a. Increased activity of the sympathetic nervous system
      b. Increased hormone secretion from endocrine glands, especially the adrenal gland
      c. Vascular damage or cardiac irregularities as a result of high blood pressure caused by "a" and "b" above
      d. Gut dysfunction, impaired nutrition, and nausea caused by blood shunt away from viscera
      e. Diseased state from prolonged secretions of adrenal cortex
      f. Reduced resistance to infection
    3. Methods to meet the stress
      a. Maintenance of as normal an environment as possible
      b. Provisions to minimize exposure to the stresses
  B. Emotional distress
    1. Sources or causes of the stress
      a. Isolation
      b. Confinement
      c. Boredom
      d. Overly close and extended contact with shipmates
      e. Sounds of meteorite bombardment
      f. Fear of possible disaster
      g. Necessity of constant performance and responsibility
      h. Fatigue
    2. Possible effects
      a. Irritability
      b. Delusions
      c. Poor performance
      d. Irrational behavior
    3. Methods to meet the stress
      a. Performance tasks to relieve boredom
      b. Close radio contact with ground station and reassuring patter
      c. Occasional privacy and free movement
      d. Recreational material
      e. Proper advanced training in space travel simulation

II. Rapid decompression as an imprtotant emergency stress condition

A. Sources or causes of rapid decompression
  1. Accident or meteor puncture of spacecraft
  2. Improper gaseous composition of the atmosphere
  3. Sudden increase in rate of decompression
  4. Vacuum in space

B. Possible effects
  1. Bends due to partial pressure of inert gases (especially nitrogen)
  2. Joint pains
  3. Earache due to compensated air pressure in middle ear acting on drum
  4. Parathesias
  5. Skin changes
  6. Paralysis
  7. Convulsions
  8. Ineffective coughing
  9. Visual distrubances
  10. Coma
  11. Abdominal pain due to uncompensated pressures of intestinal gases
  12. Dessication or boiling of body tissues at sufficiently low pressures due to uncompensated vapor pressure of water
  13. Atelectasis
  14. Hypoxia
    a. Sleepiness
    b. Headache
    c. Lassitude
    d. Altered respir-tory activity
    e. Increased heart rate
    f. Impairment of thought processes
    g. Inability to perform simple tasks
    h. Eventual loss of consciousness

C. Methods to meet the stress
  1. Pressure suits and pressurized cabin
  2. Self-sealing material lining cabin walls to meet meteor puncture
  3. Maintenance of normal oxygen partial pressure (about 180 mm Hg, minimum)
  design
  4. Avoidance of large amounts of nitrogen
  5. Only gradual press re changes when leaving or entering a chamber
  6. Provision of emergency oxygen supplies in case of accident
  selection 7. Acclimation of astronauts to low oxygen tension by chronic exposure

D. Decompression sickness and environmental factors
  1. Temperature
  2. Gaseous composition of atmosphere
  3. Rate of decompression
  4. Pressure change
  5. Duration of exposure to reduced pressure

E. Decompression sickness and personal factors of astronauts

selder
1. Age
2. Individual susceptibility
3. Activity
4. Physical condition
5. Past injuries

F. Theory of decompression sickness
   1. Result of nitrogen dissolved in the body fluids and tissues coming out of solution and forming bubbles under conditions of reduced atmospheric pressure
   2. Also, possible result of bubbles of carbon dioxide, oxygen, helium, water vapor, etc.

III. Summary and Conclusion
   A. Most outastanding effects of rapid decompression: physiological effects
   B. Psychological effects of rapid decompression: fear and panic

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LONG TERM CONFINEMENT AND THE MARS MISSION

Confinement in the space vehicle for a period of one to two years has been foreseen as a source of concern in the planning of the Mars mission. In order to establish a picture of what may happen during this long term confinement, one may make a literature search for acoounts of similar experiences of confinement particularly the accounts of submarine life, isolation at the polar ice stations, and accounts of sailing. In general the behavior pattern of a group experiencing such confinement, particularly in a stress situation (such as a shipwreck) involves the formation of the group, inhibition of hostility or at least displacement of hostility, a mid-term depression and high attachment to social role. There is an increased sensitivity to minute stimuli. This may develop to the point that the person enters a paranoid state in which he feels his friend is trying to poison him or kill him in his sleep. One can not tolerate the clearing of throats, coughing, or any other now "irritating" sounds. Toward the end of confinement the members of the group can show greater hostility and show more activity and release their aggressive tendenci s (adolescent behavior). To cover the psychological points more specifically, there is a limitation of mobility, a monotonous environment, prolonged commitment to an exacting task all causing psychological stresses in addition to the interpersonal stresses. Interpersonal strife may lead to the development of resentments and a lowering of morale, an increase in errors of operation and incidences of poor judgment.

Although the confinement anticipated for the Mars Mission seems to be a major problem, due to the nature of the crew and their training is may turn out to be a secondary or non-existent problem. In such a mission, the men will be highly selected, will probably be a homogeneous group, and will have been together as a group throughout training. Since the training program considers all the candidates a equals, i.e., such criteria as rank are not used to determine status, their should be minimal friction due to group differences. Since the group has trained together there probably will have emerged a social structure of leader and subordinate, a structure which will be carried over into the crew for the space ship. Their roles will be relatively well-defined, although is is recommended that there be a degree of cross-training to prevent the subjugation of one member of the crew to the position of technician rather than scientist-pilot. These men will need to have schedules which include adequate time for recreation and privacy. The problem of recreation in such small quarters as the space craft will require some imaginitive thinking, however, perhaps the computer may be diverted to entertain the men during certain periods. As for privacy, a quality which will most definitely be needed on such a long flight, some provision need be made for providing a place where the men may go to be alone even if it is only a curtain around their chair. They also need to have some area which they can call their*s.

The monotony of the environment may be altered by changing decor in flight as part of the recreation program.

Because of the long duration of the flight, and the tendency for confinement to magnify certain characteristics, it is important that the crew members be school in the recognition of the warning sigas of mental illness. If a crew memberX exhibits such symptoms, the other members may be able to prevent him from entering into a severe psychotic state or at least mitigate the results of the psychosis. Paranoid reactions have been noted in men isolated in the Canadian woods an in Anartica and thus the possibility of mental illness is not remote even though the crew has been selected most carefully with regard to psychological make-up.

An understanding of the space and space craft environment is important. If the men understand their position they will be less apprehensive about it and will operate more efficiently. Further, if they know when they will be returning to earth some of their anxieties will be reduced. These men need to have an ;understanding of their feelings and those of the other crew members.

One problem which does pose a major threat to the mission is the need for contact with friends and family. It seems rather harsh to deprive the crew members of all contact with home during the flight.k Indeed it would be expected that the anticipation of news from home would keep up the crew*s morale. During the Moon shots the men have been informed about news and their families. However, problems arise when there is a tragedy at home, i.e, when a member of the crew*s family dies. The question then raised would be whether or not to tell the crew member. The shock of hearing coupled with the remoteness of location might lead to severe psychological problems. Furthermore, the crew morale might also drop post-news time because they realize the remoteness of their position and the impossibility of returning home.

The existence of conflict between military and civilian crewmembers has been considered. In a less structured and less trained group, such long term confinement might lead to problems resulting from the different views of commands between the two areas. views: However, in this program, such differences are minimized to a great extent during training and thus one would not foresee any problems due to military civilian strife.

The men chosen for the mission need to have a great deal of commitment for the goal; they need to be dedicated to the mission and to their fellow crew members. They need to be men who are sensitive to the needs of his crewmates. They need to be well-adjusted men who are able to direct their hositilities inward and have low levels of generalized anxiety and aggression.

In summary, the problems of confinement to be found on the Mars Mission are minor because of the nature of the crew. The major problems for the individual will be the need for privacy and social identity and perhaps the question of remoteness from home and loved ones. Interpersonal strife will be low because of the crew cohesive nature. The problems of monotony and the provisions for recreation and relaxation present themselves as the major obstacle in the long term space flight.

CIRCADIAN RHYTHMS

THE FLIGHT TO MARS

by Eric J. Hilgeford

Circadian rhythms are of great interest to biologists when they are considering long-term space flights like the flight to Mars. Unfortunately it is also a field where much research is needed; little is definately known concerning what to expect. Concerning behavior there is even less known. Most of the research deals with lower life forms, and extrapolation to man has been questioned. This field is just now passing out of the theory stage. Except for a small school of scientists led by F.A. Brown, most are in fundamental agreement about the basics. It is granted that every cell has particular circadian rhythms, and that many cells(tissues,organs) have synchronized rhythms. The body as a whole is also lokked upon as having many circadian rhythms which, though not synchronized, have particular phase angles relative to each other. It is thus possible to draw a phase diagram on which are presented the proper phase relationships of the many rhythms. For each rhythm, biologists can work out the range in amplitudes relative to time. Emphasis is placed on defining the times of maxima and minima. These circadian rhythms are considered to be endogenous(based on internal control), but it is important to realize that they are entrained by external environmental factors(zeitgebers). The most important is light, and of secondary importance is temperature. These naturally rhythmic phenomena help to set up the periods of the endogenous circadian rhythms, and also are important for the proper orientation of the rhythms relative to each other. ( Pittindrigh, 1967)

Light is consddered the priciple "zeitgeber" for all animals, but many scientists are careful not to say this of man. Such a notable man as F. Halberg(1960) has gone far enough to say that man's social schedule may well be his principle " "zeitgeber". Jurgen Aschoff(1963) argues for the same point by pointing out that a newly born baby shows neither the 24 hour sleep-awake cycle, nor the body temperature cycle until he is one year old. He feels that this strongly indicates such rhythms are learned. Pursuing the idea of social influence, he goes as for as to mention that the presence of a clock is often suffieient to keep an individual's rhythms in proper phase and with a 24 hour period.

In a recent publicati on D.N. Orth and D.P. Island(1969) have given the reason they think such emphasis has been placed on man's social schedule as his primary "zeitgeber". They point out that in most studies no attempt is made to dissociate the sleep-awake cycle ffom the dark-light cycle. This has been the case because man is naturally diurnal and tends to sleep when it is dark. Having as much control over his environment as he does, man usually manipulates it no matter what the natural conditions so that it is dark when he is sleeping and light when he is awake.

What D.N.Orth and D.P. Island(1969) have done in their research with 17-OHCS is to dissociate the sleep-awake cycle from the the dark-light cycle. One example would be where after 8 hours of sleep the person awakes but remains in the dark for 4 hours. Their results show that it is the change form dark to light whih is the important synchronizing event. Neither the léngth of darkness, nor the change from light to dark play any role. The sleep-awake cycle has its only effect indirectly in that on awakening one usually goes from the dark to light. The only reason for maintaining an 8 hours ofdark(sleep)-16 hours light(awake) is that studies have shown man needs 8 hours of sleep. It is interesting to note that because of the relationship of 17-OHSC to sleep, the sleep pattern tends to change also but because of man's voluntary control he can keep it rom following the 17-OHSC cycle. This is not done, however, without any detrimental effects.

Circadian rhythms are typically physiological phenomena, but behavioral responses have been known to vary due to these physiological chenges. Performance and reaction time have both been shown to have a circadian rhythm. Psychologists often study physiological changes brought about by cognitive stresses. An equally valid approach is to study the effect of a physiological stress on behavior. This is the case with circadian rhythms. The behavior change may be direct where it is mediated by the nervous or endocrine system without on being necessarily aware of the physiological stress or change. In the case of severe physiological stress, the cognitive appraisal of one's situation may alos cause behavior changes. This can be called an indirect effect.(Lazarus, 1966)

As noted earlier, in a completely normal situation circadian rhythms have a direct effect on behavior. Decision making ability and reaction time peak during the day. This was pointed out as early a 1955 by B.O. Bjerner. He studied 3 shift workers at a gas plant in southern Sweden. At the plant, workers had to make hourly records in log books and make simple calculation to do this. By studying the frequency of errors he concluded that errors peaked at 3pm and 3a.m. He had two peaks because in essence he was dealing with a population in which dark-light cycles were 180$^{o}$ out of phase for the night and day shifts(afternoon a blending effect). The highest peak was at 3 a.m. The mourning shift had the least number of errors, the afternoon a median amount, and the night the most. Thsi indicates the night shift nver fully adapted. ONe may wonder if the same will apply in space or if there was some mediating factor causing this.

Reaction times were studied by K.E. Kleine(1967). Reaction times are, he says, a measurement of "ability to perform complex psychomotor actions a s quick and as accurate as possible." He reported that reaction time was at its best between 2-4 p.m., and at its worst between 2-3a.m. Thsi study agrees with Bjerner concerning 2-3 a.m. being a bad time if one is concerned with accuracy. They seem to be contradictory concerning 2-4 p.m. Further studies should be made.

All of the above should be considered in spaceflight. Schedules should be arranged so that critical operations are performed at the peak of one's daily rise in efficiency. LIft-off could easily be adjusted to take this into consideration. For landing, or placement into Mars orbit, one should anticipate the time of arrival and gradually manipulate the crews circadian rhythms so that they are at peak performance when the critical time arrives. The manipulation could be accomplished by slowly changing the light-dark cycle. This would have no adverse effect; rapid changes are needed to cause desynchronosis. From another light this may not even represent a problem. Crews will probably be large and divided into shifts. It is quite probable each shift would be large enough to fully operate the craft. Thus a shift of the crew could alwasy be at peak prerformance.

Circadian rhythms also effect behavior directly in abnormal situations. One such case is desynchronosis. Rapid transportation has unveiled thai problem by transproting men rapidly aross many time zones. One's endogenous rhythms continue at their prvious rhythms despite the vast change in the "zeitgebers" relative to these rhythms. Thus it is night when back where one came from it is day, yet one's endogenous rhythms tell you to be active becausey have been entrained to the old light-dark cycle. A conflict arises that one is unaware of unconscious, of its presence The rhythms respond by losing their proper phase relations and interrupting one's performance. The single circadian system loses its integrity; the constituent rhythms lose their phase relations. The results in physiological and behavioral changes.

M. C. Lobban (1965) desynchronized volunteers in her lab and studied body temperature and renal excretion. Her study showed that the body temperature rhythm quickly adjusted, but renal excretion was sometimes abnormal after six weeks. Thus the results of desynchronization can be long lasting. Behavior is often affected, G. T. Hauty (1965), studied reaction time, decision time and fatigue in volunteers after a rapid flight from Oklahoma City to Tokyo. In all three cases he noticed adverse effects and things did not return to normal till after three days.

If man were to be rocketed into space and then subjected to a light-dark sequence radically different (the exact opposite of what they would be experiencing on earth) , they too would probably show signs of desnychronosis. True, the astronauts would adapt as passengers do on earth within two to three days. (perhaps more),but they would be working below their peak performance for one of the most critical periods of their flight. The solution to this problem would be to regulate the light-dark cycle (sleep-awake cycle) so that it is synchronized with their usual cycle on earth. This hass the added advantage of making communication with earth easy if there is only one shift. Further manipulation is required and desirable with large crews. It is desirable that someone always be awake and on watch monitoring equipment and watching for emergencies.

Thus the shifts must have their sleeping periods staggered. (Strughold, 1965). Yet the maximum period for standing watch should be limited to four hours, so there must be at least six crewman or shifts if each is to take only one shift. (Leonov, 1968) This number could be lowered to three by having each crewman or shift stand watch for four hours, relax for ~~four~~ 8 hours, and then stand watch for another four hours during his sixteen hour awake period. Working in such shifts require or result in different light-dark cycling for each shift of the crew. One question which may be asked is how should the astronauts be maneuvered into their respective light-dark cycles. If this is done in space after lift-off desynchronosis will arise. A suitable schedule could be worked out which prevented desynchronosis through a slow schange, but what would happen in the meantime. Another alternative would be to adapt the shifts to their particular light-dark cycles three to four weeks before launch. If this is done, from the moment of launch, one shift of the crew is always ready.

I have made mention of making use of dark rooms for sleeping, rooms which are perpetually dark except when the shifts are changing. The crew should be able to move in and out at will, but activity in this room should be limited so as not to disturb the sleepers. This is done both because sleeping is easier in a darkened room, and because the phase relations of circadian rhythms have been shown to be disturbed by constant conditions of light or darkness. How true this is for man is in question. Lower animals need a variable external light source as a time cue. In the absence of clocks this has also been proved for man, but with clocks man can decide when to sleep; when sleeping, even in a lighted room, one is effectively in the dark. Thus by simply using a watch man can volunterily change his light-dark cycle, or keep it the same. The above being the case, one can seen that one has more choices besides darkening rooms periodically. One lighted room could be used in which all astronauts could sleep with eye covers, to facilitate sleep.

The room being lighted, the shifts could move in and out easily. k There being only one room for sleeping, space would be saved.

The above treats sleep only in that darkness is associated with the sleep period, but one of man*s circadian rhythms of particular attention is his sleep-awake cycle. Isolation experiments have shown that men tend to sleep for eight hours and be active for sixteen hours regardless of the absence of any time clues. Obviously this represents an endogenous rhythm. Unlike the other rhythms which are free from conscious control, the sleep-awake cycle can be volunteerily disturbed. Thus some people may force themselves to get by with six hours of sleep, or sleep for eight hours but in two four hour periods separated by active periods. Man can usually suffer such distortions without any noticeable effects, but under added stress the eight hour sleep-sixteen hour awake cycle has been shown to be by far the best (Hartman, 1967). Not only must one worry about the duration of sleep , but also its quality. The sleep period should consist of at least .23% REM sleep. If not the astronauts will show irritabilety, anxiety, and difficulty in concentrating (Dement, 1960)(Johnson, 1967).

Conscious disturbances of the eight hour sleep period can also effect other rhythms, if instead of sleeping for one period a day, one sleeps for two or more periods divided by periods of activity. This is disturbing because it is the shift from dark to light which is the main synchronizer for animals and man.

The guaranteeing of the proper quality and duration of sleep represents a problem in space. Living in such a stressful situation, sleep would be expected to be difficult, and has proven to be such in the past. Sleep inducing drugs are thus required. To be effective the hypnotic sedative drugs should fulfill three requirements suggested by Oleynik (1967). They are: 1) "ellicit 'restful sleep', presumably by sleeping the normal REM, NREM ratio," 2)"permit ease of arousal at any time from drug ingestion," 3) "cause no or minimal impairment of performance at any time after taking the drug." Some further criteria should be added;it must not be harmful when frequently used, and the drug must be found suitable for a situations in which there is no gravity. The barbituates fail by decreasing the REM (Dement, 1960) but the following are three possible drugs, their dose, and the resulting REM-NREM ratios. The normal REM-NREM ratio is 23% REM. Chlordiazepoxide at 10 mgm causes 25% REM. Meprobamate at 400 mgm produced 21%, and Methaqualone at a dose of 150 mgm causes 21%, all three appearing to be suitable. ( Oleynik, 1967)

Circadian rhythms may also have an indirect effect on man's behavior. Desynchronization resulting from any aspect of space travel may cause the awareness that something is not right. The awareness of this disorientation is a good source of psychological stress. William Dement (1960) noticed this in one of his subjects during an experiment. The subject paniced.

I Would like to close by saying that much in this line of research needs to be done. One line of endeavor is suggested by C.M. Winget (1966). What effects do different intensities and wavelengths have on the synchronizing ability of light? If David Orth applied these variables to his experiment mentioned earlier much could be learned.

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MPK

Spacebound, man will encounter many hazards he has never known on earth. Compared to the relatively new phenomena of weightlessness, angular acceleration, and chronic isolation the problems of radiation exposure sound like old acquaintances. Yet of all the dangers this one perhaps is the most serious and the least understood. Nowhere on earth can the broad and ever-changing spectrum of galactic radiation be duplicated. Studies have been attempted utilizing long-range projectiles, artificial satellites, and pilot balloons to catch a glimpse of the menace in its natural habitat. With the aid of the synchrocyclotron investigation of high energy protons has entered the realm of the possible. Clinical cases of therapeutic radiation treatment as well as the Japanese atomic bomb casualities have supplied information about the human element of this problem. All totaled, these studies still cannot adequately approximate the conditions of prolonged spaceflight. Even the recent manned ventures into space intimate little of what longer flights might entail. The questions remain as to the flux and nature of the radiation man will experience, how it will affect him, and what are the best means of protection for him.

## Sources of Radiation

There are two types of radiation to be considered. The first is electromagnetic ranging from micro- to gamma rays. Starting at the lower end of the spectrum micro- or radio waves have little known effect on body tissue. In the infrared region heat waves pose some problems for the cooling system in the spacecraft and EVA suits as well as the more serious threat of retinal burns. Even visible light can be hazardous with no atmosphere to soften extreme contrasts of shadow and light. The problem could become critical to a pilot attempting to check his control panel. Continuing into the short wave or ultraviolet region again special care must be taken to shield the eyes from damage. At the far end of the electromagnetic spectrum are the x-rays and gamma rays. Although their penetration power is sizeable their low specific ionization makes them less of a threat then high energy charged particles.

These make up the second type of radiation, ionizing radiation. It has been estimated that over 70% of the particles of primary cosmic radiation are protons with energies ranging from $10^9$ to $10^{18}$ ev per particle. Alpha particles make up most of the remaining contribution with the heavier nuclei composing only 1-2% of the total.[1] The greatest source of radiation comes not from the far reaches of space, but from only 93 million miles away in a neighboring nuclear reactor termed the sun. It supplies a steady stream of high energy protons, radio frequency waves, soft x-rays, electrons, alpha particles, and ionized gas clouds. Turbulent, even at the best of times, its 3 to 4 year peak of the 11 year cycle may include as many as 5 or 6 major flares. The earth is shielded from these by its atmosphere and the Van Allen belts which geomagnetically trap charged particles sweeping them out and away from the lower atmosphere.. Protective though these belts are for man on earth they do present a problem to spacecraft that pass through them.

Besides these natural sources, man in space may also have to contend with radiation from the nuclear-reactor propulsion or power systems of his own ship. This poses special shielding problems. Then too as on any voyage to new lands unexpected danger in the form of unknown regions of high flux may exist. This necessitates a monitoring device on the spacecraft which can detect an increased flux and

and alert the crew to special safety precautions. This may lead to a vicious circle, for even the monitoring devices themselves as is true with the rest of the ship's supplies and equipment are vulnerable to ionizing destruction. Assuming no critical malfunctions of the instruments the essence of the radiation story can be found in its effects on man, a creature so complex and delicate that a single unshielded exposure could annihilate him.

## Effects of Radiation

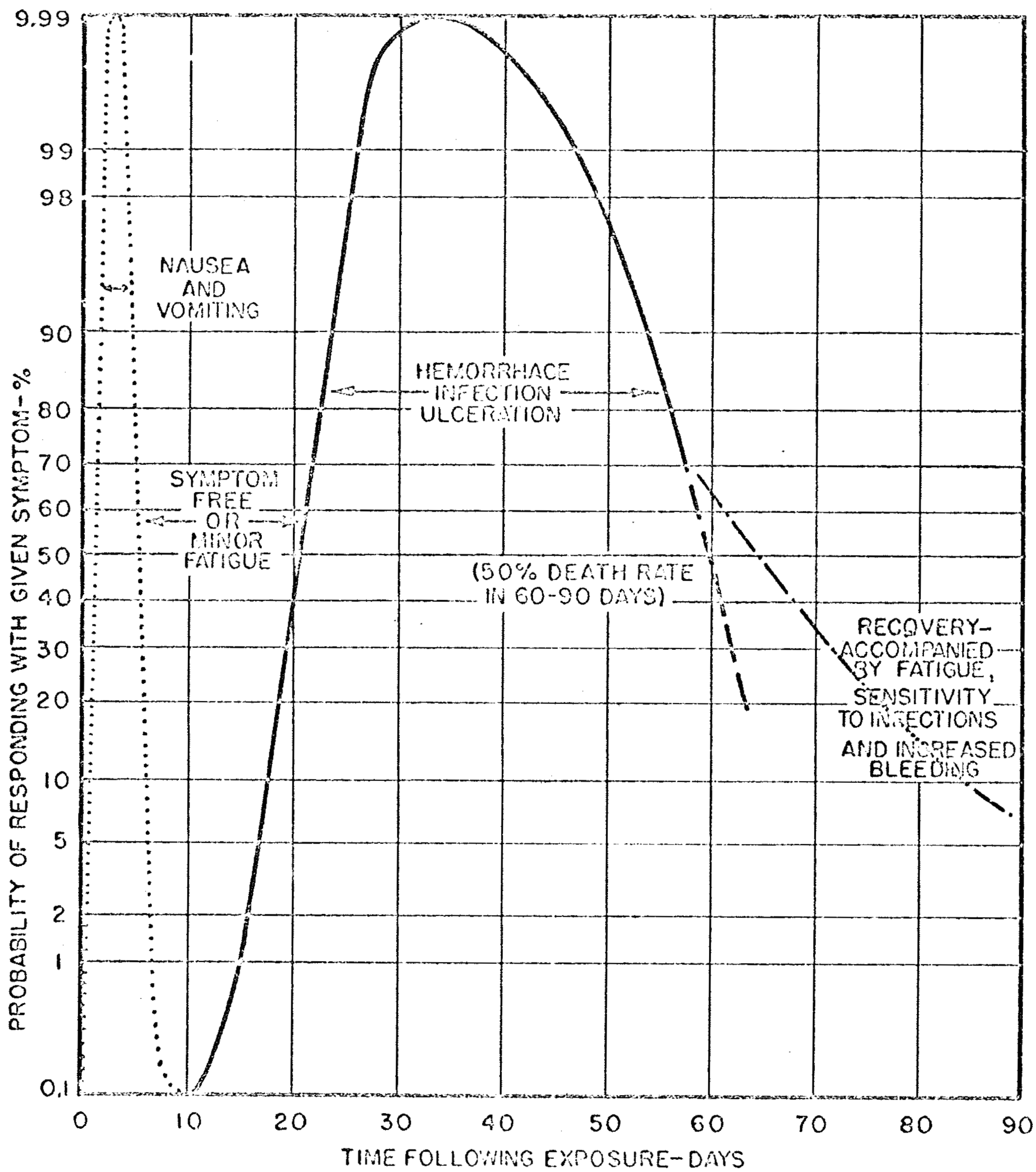
Man in space will be an active participant in his flight. Thus the level deemed safe for him must take into account not only his survival, but the fact that he must efficiently function. As always individual tolerance levels vary. Part of the screening program for the Mars voyagers should include tests for reaction to anti-radiation drugs. In the Apollo mission a ceiling of 50 rad was aimed for, 25 from daily doses in spite of shielding and 25 more for emergency exposure.[2] For a flight of several years duration 25-30 rem per year has been tenatively presented as a permissible dose.[3] As seen from Table 1, relatively few effects are anticipated at this level compared to the acute radiation illness expected from increased exposure (Graph 1). But is even this low exposure too much? As quoted from Tobias and Slate, 1962,

> Although it is generally agreed upon that only a small percentage of individuals exposured to 100 rad will suffer from nausea or other subjective of radiation sickness, much lower doses are required to cause certain physiological and pathologicla changes. Thus, radiation doses as low as 5 to 10 rad reportedly cause immediate temporary decrease in the photic response of the eye, and a detectable drop in lymphocyte count may occur after doses of 50 rad or even less, with a 50 to 90 per cent depression occuring with doses of 100 to 200 rad. Doses as low as 25 rad to the testicles, either locally or as whole body exposure, have been reported to produce a detectable decrease in sperm count. Furthermore,

.E. 11.

# GRAPH 1

## ACUTE RADIATION ILLNESS




An idealized description of the time course of symptoms of acute radiation illness following a mid-lethal exposure of whole body radiation of 250-500 rad. (Compiled by Webb Associates, 1962.)

NASA Life Sciences Data Book p. 81

# TABLE 1

## EFFECTS OF ACUTE RADIATION



Expected Effects from Acute Whole-Body Radiation

| Dose in Rems | Probable Effect |
|---|---|
| 0 to 50 | No obvious effect, except, possibly, minor blood changes. |
| 50 to 100 | Vomiting and nausea for about 1 day in 5 to 10 per cent of exposed personnel. Fatigue, but no serious disability. |
| 100 to 150 | Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 25 per cent of personnel. No deaths anticipated. |
| 150 to 200 | Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 50 per cent of personnel. No deaths anticipated. |
| 200 to 350 | Vomiting and nausea in nearly all personnel on first day, followed by other symptoms of radiation sickness. About 20 per cent deaths within 2 to 6 weeks after exposure; survivors convalescent for about 3 months. |
| 350 to 550 | Vomiting and nausea in all personnel on first day, followed by other symptoms of radiation sickness. About 50 per cent deaths within 1 month; survivors convalescent for about 6 months. |
| 550 to 750 | Vomiting and nausea in all personnel within 4 hours from exposure, followed by other symptoms of radiation sickness. Up to 100 per cent deaths; few survivors convalescent for about 6 months. |
| 1000 | Vomiting and nausea in all personnel within 1 to 2 hours. Probably no survivors from radiation sickness. |
| 5000 | Incapacitation almost immediately. All personnel will be fatalities within one week. |

(Adapted from Glasstone (ed.) The Effects of Nuclear Weapons. Atomic Energy Commission, 1957.)

NASA Life Sciences Data Book p.80

> experimental work in the USSR has revealed behavioral manifestations, for example in such end points as taste cues, radiation avoindance [sic], and conditional reflexes, in nervous system exposures with doses of only 5 to 10 rad. In fact, effects on the usual threshold have been reported after exposure to doses less than 0.01 rad, stimulation of retina after less than 1 rad, and audiogenic seizures have been produced in mice by less than 10 rad.[4]

Thus even transitory exposure to low radiation levels can cause damage. The most critical targets include bone marrow, spleen, intestine, gonads, and the brain. An important area of neurophysiology is devoted to the detection of brain damage before a chronic level is reached. Lastly, radiation changes in the adaptive regulatory functions of the body's systems may lower man's tolerance to other flight factors or combine with them for a catastrophic net effect. On the other hand, the sum of factors may not be entirely harmful. Rabbits irradiated in a total dose of 300 rad for 2 months showed no substantial change in the blood-generating organs but the same irradiation combined with vibration and decrease of barometric pressure produced marked changes in the bone marrow in half that time. On the other hand, A.A. Sveshnikov and A.V. Sevon'-kayeva exposed 8 dogs to an irradiation of 9 roentgens a day for a total dose of 200 roentgens. Four of the dogs were also subjected to vibration, noise, and a decreased atmospheric pressure at the time of irradiation. In this case functional changes in the vestibular apparatus were noted only in the group subjected only to irradiation.[5]

Not all the effects of radiation are immediately apparent. Late effects such as life shortening and genetic damage are difficult to assess. The following 3 pages relate dose incrementation to long term damage.

In addition to the life-shortening effect described in I.E 14. and 15., where death is from all ordinary causes, radiation is followed by an increased incidence of leukemia and by damage to the genes of the reproductive cells.

The leukemia effect is given as a probability of

$$10^{-6}/r/yr$$

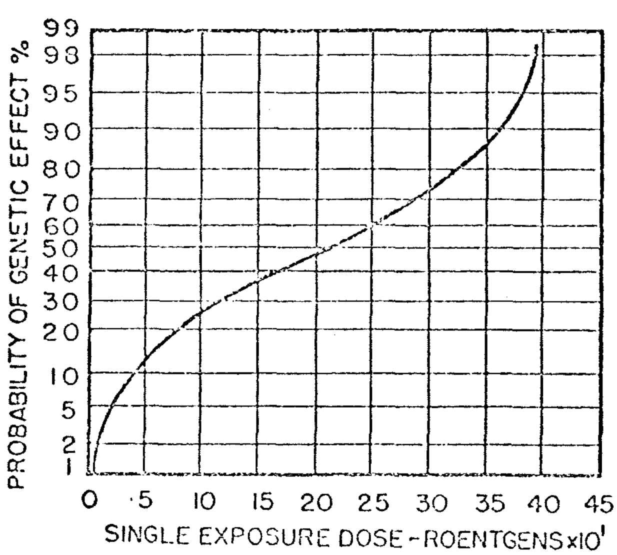
for at least the first 20 years after brief exposure to whole body radiation. (Based on Atomic Bomb Casualty Commission data collected in Japan.)

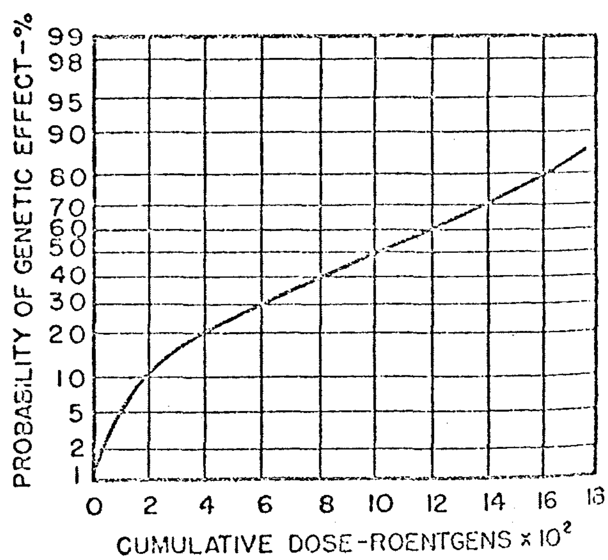
The genetic effect is expressed as a probability of

$25 \times 10^{-8}/r/gene$, for males, brief exposure; and

$5 \times 10^{-8}/r/gene$, for males continuously exposed.

These are based on mouse experiments showing recessive visible mutations produced by irradiation of spermatogonial cells. (Data of W. L. Russel, ONRL.) Man is expected to have genetic effects fairly close to these in mice. If he has from $10^4$ to $10^5$ genes per germ cell, then the probability of genetic effect would be approximately what is shown in the following two graphs.

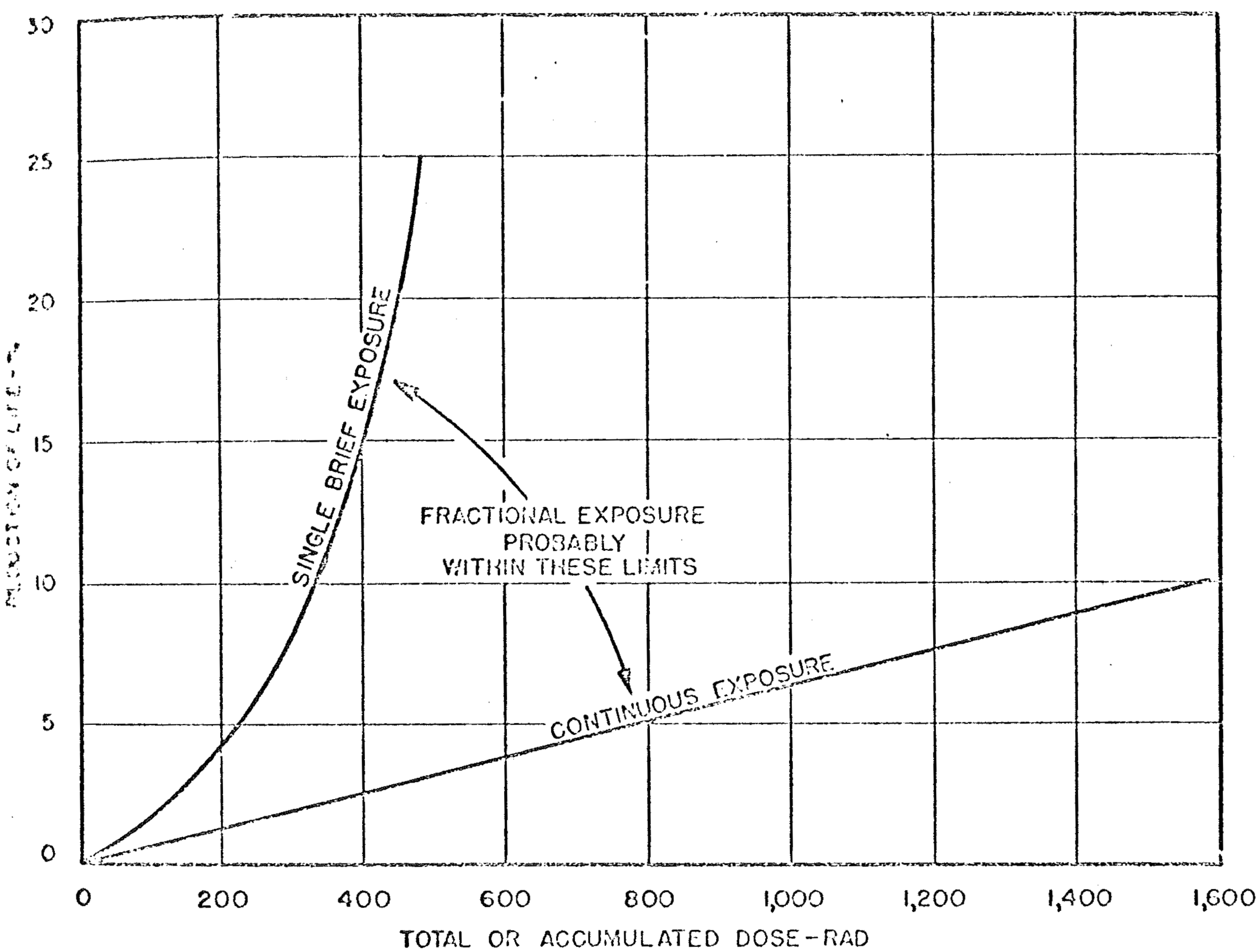



(Compiled by Webb Associates, 1962.)

I.E. 15.

# LIFE SHORTENING FROM RADIATION

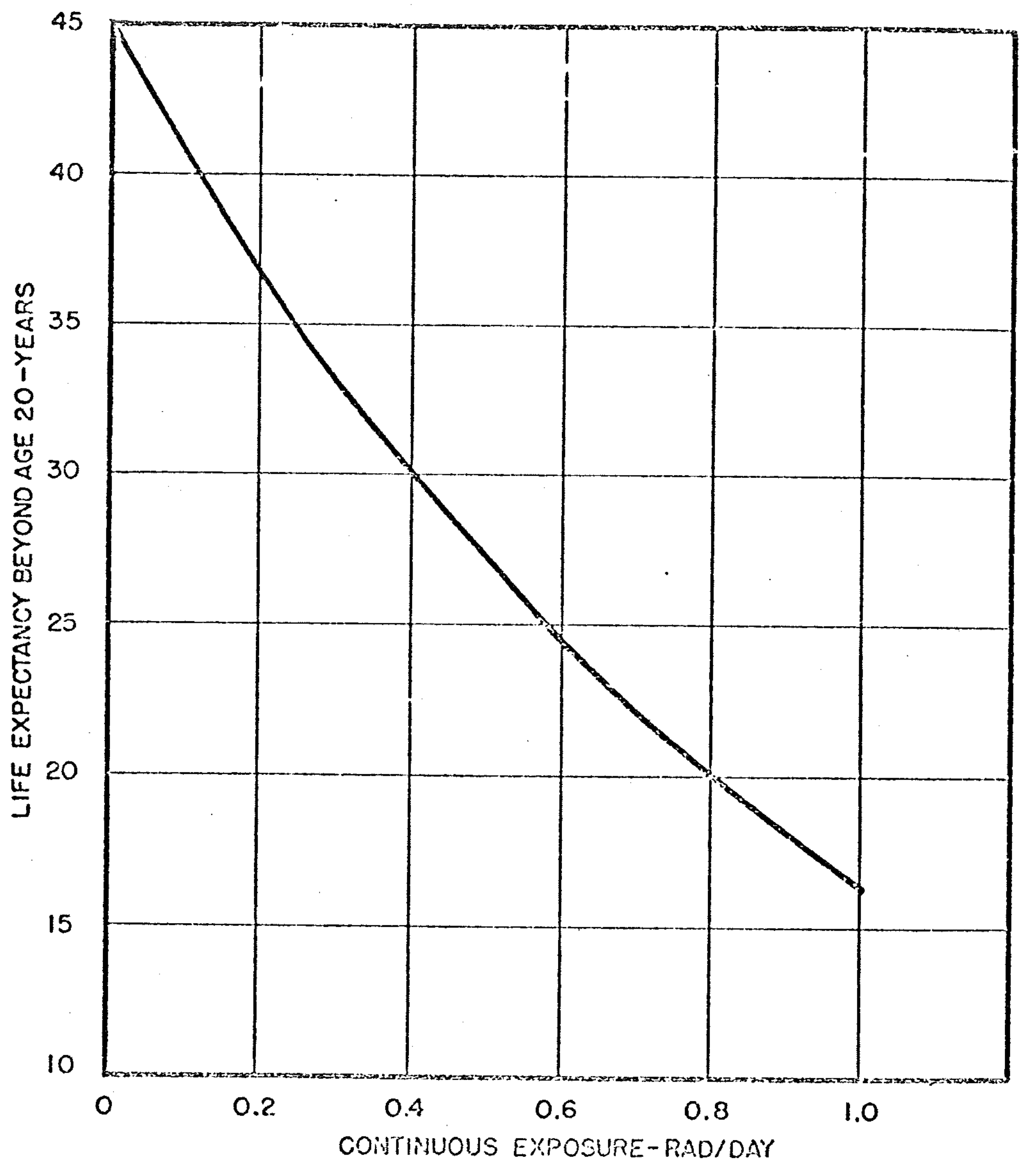



A comparison of the effects of brief single doses with continuous exposure to whole body radiation, on the shortening of life due to radiation. Multiple brief exposures, separated by days or weeks, termed fractionated exposures, will be expected to have an effect somewhere between the limits shown for single and continuous exposure. (This chart and the previous one are based on animal work, since there are no human data. Compiled by Webb Associates, 1962.)

--See also I. E. 14.

# RADIATION AND LIFE EXPECTANCY



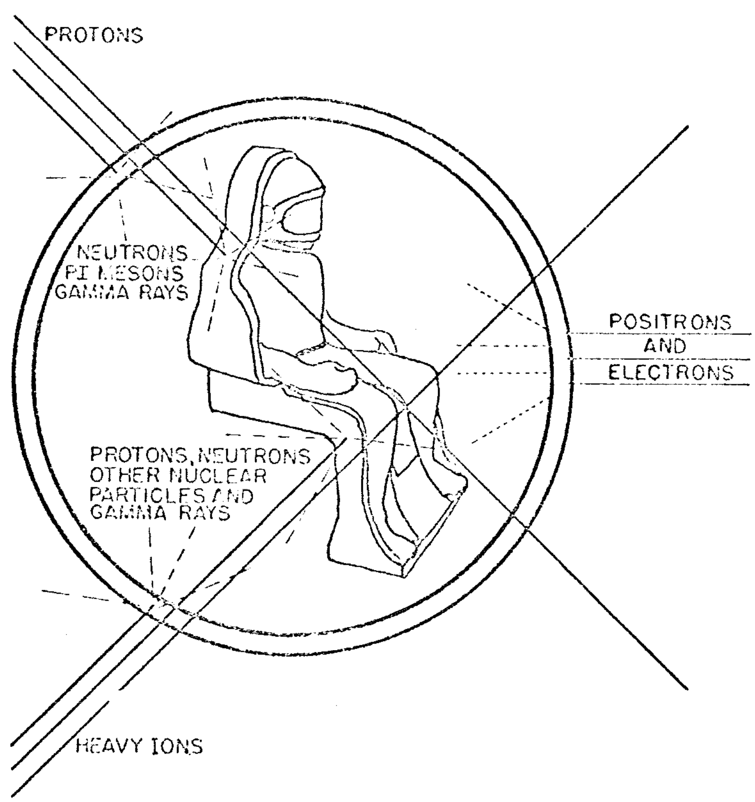



The estimated life expectancy of a 20-year-old population exposed to fixed daily doses of whole body radiation, continued until time of death. Deaths would be from all natural causes, not from leukemia and other illness related to radiation. In fact, comparisons have been drawn between the effects of radiation and the normal process of aging. (Compiled by Webb Associates, 1962.)

The most devastating effect of radiation could be fear itself. The menace is invisible, intangible, and uncertain. The symptoms of radiation sickness in the first stages could be easily attributed to other causes and therefore make treatment difficult. Dosimeters may indicate the level of exposure but tell little else. Not all individuals will receive the same dose or react the same. Cut off from the protective atmosphere of earth and in a strange enviroment, how will the voyagers bear up under the strain of knowing or rather not knowing what the radiation they cannot escape from is doing to them? Idle talk simmering for months about mutations, drastically shortened lives and irreparable brain damage could well disrupt the most efficient and stable of crews. Then too, damage of the endocrine glands upsetting the hormonal balance or of the brain itself could create further stress physiologically. Finally, who of even the most hardened could remain untouched by fear if even one of the crew members accidently receives enough exposure to critically affect him?

## Protection From Radiation

Knowing some of the hazards the question remains as to how to protect man. The best method lies in avoidance of high radiation zones. Knowing the two main sources of radiation arise from the Van Allen belts and solar flares the danger can be minimized by prior consideration of the course. A polar trajectory plus the least possible time spent passing through these belts solves the first. Planning the flight to coincide with the quiet period of the solar cycle takes care of the second plus the help of shielding. Because of the weight limitation complete shielding is impossible but a type of storm shelter employing the ship's geometry, supplies such as water, equipment and partial body shields seem to be the most feasible solution. Below is a diagram of what happens to particles as they collide with the spacecraft and its shielding. The lighter charged particles, the electrons and positrons, are stopped by the shielding and the energy of the collision is released as bremstrahlung or gamma rays. The heavier and more energetic particles such as protons, alpha particles, and beyond can pass through the shielding colliding with equipment or man himself within the spacecraft or pass entirely through. Whenever a collision occurs, secondary particles may be produced and further complicate the danger.



From the previous discussion it can be seen that exposure to a minimal amount of radiation is inevitable. This does not preclude disaster. Even with the shielding of the earth's atmosphere equivalent to 1 m of lead or 4.3 m of concrete[6] man is not without the ionizing menace. However he is not left entirely defenseless by nature. It has been estimated that for short term exposures up to 90 per cent of the injury is reparable by the body's own systems. Besides actual clean-up and repair of damaged tissues actual structural changes can occur to minimize further damage. The body's line od defense and repair can be further enhanced by the use of anti-radiation drugs. At the present stage in radiobiology over 5000 drugs of this type are known with the list growing every day. The most notable are cysteamine, cystamine, AET, serotonine, and other anti-hemorrhaging agents. The problem of finding drugs which provide suitable protection with low toxicity in the unique environment of a spacecraft requires special consideration. First, the mechanisms by which most of these drugs act are unknown; second, individual sensitivity must be taken into account; third, radiation protective preparations may lower man's resistance to other factors of the flight.

Now do you believe radiation is a problem?

---Finis---

Notes

[1] C.J.Clemedson, "Space Ionizing Radiation as a Problem in Aviation and Space Medicine," *Some Problems of Aviation and Space Medicine* (Prague: Charles University, 1967), 164.

[2] National Aeronautics and Space Administration. "University Conference on the Science and Technology of Space Exploration," *Bioastronautics* (Washington, D.C.,1962), 3.

[3] Berry, "Preliminary Clinical Report of Medical Aspects of Apollos VII and VIII," *Aerospace Medicine* (March, 1969), 13.

[4] Clemedson, *op. cit.*, 171-2.

[5] Yu.G.N. Nefedov, *Physical and Biological Studies with High-Energy Protons* (National Aeronautics and Space Administration, 1964), 15.

[6] Clemedson, *op. cit.*, 163.

Mars trip - weightlessness & C.N.S.

Ever since man first started to consider the possibilities of space travel he has been intrigued with the ~~possibilities~~ advantages and problems he would confront in the weightless state. The first thing that comes to mind when most people think of space travel in general terms is weightlessness ~~and~~ Even when the Apollo astronauts beamed backed their TV pictures from space, a noticeable part of their show was demonstrating how objects would just float in front of them or how they could be upside down relative to one another withoug having ill effects.

Weightlessness is very difficult to simulate in the one g environment although attempts which are useful have bben made. In general the simulations involve either centrifugations and then lowering of the acceleration or suspensions of individuals or organisms in liquid media with the same density as the body so that the body floats. Parabolic flights in airplanes simply do not last long enough to make meaningful studies that could be applied to long term space flight. Thus, the weightless state is difficult to study in the one g environment of earth and it is necessary to wait ~~until~~ for orbital flights or travels ~~out~~ into space until the effects of weightless can be studied extensively.

One would expect, therefore, that when astronauts train for their space flights there is necessarily something lacking in their pre-flight preparation that they must look forward to until the moment of actual flight. We would expect that the astronauts look forward with anticipation ~~the~~ ~~for~~ to the experience of weightlessness.

In addition, because of the difficulty in establishing the zero g environment on earth, we would expect a great deal of the experimentation that the astronauts would perform during flight would be concerned with weightlessness. Radiation effects and isolation can be studied effectively on the earth (although it may be difficult and very dangerous to study these problems on human subjects on earth; they will be ever present problem on space flight). Because data can be retrieved from studies of isolation and radiation it will be possible to separate the effects of weightlessness on biological systems from those of the other two problems.

Research on the biological effects of weightlessness has centered around cardiovascular effects and around neuro-muscular effects. This paper will be concerned with the neuro-muscular effects. When searching through the recent literature on the biological effects of the weightless state, one in immediately struck by the small volume of material currently being published. Again, this must be due to the difficulty in simulating the weightless state, but more importantly, since the shorter flights have shown very few deleterious effects of weightlessness, many of the researchers conclude that weightlessness is nothing to worry about. However, this does not mean that its effects, if we can find any may not be extremely interesting.

~~Thexxxxxxx~~ In the early days of the space program, the participants did not really know what to expect from weightlessness. Most reported dizziness for a short time but they rapidly became accustomed to the new environment. So far, no drastic problems have been reported. The long term effects of weightlessness, however, still remain extremely interesting and a number of questions can be raised.

For example, since the body will not weight anything, presumably the individual will have to do less work to move his body and less muscular wor k to perform physical tasks. Does this mean that his body will become less tired during the working ~~xxxxxx~~ hours and hours thatxx he is awake? If so, perhaps he can function well with a much reduced sleep period. How xxxx would a generally shortened sleeping period affect his rhythms and the different phases of sleep that he would have been accustomed to in the one g environment? During conscious states, the astronaut will realize his weighuless stiuation, but during sleeping periods, will his speep habits change? For example, it was reported that the astronauts in space thend to cling to something when they are asleep to give themselves reference about their surroundings? Perhaps there are other behavioral changes that will be noted in a bng term space flight, and only actually experienceing them will give us cluesa about the patterns they might follow.

During the working hours exercise will definitelybe needed xxxxx to prevent atrophy.

Some kind of psychological testing should be done which would enable evaluation of mental states and xxxxxxxxxxx capacities. Such things as the long term effects of working under zero g, whether a certain amount of leisure activity is needed, and so on xxxxxx could be evaluated.

The anticipation of the astronauts toward the weightless state may lead to a let down after they have been in the situation for a number of days or months. They may feel disappointment about not being abee to excecise easily, for example. They may feel they need a break from the routine of weightlessness. For this reasnn is might be desirable to alternate the spacecraft bewenn rotation to induce centripetal accelxxration and no rotation to enable the men to remain in the weightless state. Worrying about something which might occur during the weightless state may also affect the astronaut. Because it is so hard to simulstions on the gsound, the astronaut may feel he is geting into something totally unexpected and may be anxious during the whole flight for some unexpec-ted occurences

However, since the previous flights have generally shown there is nothing too strange about the weightless state except for vestibular problems a larger problem seems to occur when the astronauts return to a gravity situation. Ina addition to strange sensations like the Apollo astronauts noted(like their clothes being heavy and noticing that they felt heavy and had to hold on to the doctor's examining table) after long space flight, if there has been prolonged disuse of the feet, he may develop blisters simply by walking on his feet which are not used to walking. H^I^s muscles may be xxxxxx a little unsteady. However, all of the foreseeable deleterious effects of returning to earth or another body possibly may be counteracted by appropriate exercises.

In sum, then, from previous experience, the hazards of the weightless state upon the mature human organism seem to be minimal.x Thxxxxx xx Man can adjust quite well to his new situation and in all xxb probability, he will function quite well over long periods of time in zero g. Anxiety over unkxxxxx unforeseen problems during the weightless state may well be his biggest problem. Returning to a normal gravity situation may be anticipated by appropriate exercising. It may well turn out that weightlessness can be made to be xxxxxxx relativelyy harmless and the advantages it offers for resting and working may be considerable.

PULSE [illegible]

Definite changes in cardiac action have been noted in man.

Three phases in change

1. Pulse variations

    after effects of acceleration - immediately after launch

2. Pulse returns to normal

    Blood pressure varies

    Irregularities occur in cardiac conduction system

3. After first day of launch (orbit)

    Heart has made some adaptations

    Pulse rate decreases

    Electrical conduction takes longer - there is a delay between stimulus and response of cardiac muscle

Nikolayev and Popovich showed cardiovascular irregularities or disturbances which lasted from 7 to 10 days after return from space.

Tereshkova and Bykovskiy had disturbances including a 30% increase in pulmonary oxygen for 8-10 hours after return.

# Heart Rate During Space Flight

| | First minute of flight | Hour after landing |
|---|---|---|
| A. G. Nikolayev | 136 beats/min | 96-104 beats/min |
| P. R. Popovich | 132 beats/min | 85 beats/min |
| | Placing in orbit | At re-entry |
| V. Bykovsky | 148 beats/min | 160 beats/min |
| V. Tereshkova | 156 beats/min | 178 beats/min. |

pp 577, 614-615.

In the flight of V. Bykovsky & V. Tereshkova ..." data of Soviet specialists were confirmed concerning the rearrangement of nervous regulation of cardiac activity during the prolonged action of weightlessness. This rearrangement is accounted for by a decrease of loading on the blood circulation apparatus due to vanishing of the hydrostatic factor and by changes in interrelations of afferent systems. Against the background of increased excitation of cortical centres due to predominant impulsation from the vestibular analyzer the tonus of the parasympathetic nervous system is more pronounced. However, these changes do not cause substantial violations of performance and are of some individual nature."

Soviet Space Programs 1962-65, pg. 615

# Physiological Effects of Weightlessness

I Absence of hydrostatic gradients
Major physiological responses
1) Deminished Diminished peripheral pooling of blood
2) increased ventilation - perfusion ratio in lungs
3) (unproved) initial increase in blood volume and central blood volume due to enhanced absorption of fluid across capillary membrane.
Distention of central mechanoreceptors for volume (Gauer-Henry reflex) inducing a diuresis and fall in plasma volume to below normal.
4) Lack of normal stimulation of vascular and non-vascular mechanoreceptors with altered output from the sympathetic nervous system and altered secretion of regulatory hormones.
5) Chronic circulatory adaptation to weightlessness with a loss of responsiveness to gravitational and inertial fields.

II Lack of normal displacement of mobile structures or their constant abnormal displacement.

III Lack of weight bearing which causes
1) Diminished muscular activity and $O_2$ consumption which will bring about changes in the cardio-vascular system function.
2) Effects of diminished metabolic and neuro-endocrine functions → cardiovascular.

IV Lack of thermal convection of liquids & gases

Countermeasures to weightlessness
Induced acceleration
on-board centrifuge
rotation of space vehicle
Lower body negative pressure
Cycled venous occlusion cuffs on extremities
Intermittent positive-pressure breathing
Drugs & hormones
Vigorous physical activity

Taken from
Physiology in the Space Environment
Volume I - Circulation, National Academy of Sciences Research Council 1968. pp 160-61.

Psychology

The cardiovascular system influences the psychological status of the astronaut mainly in an indirect manner. Anxiety over the condition of the cardiovascular system and its changes during space flight could affect the astronaut. The increases in pulse rate and blood pressure are two such changes. Fibrillation of the heart muscle due to lowered temperature could definitely disturb the astronaut.

Because the cardiovascular system is the transporting system of the body it is definitely linked to neuro-endocrine function. Stresses on the system disturb the feedback mechanism between the pituitary and other glands. This can change the functioning of the hypothalamus which in turn affects appetite, motor activity, vision, personality, temperature, blood pressure, heart rate, nausea, vomiting, sleep and wakefulness, and sense. Thus the hypothalamus has a direct link to the heart and

PSYCHOLOGICAL MONITORING (J. Bonventre)

There are two general types of tests for psychological stability. One method consists of monitoring physiological functions which may be affected by psychological malfunctions or emotional anxiety. If we find an abnormality in one of these physiological functions we then have an indication that the astronaut may be undergoing some psychological stress. The other method consists of monitoring the psychological state in a more direct fashion by using methods such as testing and observation.

I am suggesting three physiological tests which will give both the astronauts and "ground control" an idea of the mental state of the crew. (1) The sweat gland activity of the astronaut should be watched closely. Sweat glands are very good indicators of nervous system activity and they may be recorded electrically. An increase in gland activity may be an indication of emotional anxiety. (2) The HCl secretion in the stomach should also be carefully measured. HCl secretion is usually accompanied by increased stomach mobility and increased blood supply to the viscera. In addition, there is usually a decrease in the muscous covering of the lining of the stomach. This total process is a fairly good indication of mental stress. (3) Also, in general, whenever a person experiences profound emotion or tension the tension in the skeletal muscles also increases. Therefore, a measure of the tension in these muscles would provide you with an indication of psychological stress.

Before I discuss the means of direct psychological testing of the crew one crucial point should be made. Throughout this whole procedure of psychological monitoring it is undesirable to have any suspicion of covert surveillance of individual performance on the ship. If any anomallies in behavior are perceived with the aid of any of these tests this should be discussed with the crew member involved. The training of the crew prior to the Mars trip should stress the reasons for these tests and the men should take them as a matter of course during the mission.

There are four types of psychological tests which, while not completely valid in themselves alone, can together provide sufficient information on the mental state of the crew. (1) Mission Tasks Performance Tests - The best method for obtaining data on crew performance would be to utilize simulation programs in the spacecraft computer. These could be used to drive displays and indicators in a quasi-operational situation. The type of functions that we would want to simulate would be things like: Systems Monitoring, Navigation Procedures, Orbit Transfer, Rendezvous, Landing Maneuver. These tests would indicate the individual's performance capability. However, when we notice a decrement in an individual's performance we must be careful not to jump to the conclusion that there is something wrong with this individual. It may be natural to experience a performance capability decrement under Mars flight conditions. For this reason ground-based and orbital simulators should be employed to help validate any results that you do obtain from this type of test. Results of the performance testing should be discussed with the crew member so that he may be made aware of his decrement in capability. Thus if a change in behavior is desired the astronaut will be immediately informed of the fact.

A second (2) means of psychological monitoring is by using standardized tests. Psychological stress effects two levels of functioning: the cognitive and the emotional. In the area of cognitive functioning the ability of abstract thinking is usually affected first. Therefore if we test abstract thinking ability we will have a means for determining cognitive ability. Tests now in use which test abstract thinking are: Shipley-Hartford Test, Wechsler Adult Intelligence Scale, and the Rorshach Test. Actually we will have to devise a method of combining these tests and others in order to come up with a test or group of tests that can be administered to the crew without any danger of learning and practice influencing subsequent tests. In order to test emotional functioning the following tests, now in use, could be used: The Forer Sentence Completion TEst, The California Psychological Inventory, the Minnesota Multiphasic Personality Inventory, and the Rorshach Test.

A third means of monitoring the psychological state is by observation by both a trained psychiatrist and by members of the rest of the crew. The members of the crew will take turns and each will have a periodic chance to evaluate the mental states of the rest of the crew. Observations should be cumulated in graphic form to allow easy detection of trends. Some of the things that might warrent cause for concern and intervention are: fluctuations in sleep behavior, abnormal toilet operation, drop in popularity, increase in complaints, decrease in interest in major recreational and creative activities, and increased distractability.

A forth means of gaining valuable information about the crew is through personal self-monitoring by each member of the expedition.

Each member of the crew should be given pre-flight training in introspective analysis techniques so that he may better analyze his psychological state. This téchnique would be the lowest of the four in terms of reliability because of such factors as: limitations in the depth of introspective analysis; the tendency not to be entirely truthful about something which is incompatible with the defense mechanisms you have developed. However when this self-report is added to the other methods of monitoring mental state and a correlation appears between the two then a great amount of validity may be attributed to the tests.

Despite all the care exercised there remains the possibility that a psychotic episode may appear on the trip to Mars. Not infrequently the individual undergoing an acute psychotic episode denies that his mentation, emotións, or behavior are abnormal. Under these circumstances he would obviously refuse to voluntarity accept medication. For this reason there should be a mechanism whereby the rest of the crew and "ground control" can inject the psychotic member with a drug that will put him to sleep.

Mars Project: Psychological Effects of Food and Diet

There are essentially three constraints which place limitations on the type of nutritional diet provided astronauts on a long-term (greater than one year) trip to Mars and back to Earth: mass (volume and weight limitations), sanitation (packaging requirements), and psychological feasibility (taste and variety requirements). A diet acceptable to all these constraints must be devised.

A closed ecological system in which food is chemically and/or biologically produced would certainly save the most mass, but its effects on the crew might be psychologically disastrous. Sensory deprivation has been a problem that scientists have so far linked mostly to weightlessness (reduced tactile perceptions) and reduced visual stimuli. However, sensory deprivation might be just as great a problem with regard to the t aste and olfactory senses if the astronauts are provided with completely bland foods. On the other hand, any type of canned or frozen-fresh foods would present great problems in preparation of the foods and maintenance of a sanitary environment, not to mention the additional 10 000 to 20 000 kilograms of mass the foods would add to the space vehicle.

Removing all water from the food so far has proved to be the most efficient means of removing mass from food supply. The freeze-dried foods so far have been the best method of meeting the three major constraints on food supply to space crews. In the future minor technological improvements should result in an improved taste in the foods.

Just as important as taste is variety. Crew members should have a say in the selection of their individual diets, but certain meals should be provided during the week (one meal per week) whose contents are unknown to the crew members. These "surprise" meals should have differint contents than most of the meals which the crew will eat. Also, the menu should be scheduled so that new foods become available every three months. Either one or both of these procedures could be employed to ensure variety in the crew's diet. Another method of improving the quality of foods is to provide hotter and colder water than now is used to rehydrate the food. Temperatures of 180° F (150° now used) and 40° F (50° now used) should be the available extremes for hot and cold water, respectively. The reason for this is simple: hot and cold foods are more palatable than lukewarm foods.

Although olfactory sense deprivation is not likely to be a major concern because man's olfactory organs are so poorly developed, it may be possible in the future to program certain aromas into a computer. Thus, during meals or certain other periods during a week, various aromas could be provided, especially of flowers and foods. Such a system would be feasible only if the apparatus which would contain the various aromatic sprays would occupy minimal space.

SANITATION AND HYGIENE

1. Whole body bath and laundry. A combined procedure of laundering clothes and bathing the entire body should be scheduled at intervals of about one week. Authorities seem to indicate that the whole body bath is more of a psychological necessity than a hygenic one, but it is useful in removing loose epithelium and microbes from the body surface. Mattoni and Sullivan first proposed a method which uses a bath suit and laundry-bag system in combination. The bath suit is made of some waterproof outer coating and is lined with sponge rubber; visualized, perhaps, as a baggy diver's wetsuit.

The bathing procedure involves removing the clothes and placing them in a separate laundry bag, which is then connected to the effluent line of the bath suit. The crewman dons the bath suit, places a soap tablet inside the suit, and connects an intake line to the water supply. After pumping about 3-4 gallons of warm water into the suit, he must agitate his body to work up a soapy solution. Bathing is accomplished by rubbing the suit at all points on the body. The bath suit is then drained of the soap solution, which is allowed to flow into the laundry bag.

Rinsing can consist of pumping a quantity of warm water, dissolving the residual soap, and draining the waste into the waste water system. Finally, the intake line may be connected to a source of warm, dry air, which is allowed to circulate through the suit, drying it and the crewman. After bathing, clean clothes would be removed from storage and donned.

Subsequently, the laundry function can take place. The laundry bag, holding the crewman's soiled clothes is manually agitated to effect cleaning. At the completion of this procedure, the bag effluent hose can be connected to the water recovery system and stripped of all water. Finally, hot, dry air can be connected to dry clothes and bag.

2. Superficial bath. Superficial bathing can be accomplished using wet sponges, perhaps with soap solution. These sponges can be stored in plastic bags to contain the moisture in them. This technique requires much less water and can be employed at the option of the crew member.

3. Care of teeth. Dental hygiene may be exercised much the same way as on Earth. Weightlessness would require a suction device to remove toothpaste and antiseptic rinse solution from the mouth.

4. Hair cutting. Hair should be cut periodically in conjunction with shaving. This may be done with the electric razor used for shaving. Hair length is to be kept to a minimum to allow easy washing and to facilitate control of microbes. Suggested length is about $\frac{1}{4}$ inch.

5. Nail care. Probably best carried out in conjunction with whole body bath when nails will be softer. Standard clipper used, with nail cuttings collected and deposited in waste removal system.

6. Urination. A simple collection device similar to a hospital urinal may be used within the spacecraft. Pressure from the bladder is sufficient to force the urine through the valve system. The urinal may be discharged into the waste water recovery system. It would be necessary to clean the urine-collecting device with an antiseptic solution to control bacterial growth. This device cannot be used, however, when the crewman is in his pressurized suit. In such a situation, he might employ a special urine-collection bladder fitted in the suit. This bag also is to be emptied into the waste water recovery system.

7. Defecation. According to the present literature, no simple means has yet been designed to meet obvious esthetic and sanitary standards. One possible design includes a special seat with a permanent plastic collector, a vacuum line to guide feces and remove gases, a freeze-dry processing unit, and a liquid separator to recover water.

Sleeping - Although ranges from 5-10 hours of sleep per 24 hr. day have been proposed, a sleeping period of 7½ hrs. is recommended. A sleeping bag arrangement is proposed which can be attached to the wall when in use to provide a stable position. When not in use they may be rolled up and stored in the bulk head. Sleepwear may be a matter of individual choice depending on the ability of the individual to be comfortable in the ambient temperature.

Exercise - Because of the weightless condition existing in such a trip ~~[illegible]~~ the muscles will need additional exercise to prevent atrophy. Such exercise will serve to maintain skeletal and cardiovascular system tone and control calcium mobilization. and mental alertness A time allotment of two hours per 24 hr. day should be sufficient for these purposes. Various types of exercise are possible. Gym ~~[illegible]~~ devices involving pulling against devices attached to the walls and/or floor can be utilized providing there be means to attach the man to the floor. Isometrics, massage and calisthenics (or) (with feet secured to the floor) are also all possible. It is recommended that a wide variety of activities be made available.

About 2 hrs. a day of

Recreation - Free time will be available to the crew during a Mars trip and should be ~~too~~ spent in free choice recreation. ~~This~~ This will provide needed diversion from work. A variety of things should be accessible. These include movies, books which can be in the form of microfilm, television sent from earth and games playable in free gravity. Tapes to and from home on earth will provide contact with friends.

An important consideration in the routine of daily ~~routine~~ duties is to provide a wide range of selection and diversification over such a long duration trip. To assist in this it is recommended that certain exercise equipment and recreation facilities not be made available until ~~a~~ after part of the journey has elapsed. Some films, books, etc. could be stored and not used initially. ~~This will~~ If done throughout the trip it will give needed variety at various intervals.

Time Allotment

Operating on 24 hr. days the following time allotments for major activities are proposed. These are, of course, subject to variations depending on the situation of the ship. During periods of ~~[illegible]~~ requiring intensive crew activity this schedule will have to be adjusted accordingly.

| | |
|---|---|
| Sleep | $7\frac{1}{2}$ hrs |
| Work (includes monitoring) | 8 " |
| Recreation | 2 " |
| Exercise | 2 " |
| Eating | 3 " |
| Hygiene | $1\frac{1}{2}$ " |