REPORT

of the

WORKING GROUP ON GEMINI-APOLLO MOL EXPERIMENTATION

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Space Science Board
National Academy of Sciences
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SUMMARY

A review of the planned bio-medical experiments for the Apollo and Gemini manned spaceflight programs was conducted by a Working Group from the Life Sciences Committee.

The review also included experiments planned for the Manned Orbiting Laboratory (U.S. Air Force) and the Orbiting Research Laboratory which will be covered in an addendum to this report to be submitted later.

At the request of the Life Sciences Committee, Space Science Board, an Ad hoc Working Group has undertaken to survey and evaluate biological experimentation in the Gemini-Apollo MOL manned spaceflight programs.

Relative to space flight, three classes of bio-medical investigation are contemplated:

1. Mission support experiments necessary to the success of the flight, by providing a maximum degree of safety for the flight crew. Such experiments stress clinical medical evaluation and are directed toward providing the information on which go, no-go, flight abort, and therapeutic decisions depend.
2. Experiments providing knowledge necessary to later missions. Such studies generally relate to the longer-term physiological and psychological effects of spaceflight.
3. Experiments in pure science which are designed to increase the general store of biological knowledge.

The limitations of spaceflight - limitations of weight, space, crew time, mobility and comfort - impose severe restrictions on the number and kind of experiments which may be used. Thus, it is particularly important to include those experiments - and only those experiments - from which the most information on biological effects of space may be obtained. This places a heavy burden on experimenters and administrators to develop a well-rounded, con-

cise, imaginative and farsighted program.

The Working Group has approached its evaluation of the biological programs with four objectives in mind:

1. To consider the experiments which have been proposed and, in particular, those which have been approved, in the light of their relative importance, design, and need, if any, for modification. Owing to the extremely wide range of disciplines under consideration, the Working Group has not considered itself competent to evaluate the merits of individual experiments, but rather to assess their general importance and relevance to needed information.
2. To note important gaps which may exist in the experimental program.
3. To identify any factors, scientific, administrative, or logistic, which could limit the effectiveness of the program.
4. To identify areas, if any, of unnecessary duplication.

The Working Group's study is still in process. The following report, based on three meetings with briefing sessions, represents a preliminary evaluation of the NASA Gemini-Apollo biomedical program. The Air Force Manned Orbiting Laboratory (MOL) project will be discussed in a future report. At its first

meeting in Washington on May 25, 1964, the Group was briefed by representatives of the NASA Offices of Manned Space Flight and of Space Science and Applications. A second briefing was conducted at the NASA Manned Spacecraft Center in Houston, July 16-17, 1964; reviews of the program were given by the Medical Operations Office, the Space Medicine Branch of the Crew Systems Division, and the Astronaut Activities Division. Further discussions were held with NASA officials on October 19, 1964 in Washington.

The NASA Manned Space Flight Program

The NASA program envisages three stages of manned space flight:

1. Gemini, a two-man, earth-orbiting series, will provide information on engineering and human capabilities in flights lasting 2 to 14 days.
2. Apollo, with three crew members, will begin with preparatory earth- and lunar-orbiting flights and will culminate in 14-day lunar landing missions.
3. Extended Apollo missions will continue exploration of the moon and will begin planetary flights.

Intercurrently, a series of Manned Orbiting Research Laboratories (MORL) may be initiated to supplement biological data from Gemini-Apollo and to obtain information on the effects of flights lasting

15-30 days. An unmanned biosatellite series, beginning in 1965, will study biological effects of space covering the spectrum from one-celled organisms through primates, with emphasis on the single and combined effects of radiation and weightlessness.

Consideration of Proposed Experiments*

The biological experiments scheduled for the Gemini program have been kept to a minimum and deal almost exclusively with mission support. Owing to the stringent space limitations of the Gemini capsule, a broader bio-medical program is probably not feasible. For the same reason, Apollo biological experimentation may have to be modest. The Working Group felt that the planned experiments should be adequate to assure mission safety from a medical standpoint, since they do provide minimum information on the three necessary areas of study: cardiovascular, metabolic, and central nervous system. The Working Group was surprised to learn that the Gemini biological experiments are still tentative. Notwithstanding apparently final published lists and the imminence of the flights, it appears that both the types of experiments to be performed and their actual performance is still subject to change. Neither the rationale nor the protocol for the experiments has been fully developed. Owing to the lead time necessary to efficient experimentation, and the importance of the studies, the Working Group considered this tentativeness

*For listing see Appendix A

to be unfortunate.

Possible Gaps in the Experimental Program

The bio-medical program as a whole appears to be quite limited in scope. The emphasis on mission support experiments, largely necessary in the Gemini program, is clear. Basic studies, which would stockpile information essential to the success of future missions, are given equal priority in theory but apparently not in practice. The variety and quality of the experiments planned to yield such basic information may be subject to improvement. The Working Group considered it of prime importance that basic studies be stressed as much as possible in the Apollo program, and particularly, in planning for the MORL and extended-Apollo program.

The fuller development of the rationale of the program - its precise objectives and the experiments required to obtain them - would, the Group believed, help to reveal specific gaps in the experimental program. It would also tend to put the program in long-term perspective where relative importances are clarified.

The Working Group further believed that greater efforts can be made to increase the number of outside experimental proposals. It was felt that possible sources of imaginative approaches and ideas in industry and universities have not yet been fully tapped.

Factors Which Might Limit the Effectiveness of the Program

a. The Criterion of Mission Success. The existing criterion in the Gemini-Apollo programs for the inclusion or omission of bio-medical experiments appears to be whether a given experiment is essential to the success of a given mission. The success of the mission would depend, in this connection, on the medical safety of the crew and on non-interference with essential tasks which the astronauts must perform. Thus, monitoring of temperature, blood pressure and respiration are deemed necessary, while the necessity for calcium tests is questioned. This criterion in the case of the Gemini capsule with its severely limited space may be justified. Certainly any unnecessary discomfort or inconvenience to the crew must always be avoided owing to the enormous demands being made on them. However, the criterion may be shortsighted: The ultimate purpose of all bio-medical investigations is to assure the well-being of all astronaut crews, not merely the crew of a given mission. Latent slowly developing deleterious effects of space flight may occur, and may be more harmful than those routinely anticipated. Failure adequately to provide for these contingencies would compromise the safety of future astronauts, and, quite possibly, the success of future missions. The Working Group believed, therefore, that a more satisfactory criterion for the inclusion or

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Note: During the course of this study a willingness of the astronauts to participate in bio-medical experiments on a non-interference basis has been noted.

omission of biological experiments is whether, within the constraints imposed by spacecraft and crew, they best provide the widest information on the physical and psychological effects of space flight.

b. Emphasis on Engineering Test. The Gemini-Apollo programs have two broad objectives: To develop and test engineering capabilities in space flight, such as rendezvous and docking techniques, and to obtain biological data. Since the engineering aspects of the program may be more complex and certainly require relatively more time, cost, and equipment, the temptation is strong to stress engineering considerations at the expense of biological objectives. The Working Group had the impression that such has occurred. Since both engineering and biological programs are essential - the engineering would be of little help if the crew were killed or incapacitated by the space environment - the Working Group felt that it would be unfortunate if relative importance were not clearly thought out and implemented.

c. The Ground-based Bio-medical Programs. The successful completion of in-flight biological experiments depends upon extensive ground-based facilities to provide 1) immediate mission support, 2) back-up support, 3) control experiments under both terrestrial and simulated space conditions, and 4) continuing research and development. At the present time, the NASA Manned Spacecraft Center at Houston is able to provide the first requirement, while arrangements have been made to utilize the aero-

space facilities at Brooks Air Force Base for Gemini back-up support. The Working Group learned that the Manned Spacecraft Center has not yet arranged a program for Gemini control experiments. Since in-flight biological findings are meaningless without base-line data acquired by control experiments, it is urgent that a suitable program be planned and carried out.

Owing largely to a lack of personnel, neither the Manned Spacecraft Center at Houston nor the NASA Office of Manned Space Flight in Washington has a program of the necessary scope for bio-medical research and the development of techniques and equipment. The Working Group agreed with NASA officials on the necessity either to have access to adequate facilities or to develop its own. Recruitment, even if manpower ceilings are raised, will present the principal difficulty to development of NASA facilities. The shortage of professional bio-medical personnel is such that the Working Group believed that NASA should continue to explore methods of alleviating this situation.

d. Outside Experiments. The receipt and utilization of outside proposals for Gemini bio-medical experiments have been very limited owing to the brief amount of time between the decision to include such experiments in the program and the deadlines imposed by selection, funding and engineering requirements. Partly as a result, the great majority of the proposals received were poorly conceived and prepared, rendering them unuseable. The Group felt that there is in any case the tendency - perhaps not confined to

biologists - to wait until the last moment and then to rush in with a poorly planned experiment. Procedures for submission and selection of experiments - in-house and outside - have alternated between being overly complex and overly informal.

e. Role of Principal Investigator. It was considered by some of the Working Group that clarification of the authority of the principal investigator would increase the efficiency of the program. In fact the special characteristics of experimentation with biological material may require reconsideration of the role of the principal investigator in the project team. While the project manager cannot avoid final responsibility for the conduct of the flight, it will often be necessary for him in close collaboration with the principal investigator, to take special precautions to ensure the success and validity of critical biological experiments.

The Working Group welcomed statements by NASA officials that the selection process and the forms for proposed experiments are to undergo substantial revision. It is suggested that the National Institutes of Health format be used for project proposals, and that review of the proposals be carried out first by the NIH Review or Study Panels, then by the NASA Medical Experiments Board and the Manned Space Flight Experiments Panel. Such a procedure would involve the expertise of specialists in the many fields covered by the bio-medical experiments and also take into account the physical limitations imposed by space flight constraints.

SUMMARY

The preliminary findings of the Ad hoc Working Group on Gemini-Apollo MOL Experimentation indicate the importance of broadening the scope of the biological program for manned space flight, developing a long-range blueprint of desired investigations, and clarifying the role of such investigations relative to the priorities of the space program as a whole.

APPENDIX A

Gemini Medical and Biological Experiments
(Source: Description of Gemini Experiments, NASA, April 13, 1964)

Cardiovascular Reflex:

To determine the effectiveness of the Graveline cuffs in preventing cardiovascular deterioration induced by prolonged weightlessness. Pneumatic cuffs on the astronaut's upper arms and thighs will be inflated to a prescribed pressure (approximately 50 mm of mercury) for five minutes every half hour while awake.

Cardiovascular Effects:

To establish the occurrence and degree of cardiovascular deterioration induced by prolonged weightlessness. Pre-flight tilt table measurements of pulse rate and blood pressure will be made to obtain baseline data. Similar tilt table measurements will be made post-flight, immediately after egress from the spacecraft and at prescribed intervals thereafter.

In-flight Exerciser:

To assess the general capacity of an astronaut to perform physical work under space flight conditions. The astronaut will carry out isotonic exercises twice every 24 hours for a half minute each by stretching a bungee cord. The cord will have crossbars at each end, one to be anchored between the feet, the other pulled. The arm, leg, back and shoulder muscles will be exercised by this method. Blood pressure will be measured before and after the exercise, and the pulse rate monitored continuously. The time required for heart rate

and blood pressure to return to pre-work levels is an index of the astronaut's general condition. Results will be compared with pre-flight baseline data.

In-flight Phonocardiogram:

To serve as a sensitive indicator of myocardial deterioration when compared with simultaneous electrocardiogram. Heart sounds will be detected by a phonocardiographic sensor at the cardiac apex and recorded on one channel of the bio-medical recorder. This tracing will be compared with the onset of the QRS complex of the ECG to determine the interval between electrical and mechanical systole of the heart muscle.

Biochemical Analysis of Body Fluids:

To determine the astronaut's reaction to space flight stress by means of analysis of excreted hormones. In-flight urine samples will be collected. Pre- and post-flight plasma samples - two or three daily - and timed urine samples will be collected for comparison.

Bone Demineralization:

To establish the occurrence and degree of bone demineralization resulting from prolonged weightlessness by a direct x-ray visualization technique. Three pre-flight and three post-flight x-ray exposures of the heel bone and tip of the little finger will be taken to determine whether a reduction in bone density has occurred.

Calcium Balance Study:

To establish the rate and amount of calcium lost by the body under conditions of orbital flight. Astronauts will be maintained on a 0.8 to 1.0 gram calcium diet for two weeks prior to flight, during flight, and for two weeks post-flight. Careful recording of intake and output will be required and 100 cc. aliquots of timed urine specimens will be analyzed. Dietary intake will be carefully analyzed for calcium content and a careful dietary record maintained. A mild laxative will be required post-flight. Two 5 cc. blood samples will be required before and after flight with approximately a week between each sample. Urine will be analyzed for phosphorus, nitrogen, other minerals and hydroxproline.

In-flight Electroencephalogram:

To assess the state of alertness, levels of consciousness, and depth of sleep of astronauts in-flight. The electrical activity of the cerebral cortex will be monitored by two pairs of nontraumatic scalp electrodes and recorded on two channels of the 7-channel biomedical tape recorder.

Vestibular Effects:

To measure changes in otolith function during prolonged weightlessness by determining the astronauts' ability to orient in the dark. Egocentric visual location will be measured before, during, and after the mission by means of special light-proof

goggles, one eye-piece of which contains a self-powered light source in the form of a moveable white line. With head fixed, the astronaut will position the white line with a calibrated knurled screw to what he judges to be the pitch axis of the spacecraft. The second astronaut will read and record the numbers. Sometime before and immediately after flight, ocular counter-rolling will be measured photographically by tilting the astronaut to one side.

Sea Urchin Egg Growth:

To evaluate the effects of weightlessness on the growth of simple cells. The eggs in four of the growth chambers will be fertilized shortly before launch, while those in the other four will be fertilized shortly after weightlessness begins. The growth of the eggs in each chamber will be fixed at prearranged times during the flight. Fertilizing and fixing is done by turning a knob at one end of the cylinder.

Radiation and Zero-G Effects on Blood:

To determine whether a synergistic relationship exists between the effects of weightlessness and radiation on human white blood cells. At sometime during the second orbit, a slide (a tissue culture containing white blood cells) will be manually actuated, placing the experimental material close to the radiation source. After an hour the slide is actuated, the material removed and placed in terminal culture. The material may be evaluated later.

IN-FLIGHT MEDICAL EXPERIMENTS

FOR APOLLO 204 AND 205

APOLLO 204

M-1A	(Cuffs)
M-5A	(Hormone Assay)
M-6A	(Bone Densitometry)
M-9A	(Vestibular Study)
M-12	(Parts a. and b. Bicycle Ergometer)
M-17	(Cardiac Output)
M-18	(Frank Lead ECG and VCG)
M-19	(Metabolism)
M-20	(Pulmonary Function)

APOLLO 205

M-4A	(Phono-ECG)
M-5A	(Hormone Assay)
M-6A	(Bone Densitometry)
M-7A	(Electrolyte Balance)
M-9A	(Vestibular Study)
M-11	(Cytogenetic and Immunological Studies of Blood)
M-12	(Bicycle Ergometer)
M-17	(Cardiac Output)
M-18	(Frank Lead ECG and VCG)
M-19	(Metabolism)
M-20	(Pulmonary Function)
M-21	(Semicircular Canal)
M-22	(RBC Survival Time)

IN-FLIGHT MEDICAL EXPERIMENTS

M-1 (Cuff Experiment)

M-3 (Calibrated Exercise Test)

M-4 (Phonoelectrocardiogram)

M-5 (Hormonal Studies - Steroids, Catechols, ADH)

M-6 (Bone Densitometry)

M-7 (Electrolyte Balance)

M-8 (EEG)

M-9 (Vestibular Study)

M-11 (Cytogenetic and Immunologic Blood Study)

M-12 (Bicycle Ergometer - a. As Preventive: b. As Provocative Test)

M-17 (Cardiac Output by Electrical Impedance)

M-18 (Vectorcardiography - Frank Leads)

M-19 (In-Flight Metabolic Rate)

M-20 (Pulmonary Function)

M-21 (Semicircular Canal Function)

M-22 (RBC Survival)

Operational Procedures -

M-2 (Tilt Table and Body Fluid Compartments)

M-10 (Astronaut Body Movement)

M-13 (Venous Compliance and Arteriolar Reactivity)

Under Consideration -

M-14 (Ear Oximeter)

M-15 (Performance Measurement)

M-16 (Nephelometer)

M-23 (Physical Fitness Following Weightlessness)

	GT-3	GT-4	GT-5	GT-6	GT-7	GT-8	GT-9	GT-10	GT-11	GT-12
M-1			X		X					
M-2	Include as Med. Ops. Procedure									
M-3		X	X		X					
M-4		X	X	X	X					
M-5				X	X	X	X	X	X	X
M-6		X	X		X					
M-7					X					
M-8					X		X			
M-9			X Part (A)		X					
M-10	Included as Operational Procedure									
M-13	Included as Med. Ops. Procedure									