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November 17, 1964

Dr. Sherman P. Vinograd
Director
Medical Science and Technology
National Aeronautics and Space Administration
Code MMD
Washington, D.C. 20546

Dear Dr. Vinograd:

Thank you for contributing "Medical Experiments in Gemini" to the November ASTRONAUTICS & AERONAUTICS. The article was succinct, informative, and very appropriate for the issue.

Enclosed is a copy of the issue, two tearsheets of your article, and a schedule of reprint costs. I hope that you found our treatment of the article satisfactory. If you have any suggestions or comments, please let me hear them.

Moreover, I hope you will bring to my attention other articles concerning life sciences that you think would be valuable and timely in the magazine. Life sciences and associated biomedical studies have some of the weaker areas of the space program. Why this should be so, I don't understand. Maybe I don't see the big picture. Would you let me know what you think about this? About the appropriateness and completeness of coverage of this work in the AIAA? The work reflected in other technical societies?

Sincerely,

John Newbauer

John Newbauer
Editor, A/A

JN:EG

Enclosures

Medical experiments in Gemini

They seek to attack methodically the critical questions of long-duration flight under weightlessness

By S. P. VINOGRAD, M.D.
NASA Office of Manned Space Flight

Ever since the space program began, and even before, when it was not much more than a budding idea, a multitude of questions have been asked and prognostications made concerning the welfare of man in space. Many of these, such as the predicted appearance of hallucinatory little green men, have since fallen by the wayside. Sensory deprivation in flight simply isn't that complete. Others, however, remain to be answered, and new ones framed in the reality of space-flight experience and ground-based research continue to be added.

In general terms, the goals of the medical-experiments program are these. To gain maximum insight into man's physiological and functional integrity as affected by prolonged existence in the space environment and to determine how best his missions there can be extended. This discussion reviews important generalities constituting the basic framework of the medical-experiments program, and describes the in-flight medical experiments scheduled for inclusion aboard manned Gemini flights.

Medical information gathered from man during space flights can be put into two primary categories. The first comes under the heading of medical-safety monitoring, better known in the field as "how goes it" information. In-flight, this calls for real-time telemetered data, since important and immediate decisions such as *go* or *no-go,* flight-abort, and therapeutic determinations depend entirely on this kind of intelligence.

The second type of medical information is more fundamental. Although it may be of little importance to the successful completion of the particular flight from which it is gathered, it is essential to the planning of subsequent missions and future space programs. It is to this second area that the medical-experiments program is primarily addressed.

The fundamental issue which we face in this over-all effort is the ability of man and machine to support prolonged manned flights, such as those of a year or more. The Office of Manned Space Flight has elected to resolve this issue by step-wise extension of manned flights. The medical-experiments program must take maximum advantage of each incremental mission to spot potential problem areas, establish quantitative trends, and prepare effective preventive measures. This requires careful planning.

The incorporation of experiments into the spacecraft and the mission involves attention to many engineering and operational constraints. Important among these are such technical factors as volume, weight, power, and telemetering or tape-recording requirements, and such operational factors as time requirements, noninterference with other mission objectives or the astronauts' freedom of motion, ease of performance, and ground-support requirements. Space-flight experiments, it is clear, not only require the usual attention to such things as control data, isolation of variables, and statistical significance of resultant data, but also thoughtful consideration of these engineering and operational limitations. Potential medical experiments are therefore screened from the standpoint of relative importance to our basic goal, validity, and reliability of experimental design, and finally, technical and operational feasibility.

Although many questions have arisen and many problem areas remain to be settled, the only stress factor of space flight which cannot be duplicated in an Earth environment is prolonged weightlessness. Consequently, the major stresses which warrant in-flight medical experiments relate to weightlessness, itself, and combinations of it with other factors. The box on next page gives a fairly comprehensive list of these potential stress factors. Even with respect to such poorly defined conditions as ionizing radiation, magnetic-field altera-

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is OMSF director of Medical Science and Technology, Space Medicine. In this capacity, as well as in his last position, he is concerned chiefly with medical and biological factors involved in man's exploration of space. He is responsible also for the biomedical experiments to be included on manned space flights. Prior to his affiliation with NASA, dating from 1961, Dr. Vinograd practiced privately, specializing in internal medicine. From 1955 to 1960, he was an assistant professor of clinical medicine, Univ. of Wisconsin Medical School.

tions, and micrometeoroid hazards, once the environment is defined, these questions, too, can be studied rather thoroughly on the ground.

Of the possible effects of prolonged weightlessness, it is perhaps safe to say that those most seriously anticipated are cardiovascular deterioration, dehydration, bone demineralization, and muscle atrophy. All of these with the exception of dehydration are disuse phenomena which have been observed repeatedly during bedrest and water-immersion studies. Other possible effects, however, are far from excluded from consideration—respiratory, vestibular, metabolic, peristaltic, ciliary, "alertness," and, of comprehensive importance, effects on total performance. All of these deserve and are receiving further study.

With respect to disuse effects, overt manifestation would be most likely to occur during the high-*g* stress of re-entry or the sustained 1-*g* stress of terrestrial existence resumed on landing.

In-flight medical experiments are designed to investigate these potential problem areas with the following four key objectives in mind: To determine the human effects of space flight, the mechanisms by which these effects are manifested, means of predicting the onset and severity of these effects, and the most effective and practical means by which these effects can be prevented or remedied.

In-flight medical-experiments, like any valid experiments, call for the comparing of experimental (flight) with control or baseline data. Baseline data consist of astronaut information obtained during the process of medical selection, centrifuge runs, pressure-chamber runs, simulation and trainer activity, numerous physical examinations, and special preflight control studies for specific in-flight medical experiments.

Further control data comes from an active program of ground-based medical experiments involving nonastronaut subjects. Some of these include absolute bed rest used to approximate weightlessness. With the body in the horizontal position, the cardiovascular system need not support the weight of the column of blood, nor the musculoskeletal system, the weight of the body in the long axis. Bed-rest subjects provide a great variety of data on the cardiovascular system, endocrine system, general metabolism, bone and muscle metabolism, and fluid and electrolyte balance. These studies also serve as a trial for provocative tests such as the tilt-table procedure, muscular exercise and calibrated ValSalva maneuver, and various preventive techniques, such as extended muscular exercise and Graveline cuffs.

SPACE-FLIGHT ENVIRONMENTAL FACTORS

Weightlessness
Radiation
Confinement
Social restriction
Monotony
Threat of danger
Artificial atmosphere
Toxic substances
Particulate matter (in weightlessness)
Microorganisms
Change in circadian rhythms
Magnetic fields
Ultraviolet exposure
Infrared exposure
Noise

Other ground-based efforts range from the study of the EEG as a measure of alertness and depth of sleep to the study of the phonoelectrocardiograph and similar methods to time the phases of cardiac activity. One particular study series perhaps worthy of mention here involves medical monitoring of individuals under stress, such as participants in skydiving, sportscar racing, hockey, and even bullfighting. The results of these studies have been of considerable assistance in assessing and evaluating the relative importance of physiological events observed in manned space flight.

Turning now to the Gemini program, medical safety monitoring will again incorporate the same four measurements made in Project Mercury (ECG, respiration, temperature, and blood pressure), but with some modification of equipment. Miniaturized signal conditioners, inserted into the bioinstrumentation circuit and worn inside the pressure suit, have been shown to produce an improved signal, and a greater degree of accuracy and reproducibility of the records obtained. A new tape recorder, very light and compact, has also been developed for the Gemini program. It will record seven channels of data for an extended period of time, both medical safety and experimental data.

The Gemini in-flight medical experiments program now consists of a total of nine experiments, five relating to the cardiovascular system, two concerned with bone metabolism and electrolyte balance, one on EEG, and one on vestibular function.

Before any experiment—medical, basic biological, or physical—can be carried aboard a manned space vehicle, it must first pass a high-level board, the Manned Space Flight Experiments Board. Board action is requested only after priorities have been established and the experiments have been screened for scientific validity and reliability. Board recommendations for approval of all in-flight experiments are of necessity provisional at this point, final approval depending on a determination of feasibility of the final flight equipment and operational plan. The very long lead times required for engineering of experimental hardware for the spacecraft and fitting the experimental procedures into the operational flight plan make early programming essential. Yet, considering that the results of early flights may necessitate changes in experiments now planned for later flights, the reason is clear for retaining some degree of flexibility in these long-range planning methods.

What exactly will the Gemini in-flight medical experiments (see box on page 72) be like?

M-1 is a study of the effectiveness of a cardiovascular preventive measure. It consists of the application of inflatable cuffs to the upper portions of the lower extremities (upper thighs) as a countermeasure to possible cardiovascular deterioration. The cuffs will be applied to one astronaut and his cardiovascular evaluation will be compared with the other, uncuffed astronaut. This experiment is based on the work of Graveline, who in 1961 demonstrated the effectiveness of similar cuffs in preventing the degradation of tilt-table tolerance following water immersion.[1] The intermittent inflation of the cuffs is thought to act beneficially by preventing or slowing the redistribution of blood volume within the body, and also by exercising the venous network of the lower extremities to maintain tone. Optimal level of inflation, duration of inflation, and interval between periods of inflation are currently being worked out by means of bed-rest studies.

M-2 is the tilt-table study done before and after flight as in MA-9, Cooper's flight.[2] This is essentially a provocative test which brings out incipient changes in cardiovascular responsiveness. Heart rate as obtained by continuous recording of the electrocardiogram and a rapid succession of blood-pressure measurements are obtained while the subject is in a horizontal position for 4 min, is passively raised to the 70-deg (off of horizontal) position for 5 min, and is returned to the horizontal position for 4 min. As a part of this experiment, blood volume, and perhaps total body water and interstitial fluid volume determinations, will also be made before and after flight.

M-3 is the in-flight exercise test performed as in Project Mercury with the bungee cord,[2,3] which requires a 60-lb pull to stretch it to its limit of 1 ft. In Gemini, the cord will be held by loops about the feet rather than attached to the floor of the vehicle, as it was in Mercury. Present plans call for an exercise of one 60-ft-lb stretch per second for a period of 60 sec. Pre- and post-work heart rates, respiratory rates, and blood pressures will be evaluated. In this experiment, it should be pointed out, exercise is used as an in-flight provocative test rather than as a preventive or remedial measure.

M-4 is the in-flight phonocardiogram—the visual recording of heart sounds. In this experimental procedure, comparison of the phonocardiographic trace with the electrocardiogram taken concurrently may provide a sensitive indication of small changes in heart-muscle response, by defining the timing of events of mechanical systole, as indicated in the work of Agress and others.[4]

M-5 is the examination of body fluids for hormonal assays; that is, before and after flight blood and urine, and in-flight urine specimen examinations for steroids, adrenalin, norephinephrine, and also antidiuretic hormone. ADH assays may yield important clues to the mechanism of body-fluid shifts in prolonged weightlessness, as suggested by the work of Henry and Gauer.[5] The norephinephrine determinations may provide a clue to the mechanism of the cardiovascular response to weightlessness, since this substance is discharged at the neurovascular junctions.

M-6 is the use of bone densitometry, a special x-ray technique devised to determine the degree of calcification of bones. As presently planned, the Os Calcis (heel bone) and the distal phalanx of the right fifth finger will be x-rayed by this technique before and after flight to determine whether any demineralization has taken place and, if so, to what extent. The anticipation of the possibility of loss of calcium from the bones during weightless flight is based on years of clinical experience with patients confined to bed or in casts. Whether a similar problem occurs during prolonged weightlessness remains to be seen. Although no calcium problem has been demonstrated thus far in weightlessness, we must remain alert to it as flight durations increase.

GEMINI IN-FLIGHT MEDICAL EXPERIMENTS

M-1 Cardiovascular Reflex Conditioning Experiment: Cuffs
M-2 Cardiovascular Effects of Space Flight: Tilt Table
M-3 In-flight Exercise: Work Tolerance
M-4 In-flight Phonocardiogram
M-5 Biochemical Analysis of Body Fluids: Steroids: Catechols: ADH
M-6 Bone Densitometry
M-7 Electrolyte Balance Studies
M-8 In-flight Electroencephalogram (EEG)
M-9 Vestibular Experiment

M-7 is a calcium-balance study, a very closely controlled total calcium intake and output study planned to reveal changes in the mobilization and metabolism of calcium under weightless conditions. Nitrogen, phosphorus, potassium, sodium, and magnesium balance will be ascertained at the same time, as will the output of hydroxyproline, the primary amino acid constituent of bone matrix. Including the evaluation of these electrolytes with the calcium-balance study, imposes no additional requirement on the flight protocol or on the astronaut, as the assays are made in the laboratory on the same food and waste specimens. The determination of nitrogen balance may provide pertinent information concerning muscle atrophy. Important baseline data relative to calcium balance has already been supplied as far back as the classical bed-rest study of Dietrick, Whedon, and Shorr in 1947, and continues to be augmented by current ground-based studies.[6]

M-8 is the study of in-flight electroencephalography. To date, we have had no first-hand knowledge of the appearance of the electroencephalogram in weightless man. This experiment will help to verify or refute Russian reports of EEG changes occurring in their long-duration missions.[7] Even if found, their significance will remain to be determined. It is also possible that the EEG may later prove to be of practical value to help quantitate the state of alertness, and depth of sleep.

M-9 is a vestibular experiment patterned after a great deal of baseline investigative work by Graybiel of the Naval School of Aviation Medicine.[8] It is designed to shed some light on the activity of the otolith mechanism of the internal ear during flight, as there is evidence to support the view that this gravity-dependent sensing mechanism for linear acceleration does not function in the absence of gravity.

Experiment is set up to identify and quantitate this phenomenon, and has two parts. The first is to determine the degree of ocular counter-rolling by special photography when the flight-crew members are placed in a sideward tilt position before and after flight. The second is to determine egocentric visual location of the horizon in flight. This will be done by means of a goggle-like blindfold which contains a rotatable illuminated white line. At various times during the flight the astronauts, alternately, will don this instrument and rotate the white line by means of a calibrated knurled screw at the side to an estimate of the horizontal (pitch) axis of the spacecraft. The other astronaut will take the readings. The degree to which the subject approximates the horizontal relates directly to the activity of the otolith mechanism, according to baseline investigational work.[8]

Future in-flight medical investigations will aim at further amplifying existing knowledge in the general areas outlined earlier. This does not, of course, preclude the addition of experiments addressed to unforeseen problems. In the entire program of medical observations of man in space, the development of measurements and methods of sufficient sensitivity to enable the detection of early trends of changes, whether anticipated or unanticipated, continues to receive close attention.

By employing a well-planned program of baseline studies and carefully selecting groups of medical experiments within the constraints of each mission, it is the design of the NASA Inflight Medical Experiments Program to gather pertinent and valid information concerning the effects of prolonged space flight on men. Potential problems have been both overstated and understated many times in the past. The logical antidote, in our view, is to find out.

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Simulating Gemini-Agena docking

Moving- and fixed-base simulator experiments show that the astronauts will be able to develop the skill for visual docking day or night

By HOWARD G. HATCH JR., DONALD R. RILEY, and JERE B. COBB
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Developing the necessary techniques and demonstrating the ability of human pilots to use them for docking two vehicles in space represents a prime mission of the Gemini program. Accomplishing this will not only insure success of the lunar-orbit-rendezvous technique for exploration of the Moon but other space missions as well.

At present, man's capabilities and limitations in space operations are relatively unexplored. Project Mercury experience has shown that man can contribute significantly to a successful mission. In Project Gemini, man's role will be expanded. Besides duties as an observer, systems monitor, and systems backup, the astronaut will be utilized as a primary system in the docking phase of orbital rendezvous. For this operation, he will serve as the primary system for information gathering, guidance logic, and control application.

Although final verification of the success of this increased human participation in space operations must await actual flights, ground-based simulators are being used extensively to explore the wide range of operational situations that the astronaut could encounter. Full-scale simulations of the docking of the Gemini spacecraft and Agena target have recently been completed at the NASA Langley Research Center using both fixed- and moving-base simulators. This article presents research results with both simulations for pilot ability to dock successfully, piloting techniques, and performance with the pilot using only visual observation of the Agena target for guidance information. Both rate-command (primary) and acceleration-command (backup) modes for attitude control have been investigated, as well as the effects of control-jet malfunctions and target lighting conditions.

The Simulators. The moving-base simulator, shown on page 75, consisted of a full-scale Gemini model mounted in a hydraulically driven gimbal system suspended by eight supporting cables from an electrically driven overhead carriage.[1] A dolly mounted on the main carriage provided lateral motion while the whole system moved longitudinally. A cable drum on the dolly reeled and unreeled the cables for vertical motion. The cable arrangement and attachment angles were designed to prevent penduluming. The system allowed the pilot to move in six degrees of freedom, which he controlled from the capsule through a ground-based analog computer.

The full-scale Agena target model did not move. It was suspended by a single cable and held in place by four stabilizing cables. Three models of the Agena, shown on page 75, were used during the program. The first was a lightweight model of wood and paper used during the initial checkout and familiarization to reduce chances of pilot injury in the event of a high-speed collision. After the familiarization period, the metal model was used because it had a more realistic spring-mounted docking ring. The third model, constructed by McDonnell Aircraft, was an actual mockup of the Agena docking ring.

The fixed-base simulator, illustrated on page 76, employed a modified Air Force F-151 gunnery trainer and a full-scale wooden mockup of the Gemini vehicle housed in a 20-ft-diam spherical projection screen. A closed circuit television system and a two-axis mirror projected a full-size image of the Agena target on the screen. A small model of the Agena target having three angular degrees of freedom was mounted on a range bed in front of the TV pickup camera. By a combination of model and mirror movements, a full six degrees of freedom was obtained and commanded through analog computing equipment.

Gemini Orbital-attitude and Maneuvering Control System (OAMS). This is the propulsion system used to control Gemini in orbit. The OAMS control jets reside in the adapter attached to the re-entry module, as shown in the sketches on page 76. There are 16 jets, eight for translation and eight for attitude. Because of CG location, having all the control jets on the adapter allows control coupling between translation and rotation. Thus, in terms of motion of the body axes, when a vertical or lateral translation is commanded, a pitch or yaw rotation will also occur. Similarly, when pitch

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