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INTRODUCTION

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Mission simulation has come to be a critical ingredient in the development and preparation for a space mission. In the early Mercury program, however, this was not so. Although astronaut procedures were carefully rehearsed, there was no great need to simulate all aspects of a flight. It was not until the Gemini program that the need for ground-based simulation became increasingly apparent. The experience of astronaut Charles Conrad in Gemini 11 showed that extravehicular activities which seemed reasonable during mission planning could prove quite exhausting when performed in zero gravity and outside a spacecraft. The success of astronaut Edwin Aldrin in performing comparable EVA tasks in Gemini 12 was in large measure due to extensive underwater simulation and training. This simulation allowed the development of a more meaningful timeline of astronaut tasks.

Too many words

For the Apollo lunar missions, the need for simulation increased. There were certain points in the mission, such as the landing of the Lunar Module, in which precise astronaut performance was required. The only way in which the necessary skill could be developed was through use of simulation techniques which duplicated at least that part of the mission sequence. A number of variations of lunar landing trainers were developed to meet this particular need. Thus, by the time of the first actual landing on the Moon, all critical mission points could be simulated with reasonable fidelity.

The Skylab Medical Experiments Altitude Test represents a ~~quantum~~ logical step forward in the progress of simulation procedures for mission support. The SMEAT Program was a simulation of a 56-day Skylab mission and was conducted at the Johnson Space Center. This simulation, in which three members of the astronaut corps served as subjects, provided an excellent test bed for the evaluation of crew procedures, flight equipment, and mission support. In many respects, the SMEAT Program was a separate space mission in its own right. It was unique in the extent to which it approximated full simulation of a space mission. The physical facility was quite similar to that of Skylab; the atmosphere was identical; crew activities were fully representative; the timeline of events was that of an operational mission; and full mission support was provided, just as would be the case in Skylab.

Facts not words

The antecedent of Skylab, and SMEAT, reach into the early days of space activity. At that time there were two fundamental questions to be answered. The first of these was "Is it possible to send man into space and recover him unharmed?" The affirmative answer to this question now has been demonstrated many times. The second question was "Can man live and perform efficiently in space over long periods of time?" There is not as yet a definitive answer for this question. Although results of earlier flights, such

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as the 14-day Gemini 7 mission, are very encouraging, the information obtained does not provide a clear picture of the changes produced in man by exposure to the space flight environment and of his readjustment to the earth environment upon return.

Major manned space missions of the future can be planned only if the conditions assuring man's well being and effectiveness are assured. Even the relatively short space activities to date, such as the Apollo missions, make it clear that changes take place in the major physiological systems of the body during exposure to space. The true nature of these changes is yet to be determined. It is not known at this time whether they represent the beginnings of a gradual process of deterioration or whether they are adjustments leading to a new adaptive state. If the latter should be true, it will be necessary to obtain an accurate time profile of this adaptation process and, further, to assess the changes brought about during the period of readaptation following return to earth.

One of the primary objectives of the Skylab Program is to allow better observation of man-in-space than has been the case. This program affords an opportunity to study biomedical questions in depth. The 28- and 56-day missions are sufficiently long for one to observe any critical changes and to make detailed records of the progress of gradual alterations in basic biological processes.

In early planning for the Skylab biomedical program, a move was initiated to consolidate the list of proposed medical research measurements into five principal categories, each of the five to be related to a major physiological system. Thus, measurements relating to the performance of the cardiovascular system were organized so that they together would comprise a flight experiment, the ultimate meaning of which would be greater than the sum of the knowledge gained from individual measures if the latter were to be conducted out of context. Similarly organized were measurements relating to the musculoskeletal system, the nervous system, the renal-endocrine-mineral system, and the respiratory-metabolic system. Under this philosophy, a set of Experiment Implementation Plans were prepared for approval by the NASA Manned Space Flight Experiments Board. As preparations for Skylab proceeded, it was necessary to make a number of changes in the organization of the measurement program, particularly where complex hardware or instrumentation systems made desirable a separately identifiable task to speed implementation and to reduce cost. However, the overall biomedical measurement program still adheres to the philosophy that the sum of these measurements should provide an accurate and detailed assessment of both gross and subtle changes which might occur within the major physiological systems of the body.

Program Objectives

The objective of the Skylab Medical Experiments Altitude Test was to provide a nearly full-scale simulation of a 56-day Skylab mission. Through this simulation, all crew procedures and equipment operations could be validated, all components of the life support system could be tested, and final training for both crewmembers and support personnel could be conducted. Of particular importance was the opportunity to test and refine data collection techniques for, after all, the entire raison d'être for Skylab lies in its ability to return meaningful measurements.

For program planning, six specific objectives were listed for SMEAT, as follows:

1. Obtain and evaluate baseline medical data for up to 56 days for those medical experiments which reflect the effects of the Skylab environment. SMEAT simulates the Skylab environment in terms of all major parameters except one, weightlessness. The atmosphere, the work program, and the social environment all were essentially identical to that of Skylab. Therefore, it was considered quite important to obtain baseline biomedical measures as well as data from all major medical experiments to provide a baseline against which one could compare later results from Skylab missions. In this manner, an indication could be gained concerning the biomedical importance of weightlessness per se as an experimental variable.

2. Evaluate selected experiments hardware, systems, and ancillary equipment. This proved to be an invaluable part of the SMEAT effort. Many instances were found in which specific hardware items failed to function appropriately. In other cases, use of the hardware made it obvious that its utility and acceptance could be increased through a redesign program. Certain items of equipment, such as the urine collection system, underwent extensive redesign subsequent to SMEAT and prior to use in the Skylab Program.

3. Evaluate data reduction and data handling procedures in a mission duration time frame. To meet this objective, all constraints imposed by an actual mission were included, even for such matters as dumping data only at times when such would be possible during a mission.

4. Evaluate preflight and postflight medical support operations, procedures, and equipment. This was considered particularly important in view of the heavy biomedical orientation for the first manned Skylab mission. To this end, a flight surgeon remained in attendance at Mission Control during the entire period of SMEAT.

5. Evaluate medical in-flight experiment operating procedures. SMEAT involved use of actual Skylab medical experiment hardware as it would be installed in Skylab and with the requirement to provide usable measurements. Changes were made in this equipment subsequent to SMEAT only to improve accuracy of data collection.

6. Train Skylab medical operations team for participation during the flight. In fact, the training benefit of SMEAT proved to be considerably greater than indicated by this objective. All management and support personnel received invaluable training for Skylab during the conduct of SMEAT.

Program Plans

Formal plans for a Skylab Medical Experiments Altitude Test were approved in February 1971, although initial planning had been going on for some time prior to this. Following the approval of the test plan, an intensive program was undertaken, largely under the direction of the Marshall Space Flight Center, leading to the development of Skylab medical experiments hardware. These equipment items were delivered to the Johnson Space Center in early 1972 and served as the test equipment for the SMEAT program.

The SMEAT test was conducted in three phases: prechamber, beginning six months prior to the chamber test; chamber test, lasting for 56 days; and postchamber, extending for 21 days after completion of the chamber test. The actual chamber test began on 26 July 1972. During this test, Skylab mission procedures were used to the fullest extent possible. The test was conducted in a cylindrical, 20-foot diameter vacuum chamber at the Johnson Space Center. This chamber was configured to resemble the part of the Skylab in the Orbiting Workshop (OWS) referred to as the Crew Quarters. Skylab mission procedures were used to the fullest extent possible. All communications with astronauts, for example, were relayed through the CAPCOM communication technique. Crew support procedures, such as those for food service and personal hygiene, also were structured in close accordance with those of Skylab. The following sections describe the major medical experiments (MO's) and the detailed test objectives (DTO's) accomplished during the SMEAT program.

Skylab Medical Experiments

Cardiovascular/Hemodynamic

M092 Lower Body Negative Pressure - to obtain baseline ground-based data concerning the time course of cardiovascular deconditioning during long term confinement and to predict the degree of physical impairment that is to be expected upon return to normal activity. To obtain verification of procedures and crew operational capability.

M093 Vectorcardiogram - to determine reference data and changes in the electrical activity of the heart caused by exposure to the Skylab atmosphere and other specific stressors. To correlate the changes that are detected with those known to occur after specific stress in normal environments.

M111 Cytogenetic Studies of Blood - to determine the preflight and postflight chromosome aberration frequencies in the peripheral blood leukocytes of the Skylab crewmen. Because chromosome aberration yields of peripheral leukocytes have been sensitive indicators of radiation exposure, this experiment could also be used to assess the radiation exposure of the crewmen.

M112 Hematology and Immunology - to determine the effects of space flight on the hormonal and cellular aspects of immunity and to detect quantitative and qualitative changes in the immunoglobulins and related proteins and lymphocyte functions. Of special interest are measurements that contribute to man's ability to combat infections and repair traumatized tissues after exposure to the space environment.

M113 Blood Volume and Red Cell Life Span - to determine changes in red cell mass, red cell production, and red cell survival caused by a Skylab environment. Experiment will also provide analytical information in the form of plasma volume shift data that may offer insight into the mechanism of cardiovascular deconditioning and orthostasis.

M114 Red Blood Cell Metabolism - to determine the causes of any changes in red cell metabolism and in membrane integrity in man as a result of long term confinement in a space environment.

M115 Special Hematologic Effects - to examine critical physio-chemical hematological parameters relative to the maintenance of homeostasis and to evaluate the effects of space flight on these parameters. Also to provide essential hematologic data that will be useful in the interpretation of data from the other M110 series experiments.

Musculoskeletal/Metabolic

M071 Mineral Balance - to determine the effects of space flight on musculoskeletal metabolism by measuring the daily gains or losses of pertinent biochemical substances. Substances measured included calcium, phosphorus, magnesium, sodium, potassium, chlorine, nitrogen, urea, hydroxyproline, and creatinine.

M074 Specimen Man Measurement - to demonstrate the capability of accurately weighing masses as great as 1,000 grams in a zero-g environment. The experiment provides a means for the accurate determination of the mass of feces, vomitus, and food residue generated in flight.

M078 Bone Mineral Measurement - to measure bone mineral changes that result from exposure to weightlessness. Mineral measurements were taken of the left os calcis and right radius of each crewman; measurements were taken prechamber and postchamber.

M171 Metabolic Activity - to evaluate the metabolic rate measurements of man while resting or doing work during prolonged exposure to the spacecraft atmosphere and to compare these results with those obtained in normal sea level environments.

M172 Body Mass Measurement - has two purposes: (1) demonstrate body mass measurement in a zero-g environment and validate the design of the body mass measuring device; and (2) support the medical experiments that require body mass measurements (M071, M073, M171).

Endocrine/Electrolyte

M073 Bioassay of Body Fluids - to evaluate the endocrinological inventory resulting from exposure to space flight environment, foods, and work loads for extended periods. Also, to facilitate identification of changes in hormonal and associated fluid and electrolyte parameters as indicated in samples of the blood and urine of the crewmen.

Neurophysiology

M131 Human Vestibular Function - to determine the effects of prolonged weightlessness on man's susceptibility to motion sickness and on his judgment of spatial coordination.

M133 Sleep Monitoring - to evaluate objectively the quantity and quality of inflight sleep by means of an analysis of electroencephalographic (EEG) and electrooculographic (EOG) activity. Head movement, EEG, and EOG data were taken from a crewman during several regularly scheduled 8-hour sleep periods.

M151 Time and Motion Study - to evaluate the differences, correlation, and relative consistency between ground-based and inflight task performance of crewmen as measured by time and motion determinations.

Detailed Test Objectives

Habitability Considerations

DTO71-7 and DTO71-8 Food Tray and SMEAT Food System - to test the acceptability of the food items developed for Skylab, the reliability of their packaging, and the functional adequacy of food serving, preparation, storage, and clean up procedures. A special serving pedestal and tray and specialized utensils were used and evaluated.

DTO71-21 SMEAT Shower - to test the adequacy of weekly whole body cleansing during 56 days of confinement in a Skylab-type environment. The SMEAT shower was similar but not identical to the Skylab counterpart. A hand-held nozzle supplied six pounds of water per shower.

DTO71-29 Housekeeping - to test the adequacy of a housekeeping system for keeping the Skylab-like chamber clean by use of the Apollo-developed vacuum cleaner, wipes, tissues, disinfectant pads, and soap.

DTO71-30 Personal Hygiene - to test the effectiveness of the Skylab personal hygiene kit to maintain an acceptable degree of bodily cleanliness between weekly showers. The kit consisted of wash cloths, soap, razor, and tooth brush.

DTO71-27 Skylab Urine System Operational Evaluation - to evaluate the urine collection system to be flown in the orbital workshop.

Physiology/Health

DTO71-2 Effects of Skylab Medical Experiments Altitude Test on the Oral Health of Crewmen - to compare the microbial population dynamics in the mouths of SMEAT crewmen before, during and after the 56-day trial and to determine clinically the effects of space simulated environments on all health, preexisting dental cares, periodontal disease.

DTO71-18 Tests of the Inflight Microbiology Unit - to evaluate the performance of the IMMU, and equipment system design to perform basic diagnostic microbiology tests during the Skylab mission.

DTO71-19 Crew Microbiology and DTO71-28 Chamber Microbial Monitoring - to examine the effects of confinement in a semi-closed ecosystem, the Skylab diet, and the Skylab atmosphere with its reduced barometric pressure on crew microbial burdens and on the microbial biology of the SMEAT chamber.

DTO71-20 Operational Bioinstrumentation System - to test the Operational Bioinstrumentation System prior to its use in Skylab. The system is designed to obtain physiological data during launch, extravehicular activity, and return mission phases. The OBS can also provide full time monitoring for an ill crewman. In SMEAT, the OBS was tested principally during exercise.

DTO71-33 Stereometric Body Volume Measurement - to compute whole-body volume, limb volumes, and volume distribution curves before and after the SMEAT chamber confinement by a noncontact method to reveal the nutritional condition of the body. These data are helpful also for assessing neuromuscular and cardiovascular condition.

Atmosphere Purification and Control Systems

DT071-4 SMEAT Chamber Atmosphere Analysis for Trace Contaminants - to identify and quantitate trace contaminants in the SMEAT chamber atmosphere throughout the test to insure the safety of the crew from toxicological hazards and to alert the existence of any hazardous condition.

DT071-5 Carbon Monoxide Monitor - to evaluate the performance of the contact device for measuring the concentration of carbon monoxide in the habitable areas of spacecraft and for warning of dangerous levels by visual and audible indications.

DT071-6 Carbon Dioxide/Dewpoint Monitor - to evaluate the Skylab flight configuration portable carbon dioxide/dewpoint monitor from the point of view of performance and procedures used for making measurements with the instrument. This test also provided data on variations in carbon dioxide and dewpoint concentrations in a chamber configuration similar to Skylab in volume and geometry.

DT071-26 Aerosol Analysis - to provide real time count of particles in the SMEAT atmosphere by use of a small unit with a display readout available for crew use. Postflight examination of filters to determine the composition and probable source of particulate contaminants was a part of this effort.

DTO71-32 Command Module Carbon Dioxide and Odor Absorber Element Exposure Test - to determine the stowage requirements for odor absorber elements designed for use in Skylab. This test was designed to verify whether the Skylab atmosphere causes unacceptable degradation of the carbon dioxide and odor absorber elements.

Data Acquisition

DTO71-23 Skylab Data Acquisition Simulation - to test, on a noninterference basis, the operational procedures involved in acquiring and processing biomedical experiment data in a mode approaching that planned for Skylab.

SMEAT Results

The SMEAT Program lasted for the full 56-day period for which it was scheduled. No major problems were encountered that threatened its success. A number of problems did develop, however, which required correction prior to the launch of Skylab. In fact, it is generally concluded that the full attainment of Skylab objectives would be in some question were it not for the contribution of SMEAT. These contributions were in the five areas of:

1. Operating procedures. The SMEAT test provided an opportunity to conduct full team training and to evaluate all procedures in a full mission context. As a result, a Skylab "team" was developed which acquired both a mission identity and a confidence concerning its capabilities for mission control and support. There is no question but that major improvements were made in team communication procedures and coordination during SMEAT. As a result, Skylab could be approached with a sense of complete preparedness.

2. Baseline biomedical data. Usable information was obtained from virtually all of the major medical experiments to be conducted in Skylab. These data are presented in summary form in later sections of this report. Although different astronauts will participate in the actual Skylab missions, the data obtained from the three crewmembers of SMEAT will prove invaluable when scientists attempt to differentiate between effects of weightlessness and those effects due to other features of the space environment.

was thought to be the case prior to the SMEAT test. In general, however, the three crewmembers of SMEAT performed excellently and provided a fund of data from which to draw for the improvement of Skylab procedures and equipment.