SEPTEMBER 1, 1969

EXPERIMENT PROGRAM FOR EXTENDED EARTH ORBITAL MISSIONS

VOLUME II

ENGINEERING AND TECHNOLOGY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

EXPERIMENT PROGRAM

FOR

EXTENDED EARTH ORBITAL MISSIONS

REVISION NO. 1

To The

"Experiment Program For Manned Orbital Workshops"

Dated August 14, 1968

September 1, 1969

PAYLOADS DIRECTORATE
ADVANCED MANNED MISSIONS PROGRAM
OFFICE OF MANNED SPACE FLIGHT

PREFACE TO FIRST REVISION

The material contained in the two volumes comprising the experiment program for manned earth orbital missions represents the results of planning within NASA for the experiments, payloads and research facilities to be conducted on earth orbital missions of the 1970's and early 1980's. As such it is a compendium of program office views with respect to anticipated needs and requirements for experiments to be considered for flight in that time period.

The first revision reflects a very considerable effort extending the draft version of the "Experiment Program for Manned Orbital Workshops" (Yellow Book), dated August 14, 1968. Requirement for this revision was based upon a need to review, reexamine and extend the original Yellow Book material which included the disciplines of Astronomy, Earth Applications, Space Biology and Space Physics plus a need for extension of the experiment program to embrace the disciplines of Aerospace Medicine, Advanced Technology and Materials Processing/Space Manufacturing. These changes, revisions and additions have now been accomplished, to an acceptable though incomplete degree in some cases, and are reflected in these documents.

The original Yellow Book was used as the basis for a number of advance planning activities; in particular the PSG Working Groups and as source material for space station candidate experiment programs. This and similar uses are expected to continue in the future. In addition, a continuing requirement exists to maintain in one document, as complete a set of proposed experiments as possible, together with the description and requirements for these experiments, for use by the program offices and field centers in future extended earth orbital planning and design effort.

Preparation of this document, as with the predecessor document, was accomplished with and through the appropriate program offices of NASA. Thus, the Office of Advanced Research and Technology and the Office of Space Science and Applications have made important and valuable contributions to this work, as well as the MSF field centers. This coordination and review has accomplished several important aims. First, the joint working relationship with the program offices in the definition and description of the experiment program has resulted in a common understanding of the experiment goals and objectives in each discipline and a common language in referring to them. Secondly, the effort required to develop the material has led to an improved working relationship and understanding between offices. Lastly and probably most importantly, in most of the disciplines, it has resulted in a firm understanding of the experiments to be flown and a commitment to work toward their timely flight.

This revision also reflects some important differences from its predecessor. First, the disciplines of Aerospace Medicine, Materials Processing and Manufacturing in Space, Engineering and Operations and Advanced Technology are now included. They were not contained in the August 14, 1968 Yellow Book. Secondly, the Science and Applications portion containing the Space Physics, Astronomy, Earth Surveys and Space Biology disciplines have been very extensively reworked. This has resulted in a number of changes and deletions in various sections which the user will discover, leading to an improved and expanded technical detail. Some sections, noteably Aerospace Medicine and Earth Surveys are subject to continuous scrutiny and revision; for this reason these sections should be considered as draft/source material only, with the final Yellow Book quality material due out as a replacement in the near future.

The material contained in the extended earth orbital experiment program in this document is a product of the NASA in-house Integrated Payload Planning Activity. This planning activity is a joint effort among the Office of Manned Space Flight, Bellcomm, the Office of Space Science and Applications and the Office of Advanced Research and Technology and is supported by planning groups at MSC, MSFC, and LRC. Though many individuals are involved in this joint payload planning activity, some have participated more directly in the preparation of this document. These include: P.G. Thome, OSSA; D. Novik, OART; R.W. Dunning, OART; A.T. Mattson, LaRC; W.N. Gardner, LaRC; W.T. Carey, MSFC; J.O. Hilchey, MSFC; D.E. Hagge, MSC and R.E. Hergert, MSC.

Though this document is a product of the Payloads Office and the responsibility for its contents must be acknowledged, the efforts of these individuals are much appreciated.

William O. Armstrong
Director, Payloads Office

Rodney W. Johnson
Manager, Integrated Payload
Planning Activity

ABSTRACT

Assuming completion of the Saturn AAP workshop experiments program, an experiments payloads plan has been developed for the Space Station of the mid-seventies. Based upon the objectives of the space station program and their relative importance, three experiments program options have been developed.

Each option was generated to accommodate varying levels of experiment accomplishments and assumed different levels of funding availability. Specifically, the hard core option will only provide information on the physical well-being of the astronaut and limited data regarding his ability to perform useful functions in space. The second option will, in addition, provide limited scientific data in the areas of solar astronomy and earth applications while providing additional information on man's capability to perform useful functions in support of scientific data gatherings. The third option satisfies most of the objectives of the intermediate space station program. This option will provide for exploratory experimental efforts in a number of scientific disciplines and will allow examination of man's usefulness in support of these scientific investigations, and, significantly, will provide conclusions regarding man's role in future exploration and exploitation of space.

The experiment program plan was developed to provide maximum flexibility from the standpoint of operations and funding. It allows selection of individual experiment packages or modules to accomplish a specific entity of the overall experiment program. Such selection may be dictated by considerations of logistics or development.

CONTENTS

CONTENTS

CONTENTS (Cont'd)

SPACE TECHNOLOGY EXPERIMENT PROGRAM

SUMMARY

OBJECTIVES

1. Support and enhance the Space Station experiment programs in science, applications and space medicine by providing in-flight sensor and optics calibration facilities, space hangar and evolving EVA capabilities, component check out facilities, operational drag cancellation, optional high power capabilities and measurements of external and internal environments and contaminants.

2. Develop the technology required for advanced manned orbital and planetary missions by providing facilities for verifying advanced power, life support, guidance and control, and sensor components and systems; and obtaining data relevant to advanced design criteria from measurements of the synergistic effects of the space environment.

3. Advance the technology required for other NASA missions and programs by providing advanced component and system verification facilities, large space structure deployment capability and a fluid physics and thermo-dynamics laboratory.

4. Exploit the unique characteristics of the space environment with respect to zero-gravity and vacuum by providing facilities for the investigation of crystal growth, levitation melting, whisker growth, supercentrifugation, metal foaming, blending, mixing and other processes associated with space processing of materials.

PROGRAM

In order to provide the foundation of technology required for the successful and economical implementation of future space missions, NASA sustains a major research and advanced technology program within its Centers and within industry and universities. However, space flight experiments are needed to supplement the ground based program when ground facilities cannot provide adequate simulation, when space environment data are needed as a basis for design and operational criteria, when corroboration of ground facility results is required, and when it is desired to verify a promising new concept. The Space Technology Experiment Program is designed to exploit and support the space station, within the constraints that the experiments required or are sufficiently enhanced by man, or are uniquely associated with manned spacecraft systems and capabilities.

Because technology cuts across all technical and program disciplines, the Space Technology experiments do not fall into easily defined categories. An overview of the proposed experiments indicates that they can be categorized within seven Functional Program Elements:

1. Contamination Measurements
2. Exposure Experiments
3. Extended Space Structures
4. Fluid Physics in Microgravity
5. Material Processing in Space
6. Component Test and Sensor Calibration Facility
7. Advanced Spacecraft Systems

In the material presented herein, Functional Program Elements are provided in integral write-ups for (1) Contamination Measurements and (2) Exposure Experiments. Other space technology experiments are provided in the LRC portion of the document, entitled "Space Station Experiment Program for Advanced Technology" dated 3/10/69. The experiments described in the LRC submission were not categorized in accordance with the seven Functional Program Elements listed above. However, the ensueing discussion of Functional Program Element content will identify the relationship between the LRC proposed experiment program and the seven Functional Program Elements.

It will also be noted that the LRC experiment proposals include experiments "IV. Environmental Control/Life Support System," "VI. Advanced Orbital EVA Systems," and "IX. Centrifuge Facility." These experiments represent an overlap with the Aerospace Medicine and Bio-Technology discipline, which might well be expected inasmuch as the definition of experiments in Space Technology and in Aerospace Medicine and Bio-Technology all falls within the cognizance of the OART. These overlap experiment descriptions are retained within the Space Technology submission with the expectation that they will supplement, in beneficial detail, the information presented in the Aerospace Medicine and Bio-Technology section.

FUNCTIONAL PROGRAM ELEMENTS

1. Contamination Measurements

All of the manned spacecraft designed in the 1960's produce ejecta (i.e., waste and water dumps, RCS firings, atmosphere leakage, etc.) which contaminate their immediate environment in space to a significant degree. Gross effects of this contamination, such as the window fogging encountered in past missions, can probably be controlled by appropriate changes in the waste and water management practices adopted for future spacecraft. As missions become longer and space experiment programs become more sophisticated, however, some more subtle and persistent contamination problems will come to the fore.

Three types of contamination are expected to be of particular concern:

a. Deposition of non-volatile substances (such as urine salts, or carbon or metals carried by RCS plumes, for example) on optical components or sensing elements.

b. Optical contamination (i.e., light scattering or absorption) due to particles and gaseous species near the spacecraft.

c. Chemical contamination, which can interfere with upper atmosphere studies, attempts to assay the composition of interplanetary matter, and material processing experiments seeking to make use of the "vacuum of space."

Although leakage and outgassing can undoubtedly be reduced to insignificant proportions on the spacecraft of the mid-1970's, some sources of contamination will certainly remain. It will still be necessary to fire thrusters for attitude control (or to dump angular momentum from control moment gyros, which amounts to the same thing) and for station-keeping. Occasional waste and water dumps will be required as a practical matter on very long missions. And for the foreseeable future, it will be necessary to purge the spacecraft atmosphere periodically to dispose of accumulated trace contaminants.

These major sources of contamination can be programmed to provide reasonably long periods of undisturbed operation for optical and other sensitive instruments, since ejecta will be swept away from the Space Stations quite rapidly by atmospheric drag. Nevertheless, it will be desirable to develop means of monitoring the environment to determine when contamination is within acceptable limits, and also to study the composition and distribution of the ejecta so that troublesome components and unexpected sources can be eliminated. The results will help to increase instrument life and reliability and can provide correction factors for operational sensing data. In high altitude or cislunar missions the dispersal times of ejecta will be much longer than in near earth orbits, and the spacecraft will not be shielded by the ionosphere, so that it may attract a cloud of ionized particles. Thus, it will be of considerable importance to have sophisticated instrumentation ready to identify the sources of problems which may arise.

It is proposed to include a fairly extensive selection of instruments for contamination measurements in the Space Station payloads for the mid-1970's. As presently conceived, this would partly consist of advanced versions of instruments which have already been proposed for the AAP missions, and would include the following types of measurements:

a. Means of measuring the amount of light scattering due to environmental contamination, to identify "good seeing" conditions and provide calibrations for other viewing experiments. The instrumentation would include photometric measurements of scattered light against dark backgrounds, a sun-looking instrument like the T025 mock coronagraph, and possibly a spectrometer to measure absorption curves and perhaps identify some contaminants by their band spectra.

b. Means of measuring how much material is deposited on optical components, windows, and other surfaces and identifying its composition. These would include a reflectometer like the T031 instrument and devices to collect samples for later identification, such as advanced versions of the T027 experiment.

c. Means of monitoring the composition of the spacecraft's environment and determining how contaminants move after they are released. Useful instruments would include a mass spectrometer with means of sampling the atmosphere at various distances from the spacecraft and cameras to film the dispersal of waste dumps, shapes of RCS plumes, etc.

The observation program to be conducted with the above instruments will be organized with respect to viewing experiment programs and waste management schedules so as to provide maximum operational support to the Space Station scientific program. In addition, it will include systematic engineering studies to develop the design data needed to control or eliminate contamination effects on future spacecraft.

It should be noted that there is some overlap between the "Contamination Measurements" experiments and experiments in Space Physics entitled "Air-lock Experiments."

2. Exposure Experiments

It will become increasingly important to acquire detailed, quantitative engineering data on the effects of the space environment on materials and surfaces as space missions become longer, because equipment reliability requirements will become much sharper. In the past, these effects have been evaluated mostly by ground simulation tests and qualitative theoretical considerations. The accuracy of such approaches is limited by the extent of current knowledge about conditions in space, however, and they are unlikely to provide very detailed or accurate information about combined effects resulting from interactions between several different influences.

The AAP missions will provide some data on materials and surfaces exposed to space, but the spacecraft will afford only limited access to the external environment, will generate significant amounts of gas and other contaminants, and will be subject to fairly severe restrictions on the weights and sizes of payload components. Much survey work will remain to be done in the mid-1970's, therefore, and the Space Stations planned for that period are expected to provide greater experimental resources, longer possible exposure times, and much cleaner conditions. The Space Stations will also offer the first possible opportunity to study materials and surfaces while they are exposed to space, without its being necessary to remove them to a laboratory environment which might alter the state of their surfaces. Due to the lengths of the missions, it may even be possible that the costs of launching the experiments will be competitive with the rental costs of ground simulation equipment for comparable exposures.

For engineering purposes, it appears that there are four main topics which it will be important to study in the mid-1970's:

a. Effects of the space environment on the bulk properties of materials, especially polymers, sealants, window materials and space suit fabrics.

b. Effects of the space environment on the optical and thermal properties of surfaces, with special reference to combined effects (e.g., possible sensitization to photolysis due to radiation damage, etc.).

c. Rates of micrometeoroid erosion and possible entrapment of meteoric material.

d. Development of effective methods of collecting micrometeoroids and other interplanetary material.

It is proposed to include experiments addressed to these topics in the Space Station payloads of the mid-1970's. In the areas having to do with material properties, the focus of the experiment program will be on acquiring systematic survey data covering very long exposure times. The micrometeoroid and interplanetary material experiments, on the other hand, will concentrate on studies of specific fundamental effects such as the size, momentum, and composition distributions of meteoroids and their penetration into specific materials. These studies may overlap some of the experiments proposed for the Space Physics Program, and will be integrated with them to the extent that is possible.

3. Extended Space Structure Development

Although the detailed character and objectives of the space missions of the post-1980 period are still indefinite, many of the foreseeable possibilities imply possible needs for lightweight, very extended structures external to the spacecraft. Extended solar cell arrays would be invaluable in meeting the electrical power needs of either earth-orbital or interplanetary missions, for example. Low-frequency radio astronomy will require very large antenna structures. The erection of large-area reflecting antennas will eventually become desirable both for communications and for radio astronomy. And some potential missions, such as solar-sailing interplanetary probes, must await development of the necessary structural technology before they can even be planned intelligently.

All of the structures needed for such purposes would have the following features in common:

a. Inability to support their own weight on earth;

b. Sizes too large for conventional mechanical deployment methods;

c. Little-known and virtually incalculable dynamical and thermal behavior.

It is evident that much of the testing necessary in their development must be accomplished in space.

It is proposed to begin the development sequence on the space station missions of the mid-1970's with the deployment of a specific structure of this class and studies of its behavior under operating conditions. The possibilities being considered include a solar cell array structure extending to a minimum area of 1000ft^2 and a linear antenna of the order of a mile long. The final selection will be mostly based on consideration of what type of experiment will best serve the needs of future technology, but provisions will also be included to make as much operational use of the structure as possible. An advanced solar cell array, for example, would incorporate at least some sections of active cells that could supplement the space station's regular power supply, or an antenna structure could be used in the mission's astronomy program or for radio propagation studies.

Typical experiments in this area are submitted in the LRC section of Space Technology under the title "I. Large Expandable Space Structures."

4. Fluid Physics in Microgravity

At the 200 NM altitude currently planned for the Space Station missions of the mid-1970's, atmospheric drag accelerations of the order of 10^{-5} cm/sec^2 will be experienced on board if the spacecraft is inert, and values at least two orders of magnitude smaller can probably be obtained if it has some means of applying continuous low thrust. At such low acceleration values (of the order of 10^{-8} to 10^{-10} gravity) it will be possible to levitate liquid masses for considerable periods of time, and density gradients in fluids will not cause appreciable convection currents. Effects of this sort have given rise to a number of engineering difficulties in the design and operation of fluid systems for space flight; they may also make it possible to study the fundamental properties of fluids under better controlled experimental conditions than ever before.

For example, free diffusion and thermal conduction in gases can be studied without complications from convective mixing and heat transfer. Internal friction and surface tension in liquids can be measured by observation of the oscillations of large suspended drops, and the mixing of different liquids can be made to take place purely by interdiffusion. Critical point phenomena can be observed without the density gradients and convective effects that usually complicate such experiments. Boiling heat transfer and two-phase flow will be quite different phenomena from what they are on earth. Rates of exothermic chemical reactions will be controlled by diffusion, so that the reaction kinetics will be simpler than in normal gravity. Capillary action will be isotropic. In short, a wide and potentially very fruitful field of new possibilities for experiments on fluid properties will be opened. Furthermore, the results of such work can eventually have a significant engineering impact on manned space flight technology through improved understanding of the behavior of fluids in spacecraft systems. For, although, it is true that current systems designed by "rule of thumb" give generally satisfactory performance, they can certainly be improved, and the route to improvement must surely be found through better analysis.

Since basic studies of fluids are expected to be the most immediately interesting and profitable, it is proposed to include a selection of such experiments in the Space Station payloads. Appropriate support facilities will be provided, and experiments proposed by the scientific and engineering communities will be flown as opportunity offers. In general, the selected experiments will deal with fundamental physical effects that can be observed to unique advantage in space, and with engineering problems of definite concern in the design of future systems.

Experiments included in this Functional Program Element are to be found in the LRC section, entitled "VII. Fluid Systems Experiments."

5. Material Processing in Space

It seems beyond doubt that the virtually complete weightlessness attainable in a free-flying spacecraft will have many practical uses in the development of material processing techniques involving high temperatures and/or transitions between the liquid or gas phase and the solid state. Thus, it can be expected that research in space will be of considerable value in studies of the behavior of interesting and technically important materials. Moreover, commercial materials technology includes products, particularly in the electronics industry, which can support very high material costs, because the value added by manufacturing processes applied to the basic materials accounts for practically all of the market price of the finished goods. At least in principle, therefore, material processing in space might eventually yield direct economic returns if it could provide a unique source of material for a product with a high enough market value.

A number of processing methods have been suggested to take advantage of weightlessness; some of these involve the absence of convection and settling in fluid phases, but most are based on the novel suspension methods possible in a spacecraft subject to none but very small accelerations. Current ideas on the subject can be classified roughly as follows:

a. Proposals for levitation melting processes, which are expected to be subject to virtually no restrictions on the nature of the material or the size of the melt. Such techniques should be of value in producing shapes controlled by the surface tension of the melt, and for production of cast materials without any impurity transport, nucleation, or thermal effects due to containers.

b. Ideas for floating zone refining applications, which should be free of restrictions imposed on the size of the molten zone by the weight of molten material that must be retained by surface tension forces.

c. Production of fragile structures, such as very thin castings, long whiskers, membranes, and long, thin extrusions.

d. Proposals to produce foamed metals, various kinds of dispersions, and alloys which are supposedly impossible in normal gravity because of large density differences between the components.

e. Exploitation of diffusion-controlled crystal growth from vapors, melts, or solutions.

The experimental implementation of these proposals seems feasible in general, and the only serious technical difficulties appear to lie in actually realizing some of the proposed suspension schemes in spite of the relative motions that would occur between the spacecraft and a freely floating body inside it. But it is necessary to face the fact that none of the existing proposals has a verifiable economic justification, simply because we do not yet know enough about phenomena in very low gravity to exploit them profitably. It therefore appears that the most economical and fruitful materials research program for the Space Stations of the mid-1970's will be one that concentrates on a scientific survey of the effects that occur during phase changes and chemical reactions in orbital flight, and on the development of basic manipulative techniques.

It is proposed to incorporate facilities for a preliminary materials research program in the early Space Stations, and to carry out exploratory experiments which may lead toward a continuing materials science program in the future, and perhaps even to actual manufacturing operations eventually. The basic capabilities needed will be means of high-temperature heating and temperature control, high vacuum and inert atmosphere enclosures, provisions for heat rejection, and apparatus to manipulate floating solid and liquid samples and control their positions. Instrumentation used in the facility will be specific to the experiments which are to be performed and will be mainly for recording what happens during actual processing; it is anticipated that practically all preparation of samples for processing and evaluation of the end products will be performed on the ground.

Experiments suitable for this phase of the space processing program would be as follows:

a. Melting of floating samples of various materials, in several different sizes and with a variety of heating and cooling schedules.

b. Solidification of supercooled liquid drops.

c. Floating zone refining of well-understood materials (e.g., germanium and silicon, or perhaps some metals) with known impurity contents.

d. Crystal growth on seeds suspended in liquid solutions or vapor.

The early results of these efforts can be expected to have much more bearing on technique development than on materials science. It is expected that the experiment program would proceed at a moderate pace, conforming to that of concurrent ground studies of the results, until the latter developed concrete indications of a promising line for more active research. At that point it would become appropriate to send a scientist with the proper background and suitable apparatus to the space station to perform an "open ended" series of experiments organized along the same lines as earthbound materials investigations.

Requirements on the Space Station for a Space Processing of Materials facility have been detailed in the MSFC section entitled "Product Manufacturing in Space." Inasmuch as the overall program for space processing of materials will be a joint effort of OART and OMSF capabilities, the requirements for the technology portion of the program may be considered as incorporated in the "Product Manufacturing in Space" Functional Program Element, except for equipments not yet determinable.

6. Component Test and Sensor Calibration Facility

The manned space missions of the 1960's have essentially been test flights with the central objective of gaining the ability to fly in space and return to earth safely, and they have been conducted with spacecraft which afforded virtually no room for components that did not directly contribute to operational capabilities. The overriding importance of the objective and the expense and time required to integrate new devices into vehicle systems have severely constrained the application of new technology to manned space flight, and technology development requiring experiments in space before operational equipment could be designed has faced insuperable barriers. Consequently, some worthwhile products of NASA engineering and advanced technology programs have been brought to the point where flight tests are needed, and then have been held "on the shelf" in an arrested state of development because current operations have provided no opportunities to test them. Some present examples are advanced batteries and fuel cells, air bearings, heat pipes, etc., and each passing year can be expected to add more to the list.

In the coming era of space station operations it will become both possible and necessary to pursue a more enterprising program of flight development experiments and tests to provide advanced components for future use. Mission durations will approach and then exceed the equipment lead times which have been common in the 1960's, and this will motivate a continual struggle to improve equipment reliability and life. The vehicles themselves will provide greatly increased resources for on-board experiments and tests, and as development advances, it is likely to become usual that a new vehicle will receive its initial tests while attached to a larger complex that is already operational.

Finally, and most important, mission objectives will focus on the profitable employment of manned space flight. It will be imperative to make use of the highest technology available for activities which are possible only in space, and to extend that technology continually in directions that will increase the tangible return on the investment in the whole program. This is certain to sharpen the need for new technology specifically adapted to space conditions, and to cause an expansion of development activities that can only be conducted in space. To meet these future needs the space stations will have to be provided with fairly generalized experiment support facilities and safety measures, so that up-to-date experiments can be delivered to them and run at minimal cost, without affecting the success of other mission operations.

It is therefore proposed to incorporate an advanced component test facility in the space stations which are to be flown in the mid-1970's and thereafter. Its design should be defined in terms of the support requirements (for space, power, heat rejection, tooling, etc.) of currently known types of advanced components and subsystems for which space tests are expected to be justified when the missions are performed. The eventual flight program will not necessarily include all of the experiments used to define the facility design, however, for it will be a major program objective to provide the flexibility needed to accommodate experiments which are only in the conceptual stage at present, and to support activities responding to the new technology needs which will only become apparent as actual development of the space station proceeds.

Thus, the development and use of the facility will comprise a sophisticated advanced technology experiment in itself, aimed at developing means of experiment integration which are substantially independent of experiment definition. It is expected that the experience and results gained from it will materially hasten the advent of space stations which can be truly generalized research facilities, with a degree of versatility approaching that of laboratories on earth.

The Space Station should also incorporate a facility for calibration and checkout of the many types of sensors included in the on-board experiments. As the mission duration increases it will become more and more important to ascertain that the experiment data being obtained have not been degraded. This sensor calibration facility could logically be combined with the component test facility. Requirements on the Space Station are indicated in the LRC section entitled "VIII. Remote Sensor Technology."

7. Advanced Spacecraft System Tests

In addition to the strictly experimental activities described in the preceding Functional Program Elements, it is proposed to make use of the Space Stations of the mid-1970's to conduct qualification tests of advanced spacecraft systems that might be ready for use in time for the missions, but are not selected as primary operational systems or have not been space qualified. Advanced systems expected to have important applications in future mission will be installed on the Space Stations and tested by operation as integral systems or as substitutes for the primary systems over appropriate periods of time. The systems under test could be accorded operational status while they are in operation and remain satisfactory, and the primary systems could be reactivated when the tests end.

In the LRC submission, the following experiment descriptions are included in the category of the Advanced Spacecraft Systems Functional Program Element:

(1) II Space Experiments Hangar

(2) III Guidance, Stability and Control

(3) V Advanced Power System

(4) VI Advanced Orbital EVA System

These experiments could provide, respectively, a facility for accommodation of satellites and experiment modules, an artificial gravity system, an isotope Brayton-Cycle power supply and a space shuttle; all of which could be exploited for enhancement of Space Station capabilities.

Additional possible systems, that could be in parallel with operational systems, include an advanced resisto-jet attitude control and/or station keeping system, and an advanced laser rendezvous and docking system both of which could be utilized with attendant operational improvements and propellant economies.

CONTAMINATION MEASUREMENTS

Contamination Measurement experiments consist of special instruments or samples designed to provide data relative to the amount of particulate matter and gaseous contaminants in the near environment external to the spacecraft. These instruments will be grouped together physically to the maximum extent and, as a package, will provide an assessment of the nature and magnitude of external spacecraft contamination resulting from outgassing, waste dumps, RCS firings, environmental erosion, etc. Such contamination can seriously degrade all viewing experiments such as solar and stellar astronomy and Earth applications experiments because of light scatter and absorbtion of portions of the electromagnetic spectrum. In addition, contamination deposits on optical surfaces and grating could result in cumulative degradation of all viewing instruments external to the spacecraft. On the space station it is likely that the Contamination Measurements will be a significant factor in the real time sequencing of all viewing experiments as affected by initial conditions, RCS firing and waste dumps, and in the establishment of the nature of the external environment during observations.

The present concept of the Contamination Measurements package includes: (a) a photometer for measurement of light scatter due to particulate matter, and a mechanism for deploying and retracting exposure and contamination collection samples (concept as in T027); (b) a coronagraph for calibration of light scatter when looking directly at the Sun (concept as in T025); (c) a reflectometer for measuring changes in the reflectivity of coatings and optical surfaces in-situ (concept as in T031); (d) a mass spectrometer for identification of gaseous contaminants (concept as in T030); (e) an electric field meter for determination of the relationship between the contamination environment and electric fields (concept as in T028); and (f) samples placed near RCS engines to determine the extent of the RCS contamination problem (concept as in T023).

FUNCTIONAL PROGRAM ELEMENT

1. DISCIPLINE - Contamination

2. PROGRAM ELEMENT - Experiments which study contamination.

3. REQUIREMENT

   a) Determine the extent to which spacecraft debris and coma affect astronomical and other optical experiments by reflecting sunlight or depositing material on optical surfaces.

   b) Perform certain other experiments to measure contamination around a spacecraft and deterioration of surface coating materials.

   c) Evaluate man's capability to perform scientific observations.

4. JUSTIFICATION

   a) Several experiments have been submitted to perform optical measurements that may be affected by solar light scattered from the debris surrounding the spacecraft. An evaluation of the intensity of the scattered light is necessary to determine the extent of this effect.

   b) It is necessary to determine the effect on optical surfaces due to deposition of spacecraft debris and gases in order to plan for future systems involving optical systems, such as astronomical telescopes.

   c) These experiments, because of their requirement for deployment through an airlock, EVA, and astronaut operational requirements allow evaluation of man's capability to perform useful manipulative and scientific functions on future systems.

5. COMPONENT EXPERIMENTS

   a) T023 Surface Adsorbed Materials

   b) T025 Coronograph Contamination Experiments

   c) T027 Contamination Measurements

d) T028 Electric Field Meter

e) T030 Environmental Composition

f) T031 Spacecraft Surfaces Experiment

6. DESCRIPTION

An experiment description sheet is attached for the above experiments. The experiments are related because of their relation to the optical contamination problem. With the exception of T028 and the possible exception of T030, they all require recovery of either film, samples, or the entire instrument. There are also requirements for pointing the airlock toward the Sun, the horizon, and the nadir and positioning of samples about the exterior of the space vehicle. The experiments generally require astronaut participation and attention.

7. SPECIAL CONSIDERATIONS

Three experiments, T025, T027, and T030 require a scientific airlock. Two other experiments, T023 and T031, require EVA. All experiments except T028 and possibly T030 require return of film, tape, or samples, and in some cases the entire instrument. Most of the experiments require orientation in some particular direction or placement and retrieval of samples by an astronaut. Each experiment may benefit from astronaut selection and initiation of special events.

EXPERIMENT DATA SHEET

T023 SURFACE ADSORBED MATERIALS

1. SPECIFIC OBJECTIVE - To collect specimens of materials which adsorb on the exterior of a spacecraft during various stages of insertion into orbit.

2. GENERAL DESCRIPTION - The experiment equipment consists of two or more aluminum panels and one or more specimen containers. Each panel contains and protects two fritted glass specimen collectors. The panels will be mounted on the S-IVB forward skirt external surface in line with the altitude control system thrusters. The specimen containers will be used to stow the fritted glass specimen collectors for return to Earth.

3. OPERATIONAL CONSTRAINTS - Four or more specimen collectors will be recovered from the exterior of the S-IVB and returned to Earth. Collection of specimen collectors will require one or more EVA's, the first of which is to be performed on the fifth day in orbit. All EVA's will be performed during the daylight portion of the orbit; RCS corrections will not be performed during EVA operations. There are no orbital altitude or inclination and spacecraft pointing or stability constraints for this experiment. The total number of collectors and frequency of collection has not been determined.

4. MODE OF OPERATION - This experiment is deployed and conducted automatically. As the vehicle reaches approximately 2 g's during launch, an acceleration-sensitive switch will be closed; moments later a timer will actuate a solenoid which will deploy the specimen collector on the aft side of each panel. This panel will remain open. Upon reaching orbital altitude the specimen collector on the fore side of the panel will be deployed by means of a solenoid actuated by a timer.

   The specimen collectors will be recovered during the fifth day in orbit by an astronaut via EVA. Additional collectors may be placed in the panels at this time, or at a later time during the mission.

Recovered collectors will be placed in the specimen containers for return to Earth for laboratory analysis.

5. CREW SUPPORT - EVA is required on the fifth day in orbit and probably at other times not yet determined. The outside EVA time is assumed to be about 50 minutes, and will be conducted during the daylight portion of the orbit.

6. SPACECRAFT SUPPORT

Weight and volume for each set of four specimen collectors:

Ascent: 18 pounds and 0.16 ft^3 - external
2 pounds and 0.06 ft^3 - internal

Descent: 4 pounds and 0.06 ft^3 - internal.

Astronaut mobility aids in the vicinity of each panel will be required. No subsystem electrical power is required. Four batteries per panel will be incorporated in the experiment package to power the solenoids for panel release. Voice recording of the astronaut during specimen retrieval is required.

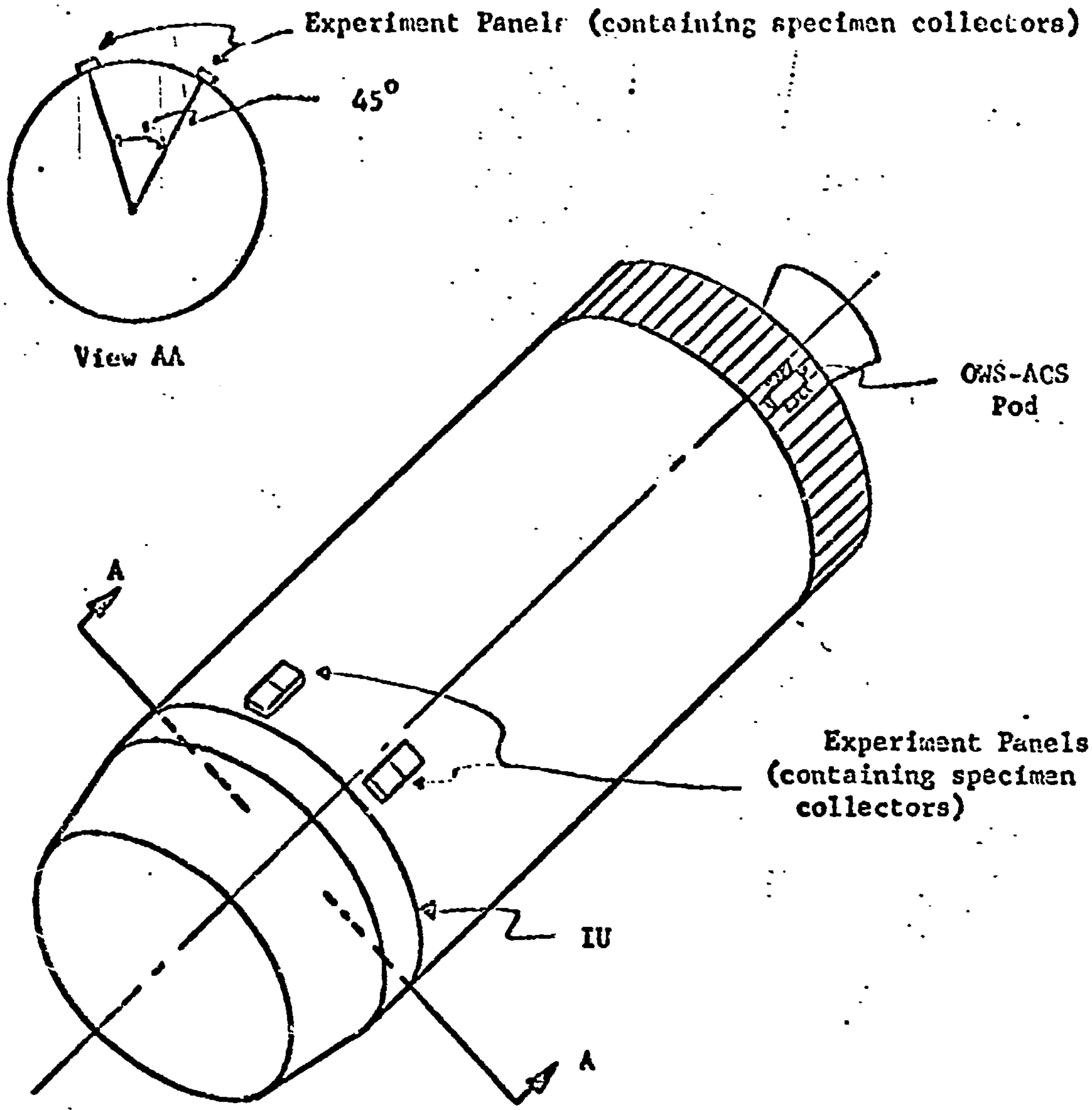
7. DEVELOPMENT SCHEDULE - The experiment is to be delivered in CY 69. It is anticipated that additional specimen collectors will be produced for the 1975-1976 mission.

8. COST (Preliminary Estimate)

FY 69-72: 240 K
FY 73-74: 120 K
FY 75-76: 120 K

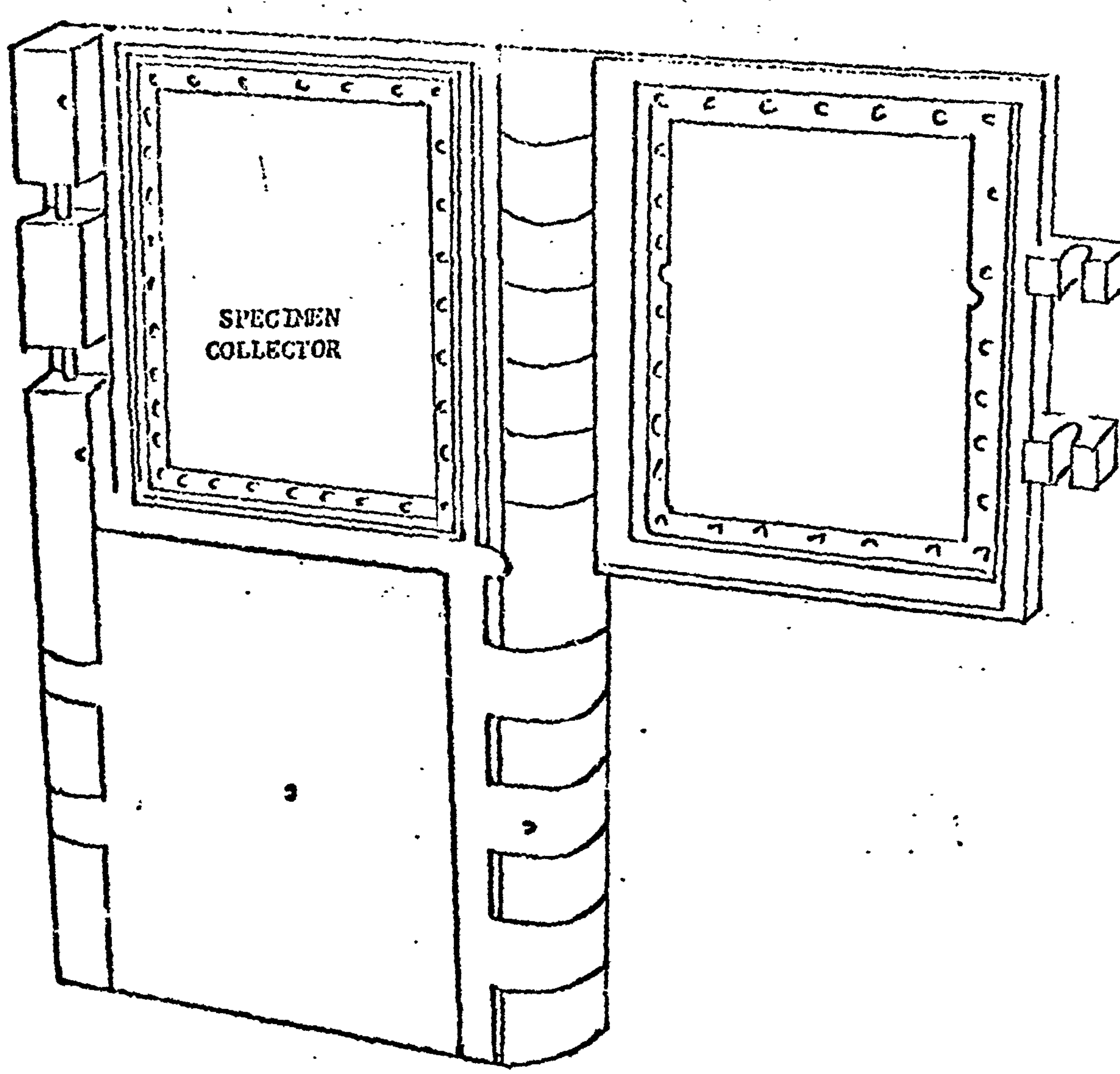
9. SPACECRAFT INTERFACE - Panels containing specimen containers will be mounted externally on the S-IVB stage. Astronaut mobility aids in the vicinity of each panel will be required.

10. TEST PROGRAM - Tests will be performed on a test unit in the given sequence; performance (operating), temperature - altitude, storage, and transportation (nonoperating), humidity (nonoperating), vibration (nonoperating), shock (nonoperating), orbital thermal/vacuum (operating), oxygen (nonoperating), and explosion (operating).



EXPERIMENT T023

LOCATION OF PANELS CONTAINING SPECIMENS



EXPERIMENT T023

ALUMINUM PANEL WITH ONE SPECIMEN DEPLOYED
(AUTOMATICALLY BY SOLENOID)

EXPERIMENT DATA SHEET

T025 CORONOGRAPH CONTAMINATION MEASUREMENTS

1. SPECIFIC OBJECTIVES

   a) To determine the presence of an induced atmosphere about the spacecraft during flight and to determine the changes in this atmosphere.

   b) To determine the nature and extent of the F corona about the Sun.

2. GENERAL DESCRIPTION - A coronograph and camera system will be deployed from the scientific airlock and oriented toward the Sun, within the pointing accuracy requirements. Photographs will be made of the Sun's corona and up to 10 degrees from the spacecraft Sun line.

3. OPERATIONAL CONSTRAINTS - Attitude control for duration of picture taking should be within a 10.1-degree unobstructed field of view 30 degrees about Earth Sun Line. Scientific airlock oriented toward Sun.

4. MODE OF OPERATION - Coronograph and camera assembly is mounted in airlock by astronaut and operated manually. Film to be returned to Earth.

5. CREW SUPPORT - About 40 minutes per orbit for three orbits which represents a minimum run time. Experiment should be performed periodically, perhaps once or twice a month, depending on resupply policies.

6. SPACECRAFT SUPPORT

   Ascent: 25 pounds and 1.2 ft^3

   Descent: 2 pounds and 1.2 ft^3 per experiment run.

7. DEVELOPMENT SCHEDULE

Def. - FY 68-69
Dev. - FY 69-70
Flight - FY 71
Data Analysis - FY 72-73
Dev. - FY 74
Flight - FY 75

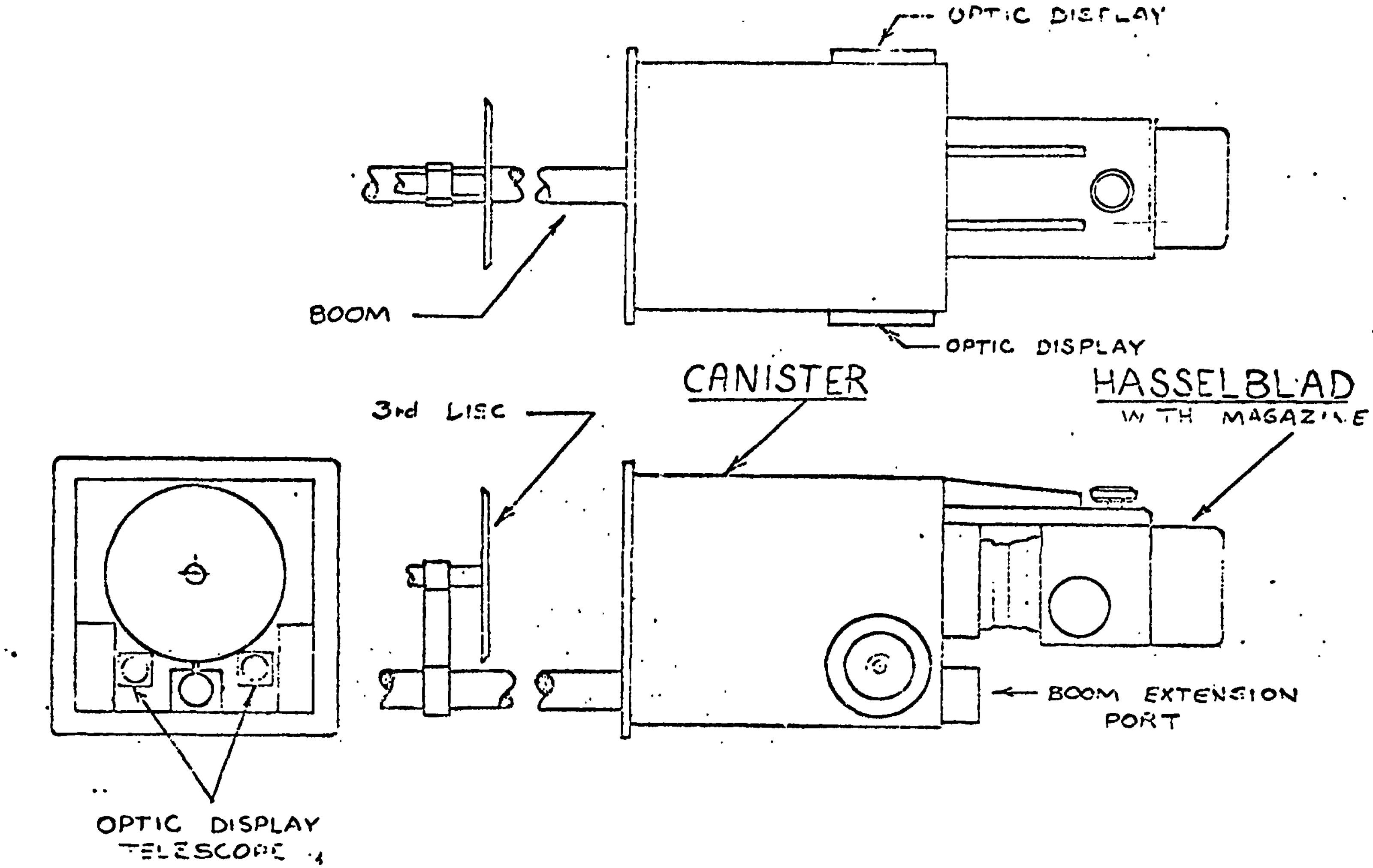
8. COST

FY 68 - 150 K
FY 69 - 110 K
FY 70 - 100 K
FY 71 - 100 K

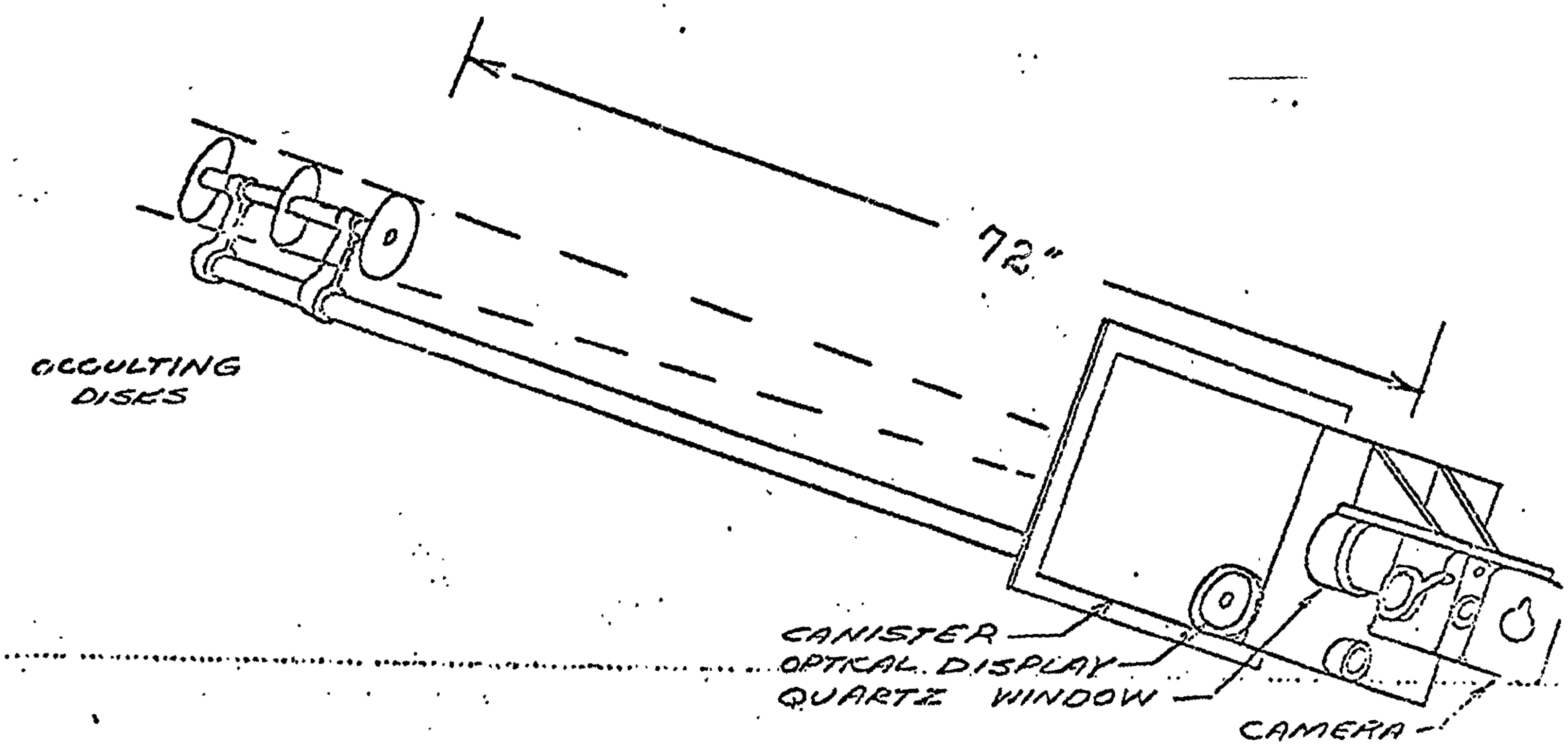
The cost is approximately apportioned to 360 K prelaunch and 100 K post-launch.

9. SPACECRAFT INTERFACE - Experiment and film are stored in canisters mounted to the spacecraft wall before and after deployment through a a scientific airlock. Provision must be made for connection to provide the experiment package with power and automatic guidance and control within specified pointing limits.

10. TEST PROGRAM - The following tests will be performed on a test unit in the given sequence; performance (operating), temperature - altitude, storage, and transportation (nonoperating), humidity (nonoperating), vibration (nonoperating), shock (nonoperating), orbital thermal/ vacuum (operating), oxygen (nonoperating) and explosion (operating).



CORONAGRAPH



CORONAGRAPH -- BOOM EXTENDED

EXPERIMENT DATA SHEET

T027 CONTAMINATION MEASUREMENTS EXPERIMENT

1. SPECIFIC OBJECTIVES

   a) To use a photometer to measure sky brightness due to solar light scattered from the debris around the spacecraft.

   b) To measure degradation of optical properties of sample materials exposed to exhaust control jet gases and other contaminants outside the spacecraft.

2. GENERAL DESCRIPTION - A camera and a white light photometer will be used to map the sky brightness on the sunward hemisphere as a function of angle from the Sun. The array of optical samples will be exposed for timed intervals so that optical degradation by contaminants may be assessed. The scientific airlock will be used for both measurements.

3. OPERATIONAL CONSTRAINTS - The photometer experiment is carried out in sunlight with the Sun on the airlock side. Spacecraft attitude controlled to ±1 degree, 4 degrees per hour maximum; 180 degrees unobstructed field of view from airlock; Sun-sensor indicator must be mounted so that pilot can see when Sun is acquired.

4. MODE OF OPERATION - Both photometer and optical samples extended and recovered through airlock manually. Photometer angle changes and data recording manually performed or automatically programmable. Sample array is to be returned to Earth's surface. The photoelectric photometer measures instantaneous luminance and may be used as a real-time contamination monitor. Values of instantaneous luminance may be recorded on the magnetic tape. A meter will allow the astronaut to monitor the luminance value.

5. CREW SUPPORT - One crewman for extension through airlock and photometer operation. Desired operation is for two cycles of photometer for four orbits. Crew time requested is about 40 minutes for four orbits. This experiment may be run periodically, once or twice a month, depending on resupply philosophy.

6. SPACECRAFT SUPPORT

Weight - 60 pounds

Photometer - 40 inches by 9 inches by 9 inches

Sample Array - 16 inches by 9 inches by 9 inches

Camera film and optical samples to be returned to Earth (26 pounds for each experiment run; 2 pounds film and 24 pounds samples).

7. DEVELOPMENT SCHEDULE

Def. - FY 68-69
Dev. - FY 70
FLT. - FY 70-71
Data Analysis - FY 72
Dev. and Mod. - FY 73-74
FLT. - FY 75

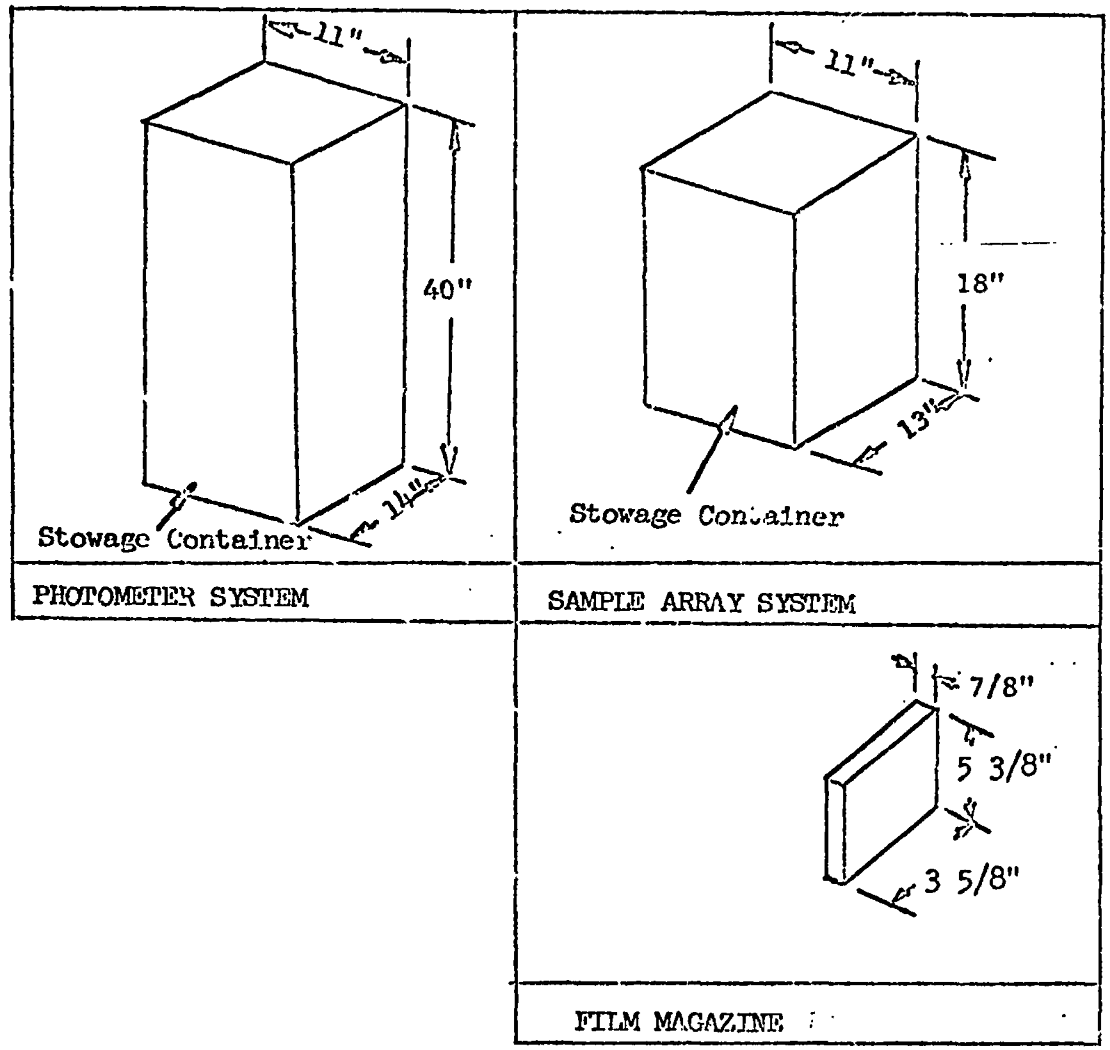
8. FUNDING (Preliminary Estimates)

FY 68 - 200 K
FY 69 - 150 K
FY 70 - 350 K
FY 71 - 200 K
FY 72 - 100 K

In terms of a longer period between development and flight, cost may by approximately 1000 K preflight and 100 K post-flight.

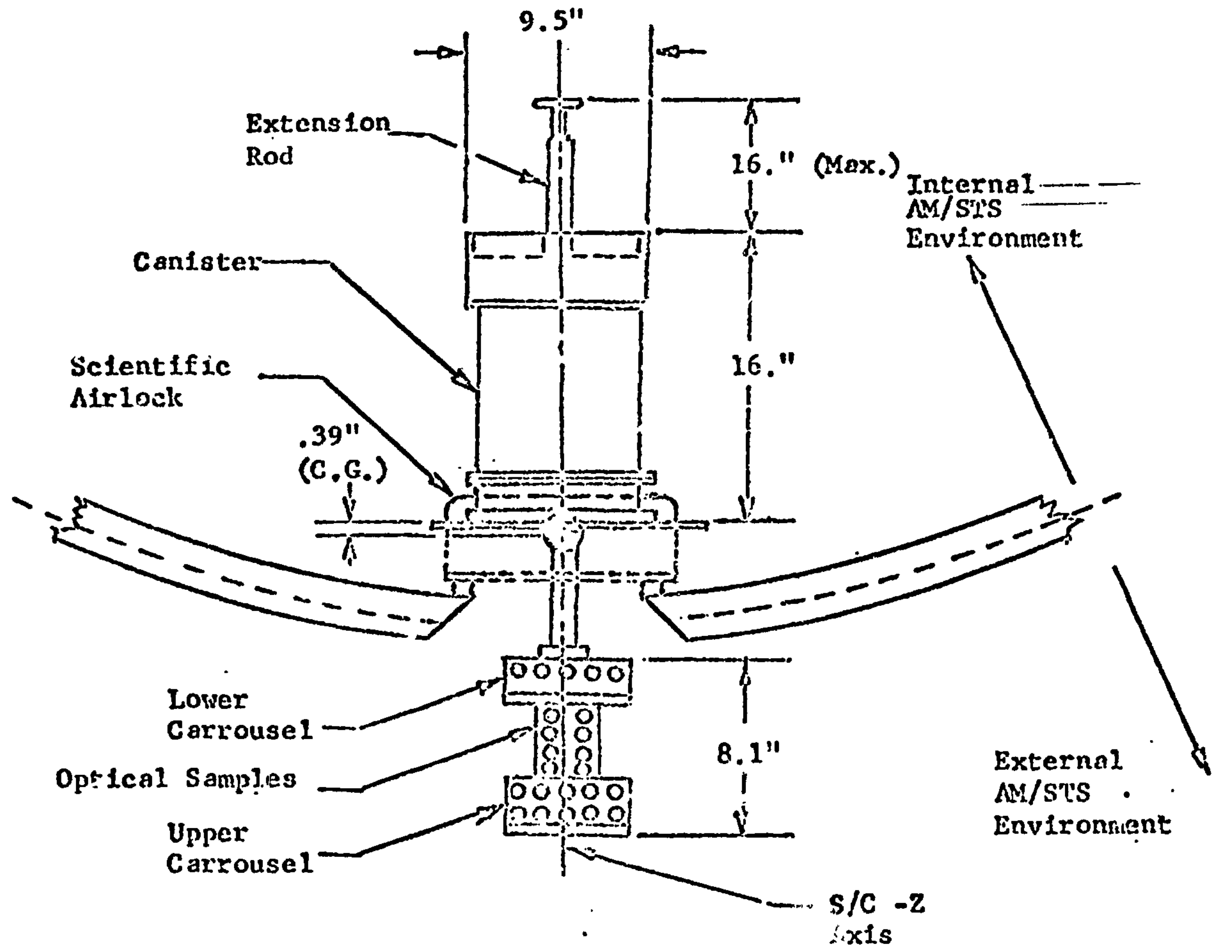
9. SPACECRAFT INTERFACE - Experiment and film are stored in canisters mounted to the spacecraft wall before and after deployment through a scientific airlock. Provision must be made for connections to provide the experiment package with power and automatic guidance and control within specified pointing limits.

10. TEST PROGRAM - The following tests will be performed on a test unit in the given sequence; performance (operating), temperature - altitude, storage, and transportation (nonoperating), humidity (nonoperating), vibration (nonoperating), shock (nonoperating), orbital thermal/vacuum (operating), oxygen (nonoperating), and explosion (operating).

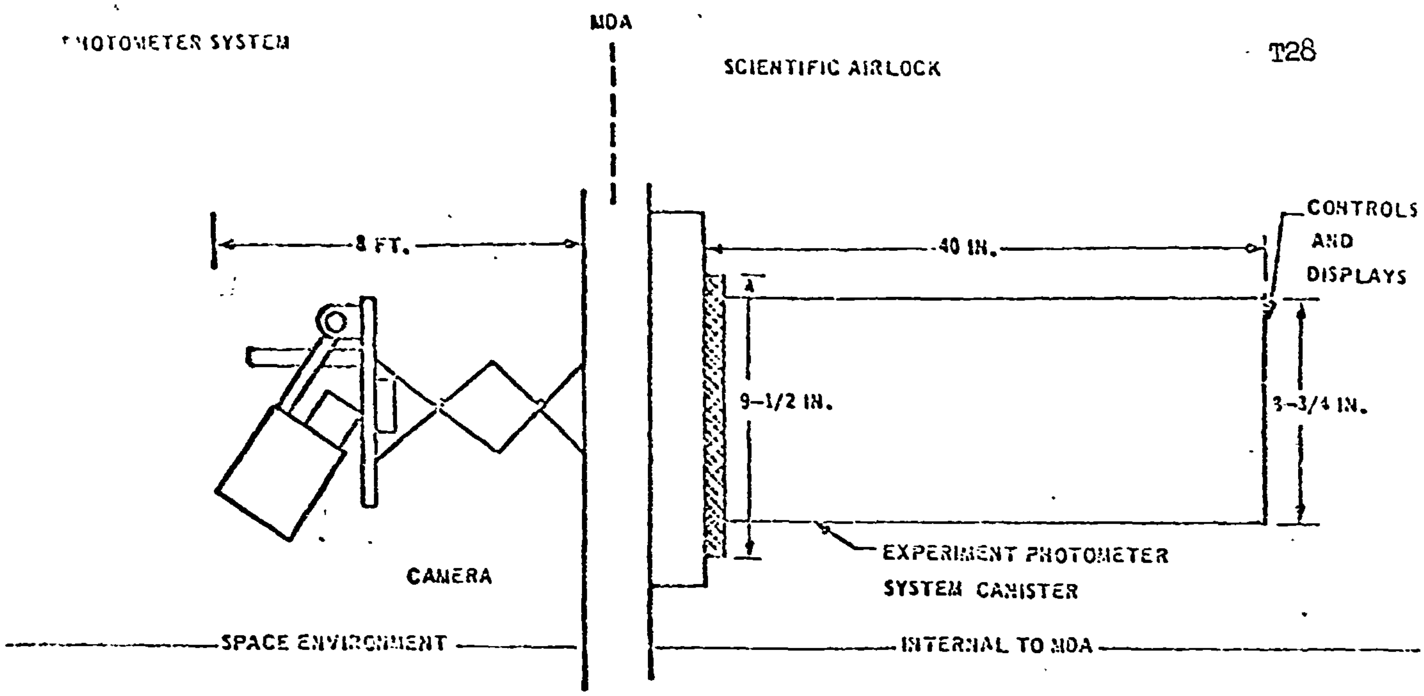


APPARATUS CONTAINERS

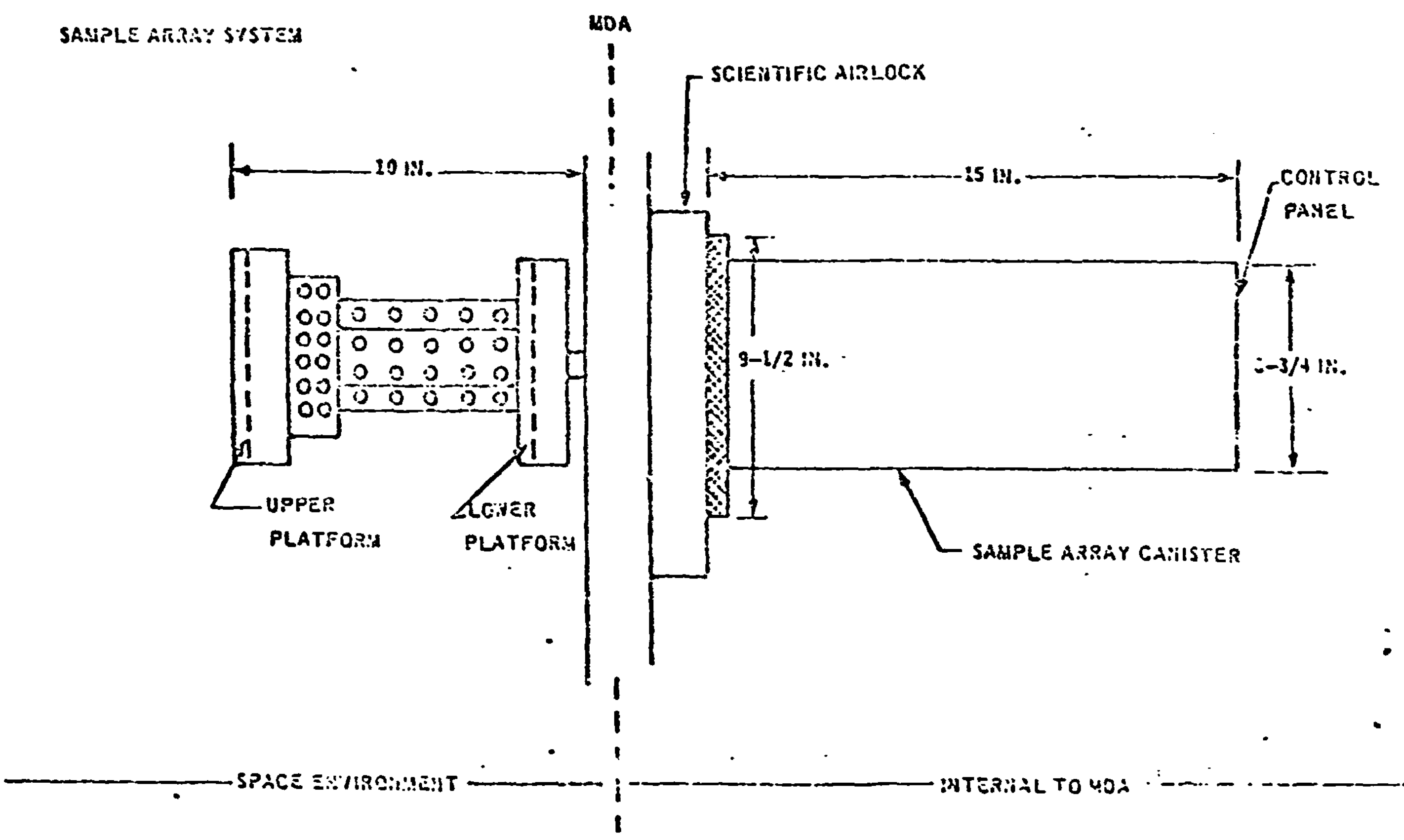
SAMPLE ARRAY SYSTEM

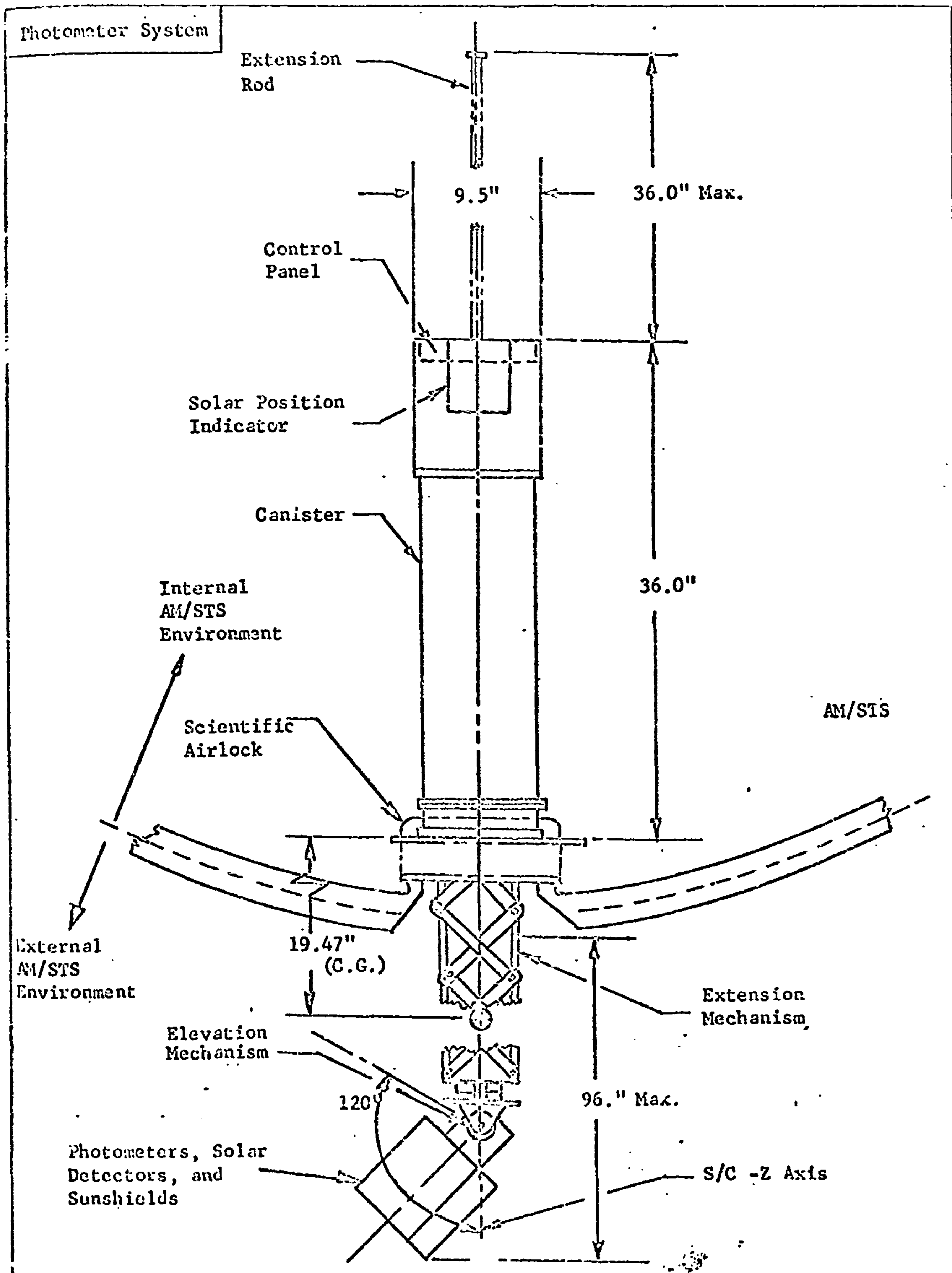


PHOTOMETER SYSTEM



SAMPLE ARRAY SYSTEM




Photometer System
Extension Rod
9.5"
36.0" Max.
Control Panel
Solar Position Indicator
Canister
36.0"
Internal AM/STS Environment
AM/STS
Scientific Airlock
External AM/STS Environment
19.47" (C.G.)
Extension Mechanism
Elevation Mechanism
120°
96." Max.
Photometers, Solar Detectors, and Sunshields
S/C -Z Axis

EXPERIMENT DATA SHEET

T028 ELECTRIC FIELD MEASUREMENT

1. SPECIFIC OBJECTIVES

   A) To determine the effect of the ionosphere on a beam deflection type electric field meter.

   B) To verify the instrument's operation in the ionosphere and to correlate the results with ground test results

   C) To measure and correlate electric fields near the spacecraft with operational phenomena such as:

      1) The presence of charged particulate clouds and/or condensation on instrument ports

      2) The interaction of the environment and other experiments with the plasma sheath.

      3) Electromagnetic forces and moments

   D) Advanced development tests of an electric field meter capable of measuring spatial and temporal variations of ambient electric fields in the ionosphere.

2. GENERAL DESCRIPTION - The electric field meter and a three axis flux gate magnetometer will be mounted on an extensible boom (up to 30 feet long). Measurements will be made of electric fields which have the possible range from [illegible]00 volts/meter to 10 millivolts/meter. In addition, the Earth's magnetic field in the spacecraft vicinity must be measured to within 1 milligauss. The vector electric and magnetic fields are measured simultaneously.

3. OPERATIONAL CONSTRAINTS - The orbit altitude must be within the ionosphere (200 kilometers to 2000 kilometers). Instrument attitude must be measurable to within 20 arc seconds for the most sensitive electric field measurements. This may be achieved by star field resolution. Accurate vehicle velocity data (one part in 10^5 or

better) is required for determination of the most sensitive electric field measurement. No real time data transmission is necessary. The electron beam of the electric field meter must be perpendicular to the spacecraft velocity vector at the time data is taken.

4. MODE OF OPERATION - The crew will extend the boom and activate the meters. If provision is made for dissipation of charged particulate clouds near the spacecraft by the application of bias voltages to the surface of the spacecraft, the electric field meter will be placed in continuous operation during this procedure. During solar storms, the meters should be made to take readings every 2 minutes. Calibration will be automatic; however, provisions for manual calibration will be provided. If the head of the boom can be tilted 90 degrees or more, the electric field meter can be positioned so that it is perpendicular to the spacecraft velocity vector at any orbit position of the spacecraft.

5. CREW SUPPORT - The crew will decide when the environment is sufficiently contaminated to put the electric field meter into continuous operation, apply the bias voltages and monitor the cloud dissipation visually as well as observe the electric field decay. The operator will also activate the equipment, override the automatic calibration procedure to check the meters manually, and possibly explore the apparent electric field due to vehicle motion through the ambient magnetic field by instrument reorientation, if the boom mounting permits.

6. SPACECRAFT SUPPORT

Weight and volume:

Ascent: 18 pounds - 0.6 ft^3
Descent: None

Electric power:

Standby: 3 watts
Average: 13.3 watts
Maximum: 18 watts

Data will be stored on tape on board the spacecraft and tramsmitted to the ground at a convenient time.

7. DEVELOPMENT SCHEDULE

Definition of early model completed:	FY 69
Fabrication, tests, and delivery of early model flight units and spares:	FY 69-70
Development of later model instrument and boom:	FY 71-73
Delivery of later model units:	FY 74
Flight:	FY 75-76

8. COST (Preliminary Estimate)

FY 69:	345 K
FY 70:	650 K
FY 71-73:	320 K
FY 74:	200 K
FY 75-76:	150 K

9. SPACECRAFT INTERFACE - The electric field meter should be placed so as not to be in the plasma wake of a vehicle appendage. The magnetometer must be sufficiently removed from the spacecraft so that internal vehicle magnetic fields are reduced below the desired accuracy level of the Earth's field measurements.

10. TEST PROGRAM - Tests will be performed on a test unit in the given sequence: performance (operating), temperature - altitude, storage, and transportation (nonoperating), humidity (nonoperating), vibration (nonoperating), shock (nonoperating), orbital thermal/vacuum (operating), oxygen (nonoperating), and explosion (operating).

EXPERIMENT DATA SHEET

T030 ENVIRONMENTAL COMPOSITION

1. SPECIFIC OBJECTIVE - To measure the chemical composition of the contamination gases surrounding the spacecraft at various distances and angles from the spacecraft.

2. GENERAL DESCRIPTION - A quadrupole mass spectrometer will be used through the scientific airlock to perform the measurement.

3. OPERATIONAL CONSTRAINTS - None.

4. MODE OF OPERATION - It is desired to extend the mass spectrometer box thru the airlock on a boom and perform measurements at several distances and angles relative to the spacecraft. The data will probably be collected on magnetic tape and returned by telemetry.

5. CREW SUPPORT - Extension and retrieval through airlock for several cycles will be required.

6. SPACECRAFT SUPPORT

   Volume - 40 inches by 10 inches by 10 inches. If the data tape is returned instead of telemetry, 10 inches by 10 inches by 10 inches and 6 pounds to be returned.

   Power: 15 watts average, 150 watts peak
   75 W-hr required

   Data: 9 channels analog.

7. DEVELOPMENT SCHEDULE

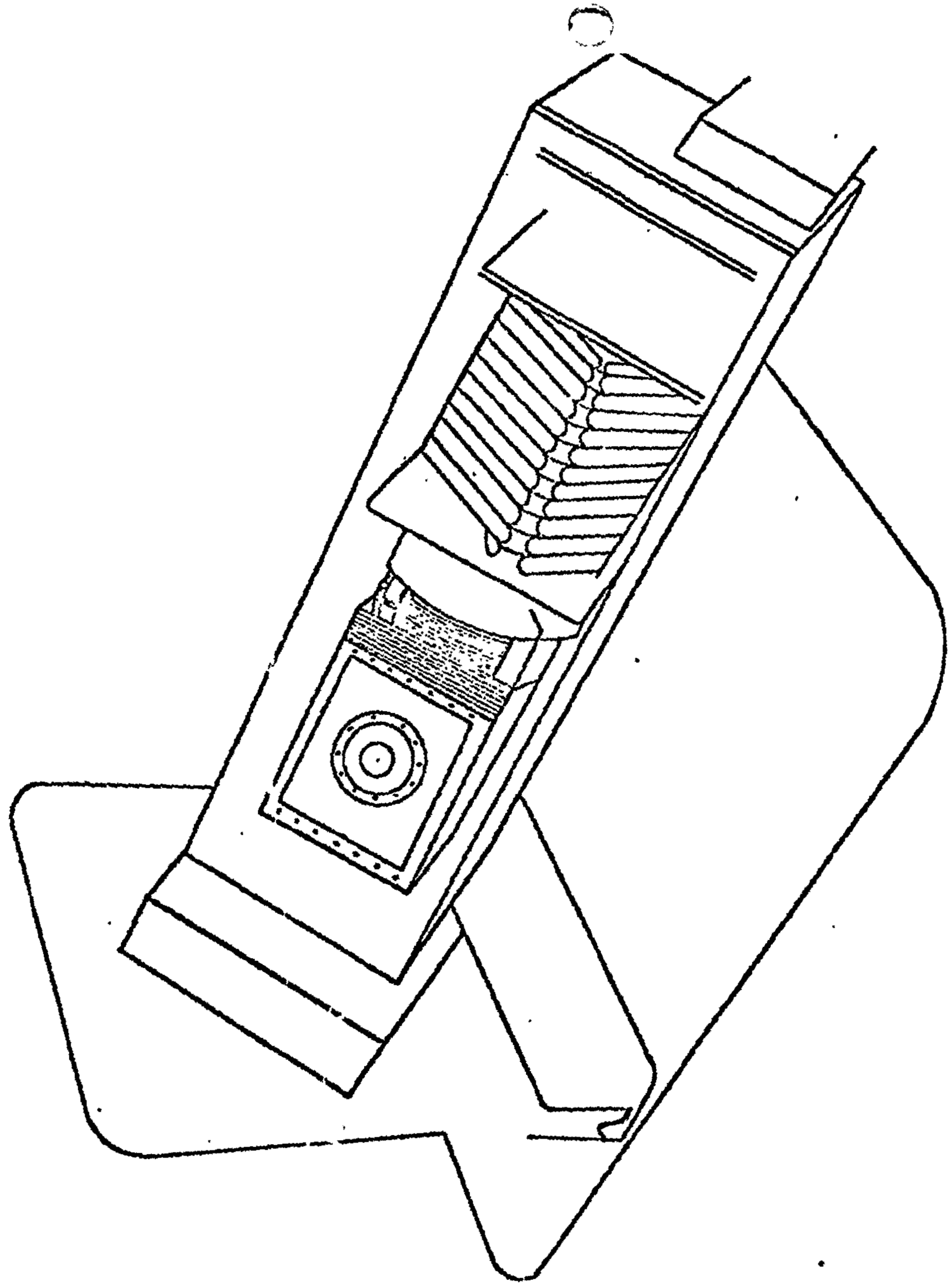
   Def. - FY 68
   Dev. - FY 69-70
   Flight - FY 70-71
   Data Analysis - FY 72-73
   Dev. - FY 74
   Flight - FY 75

8. COST

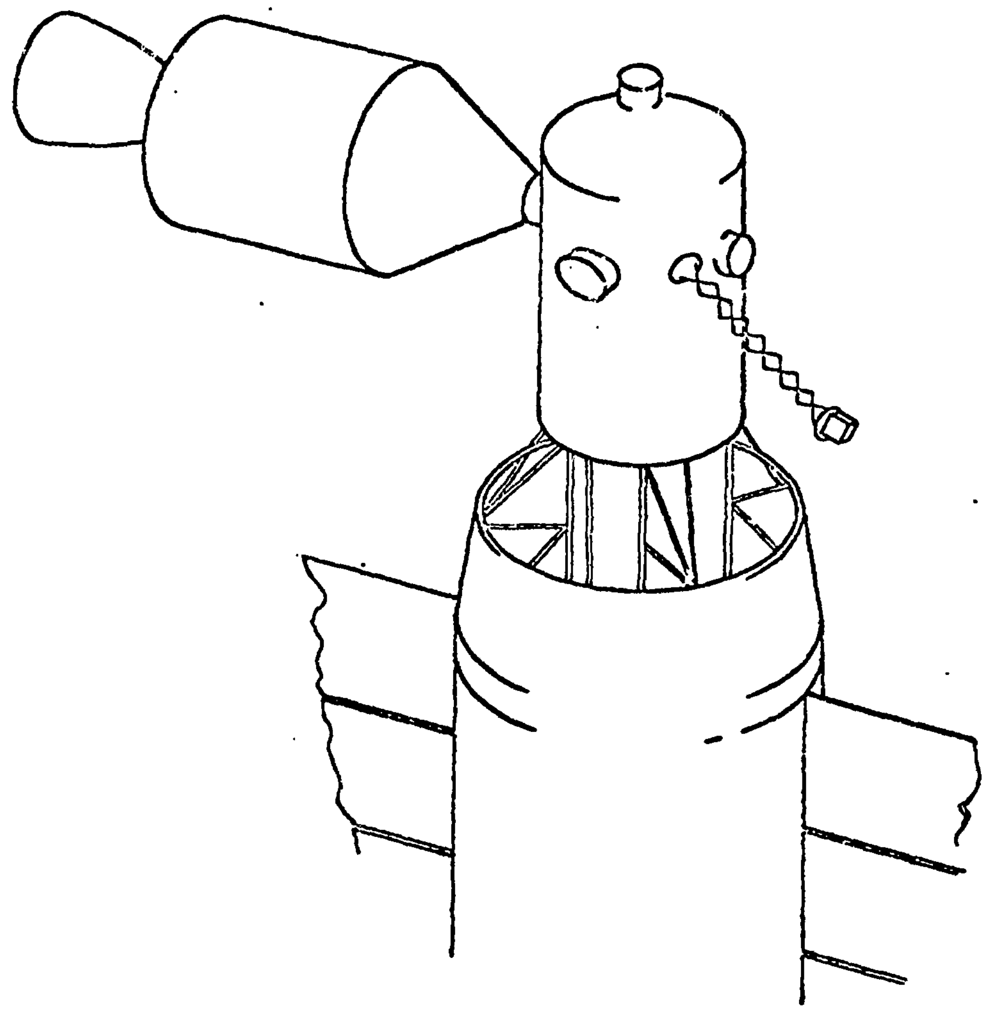
Prelaunch 390 K - Post-Launch 165 K (e.g., FY 68 - 95 K, FY 69 - 190 K, FY 70 - 210 K, FY 71 - 60 K)

9. SPACECRAFT INTERFACE - Experiment package is in a canister mounted to the spacecraft wall before and after deployment through a scientific airlock. Provision must be made for connections to provide the experiment package with power and automatic guidance and control within specified pointing limits. Onboard analog-to-digital converter and a digital magnetic tape recorder are required. The spacecraft is also expected to furnish ground command execution capability, clock timing signals, a commutator having at least 12 channels and a telemetry system.

10. TEST PROGRAM - The following tests will be performed on a test unit in the given sequence; performance (operating), temperature - altitude, storage, and transportation (nonoperating), humidity (nonoperating), vibration (nonoperating), shock (nonoperating), orbital thermal/vacuum (operating), oxygen (nonoperating), and explosion (operating).



MASS SPECTROMETER IN STORED POSITION USING TO27
DEPLOYMENT CONCEPT



MDA AIRLOCK DEPLOYMENT CONFIGURATION FOR MASS SPECTROMETER
USING T027 DEPLOYMENT MECHANISM

EXPERIMENT DATA SHEET

T031 SPACECRAFT SURFACES EXPERIMENT

1. SPECIFIC OBJECTIVES

   a) To determine the long term effects on the optical properties of various types of thermal control surfaces by the combined elements of the low Earth orbit space environment.

   b) To obtain information on the mechanical stability of thermal control surfaces in the space environment.

2. GENERAL DESCRIPTION - Several coupons containing a selection of thermal control surfaces are to be attached to the outside of the S-IVB either before launch or after insertion into orbit. In-situ spectral reflectance measurements will be made of the coupons during the mission using a handcarried, self-contained reflectometer. High-resolution color photographs will also be taken of the samples. The coupons will be retrieved at various times during the mission and returned to Earth for analysis. EVA will be required for in-situ measurements, coupon retrieval, and possibly for coupon attachment.

3. OPERATIONAL CONSTRAINTS - The coupons should be in sunlight as much as possible and it is desirable that they be in sunlight while measurements are being made. There are no other orientation requirements. There are no orbital altitude, inclination, stabilization, or pointing constraints.

4. MODE OF OPERATION - Coupon attachment will be made either prior to launch or after orbit insertion via EVA. In situ photography and reflectance measurements will require EVA. The camera and reflectometer will be carried by the astronaut; the reflectometer will be held by a temporarily attached template during measurements. Fifteen seconds are required for each sample measurement and for a calibration check. The reflectometer contains its own battery power and data tape recording equipment.

After photography and reflectance measurement, coupons are removed from the S-IVB surface and placed in a coupon collector for protection. The collectors containing the retrieved coupons are placed into a coupon container after the astronaut returns to the space station but before the airlock is pressurized. The container is then sealed and pressurized with helium to protect the coupons for Earth return.

Minimum EVA time would be required if the samples could be located adjacent to the astronaut airlock. If the samples were mounted very near the airlock outer door, it might be possible for an astronaut to bring them into the depressurized airlock, perform reflectance measurements there and, if desired, reattach them to the spacecraft outer surface without moving away from the airlock.

5. CREW SUPPORT - EVA will be required for photography and recovery of coupon samples. EVA may also be required for initial installation of samples on S-IVB outer surface.

6. SPACECRAFT SUPPORT -

Ascent: 32 pounds and 2.2 ft^3

Descent: 13 pounds and 1.8 ft^3

These figures do not include external coupon holders, data tapes, or camera and film required for sample photography. No power or communication requirements are imposed on the station since all data storage and power is internal to the reflectometer. The coupon container with coupons, the recording tape and the reflectometer are returned to Earth for analysis.

7. DEVELOPMENT SCHEDULE

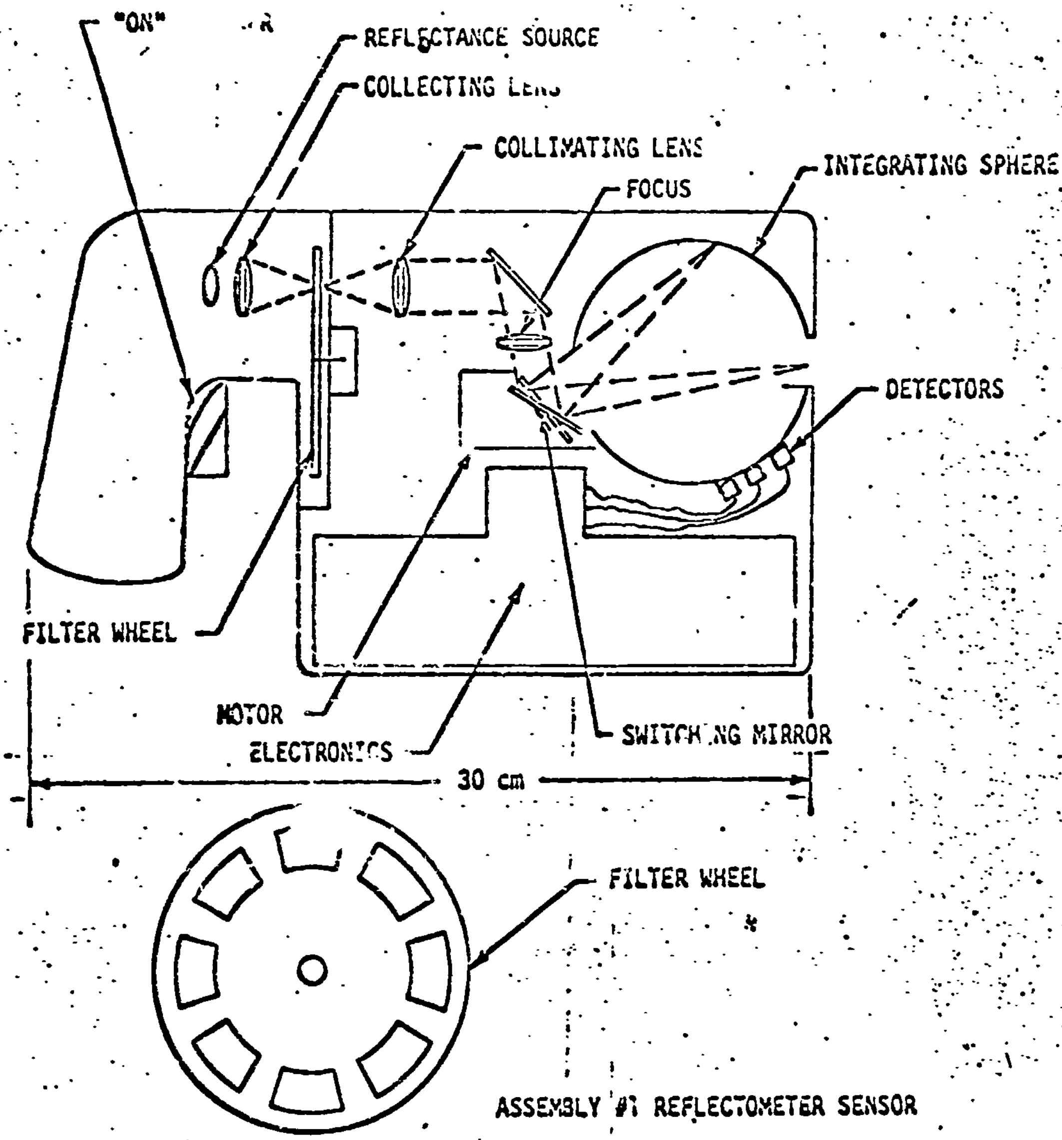
Development and delivery of early flight units - FY 69
Development of later model, if required - FY 70-73
Delivery of later model flight units - FY 74
Flight - FY 75
Data analysis - FY 75-76

8. COST (Preliminary Estimate)

FY 69:- 200 K
FY 70-72: 200 K
FY 73-74: 200 K
FY 75-76: 200 K

9. SPACECRAFT INTERFACE - Coupon supports are required on the outside surface of the S-IVB. Additional mounting cleats are required at this location to provide astronaut mobility aids. The coupons are to be mounted in a position of unobstructed view of the Sun and space.

10. TEST PROGRAM - Tests will be performed on a test unit in the given sequence: performance (operating), temperature - altitude, storage, and transportation (nonoperating), humidity (nonoperating), vib[illegible]ion (nonoperating), shock (nonoperating), orbital thermal/vacuum ([illegible]ating), oxygen (nonoperating), and explosion (operating).



ASSEMBLY #1 REFLECTOMETER SENSOR

EXPERIMENT T031

FUNCTIONAL PROGRAM ELEMENT

1. Discipline - Advanced Technology

2. Program Element - Exposure Experiments

3. Requirement:

   a. Determine meteoroid flux, velocity, mass and composition spectrum in near earth orbit.

   b. Determine synergistic effects of long duration exposure to space environment on physical properties of optical surfaces, thermal coatings and engineering material specimens.

   c. Verify experimental techniques for obtaining data on unmanned interplanetary missions.

4. Justification:

   Although data has been obtained on meteoroid momentum and related flux density, a complete lack of data exists with respect to specific measurements of meteoroid mass, velocity and composition. It is quite probable that spacecraft structures, meteoroid bumpers, radiators, etc., may be considerably overdesigned in order to be conservative in relation to available data. In addition, of course, data of this type is of direct interest to the Office of Space Science and Applications.

   Knowledge of the synergistic effect of the space environment on optical surfaces and gratings is of vital importance in the design of future large space astronomy observatives. Because of the extreme sensitivity of astronomical instruments, further data on degradation of thermal coatings is also required inasmuch as many spacecraft have exhibited unexplained temperature equilibrium anamolies.

   The Space Station offers a unique opportunity to obtain long duration exposure data. Not only can data be obtained in-situ but the samples and specimens can be brought back to earth for extensive ground based examinations.

5. Component Experiments:

   a. Meteoroid Composition
   b. Meteor Flash Analyzer
   c. Meteor Impact and Erosion
   d. Meteoroid Velocity
   e. Meteoroid Flux and Velocity
   f. Spacecraft Surfaces
   g. Orbital Fatigue

6. Description:

As a group, these experiments require long duration exposure of large areas (from 1 ft^2 surface area up to 24 ft^2). In many cases, samples and test specimens will require retrieval (possibly EVA) and return to earth. Color photographs of the exposed samples and areas will also be required. For meteoroid velocity experiments, data will be time keyed so that spacecraft orientation at moment of impact can be ascertained.

7. Special Considerations:

Experiments will require means of exposure (air-lock, EVA, or external mount with disposable protective covers); means of retrieval (EVA, serpentuator) hermetically sealed storage containers for return to earth.

Orbit altitude and inclination are not critical. Optical quality window required for some measurements. Stabilization of $\pm 10^\circ$ is required.

EXPERIMENT DATA SHEET

T-015 METEOROID COMPOSITION

1. SPECIFIC OBJECTIVES

To determine by spectroscopic observations of impacting meteoroids information about the number, velocity, size, composition, and mass of meteoroids.

2. GENERAL DESCRIPTION

An impact flash spectrometer will be used to measure the intensity, spectral distribution, and time history of the impact radiation produced when a meteoroid strikes a plate of known composition. With known plate properties, radiation in the wavelength region 3000 Å - 9000 Å will yield information about the velocity, size, and composition of the meteoroid. In conjunction with the impact flash spectrometer, an impact mass spectrometer consisting of a metal target and charge-sensitive detectors will be used to identify and determine the relative abundance of elements contained in meteoroids. On impact with the target, each meterooid produces a partially ionized vapor cloud containing charged atomic constituents of both particle and target materials. By time-of-flight techniques, ions extracted from the cloud are measured to yield the relative abundance of elements.

3. OPERATIONAL CONSTRAINTS

There are no particular spacecraft orientation requirements for the experiment. However, the detector location on the spacecraft and spacecraft orientation should be such that the detector points away from

Earth for at least 50% of the mission. Experiment must be located such that it is not in the shadow of any spacecraft components. It may be necessary to deploy the experiment to meet this condition.

4. MODE OF OPERATION

Once turned on by an astronaut, the experiment will operate automatically and continuously from a position attached to the spacecraft. Astronaut must turn on a calibration switch twice a day and must remove film upon completion of mission. Film is to be returned to Earth.

5. CREW SUPPORT

Astronaut will deploy the experiment and attach to outside of spacecraft. Upon c[illegible]ion of mission, astronaut will remove film and impact pla[illegible]ble, and place in a protective container for return t[illegible]

6. SPACECRAFT SUPPORT

Launch two instruments, each having a 10 ft^3 volume and weights of 25#. Data will be recorded on film. Maximum power required for both experiments: 50 watts.

7. DEVELOPMENT SCHEDULE

Experiment can be developed 30 months after go-ahead.

8. COST

FY 69 - $500K

FY 70 - $750K

FY 71 - $100K

EXPERIMENT DATA SHEET

T-016 METEOR FLASH ANALYZER

1. SPECIFIC OBJECTIVE

To measure and analyze optical radiation pulses from meteors entering the nightside of the terrestrial atmosphere.

Optical data will be recorded simultaneously in three wavelength bands $0.22\mu \longleftrightarrow 0.26\mu$; $0.26\mu \longleftrightarrow 0.30\mu$; and $0.30\mu \longleftrightarrow 0.40\mu$ using a three-channel radiometer. To accomplish the objectives of the experiment, the optical observables (maximum meteor intensity, integrated meteor intensity, and background intensity) will be measured in all three wavelength bands. This data will be used to: determine relative meteor radiation efficiencies in the far ultraviolet inaccessible to ground-based observation; check consistency of contemporary meteor radiation theory; determine meteor mass, meteor velocity, meteor entry angle, and atmospheric scale height; and attempt an interpretation of measured relative meteor intensities in the three wavelength channels in terms of the relative abundance ratios of $[Fe] \div [Mg] \div [Si]$ in meteors. The ultimate objective of the Meteor Flash Analyzer (MFA) experiment is to determine the mass-flux relationships of massive meteors in the vicinity of planets such as Mars, Jupiter, and possibly Venus. Although more limited in objective and scope, the present experiment constitutes a first necessary step toward the ultimate goal.

2. GENERAL DESCRIPTION

The MFA consists of two packages: a Sensor Assembly and an Electronics Assembly. The two assemblies are connected by a flexible cable of ample [illegible]th. The Sensor Assembly combines the detectors and associated optics for the three optical data channels and a fourth channel for monitoring the background intensity. The latter channel consists of a photoemissive diode of large dynamic range and associated optics; it protects the sensor channels against excessive illumination levels and provides automatic turn-on a d turn-off during orbiting. This feature permits the instrument to operate, after initial activation, without attention from the ground. The Sensor Assembly also contains the calibration lamp needed for monitoring any sensitivity changes of the channels. Aside from the optical components and the detectors, the Sensor Assembly contains the signal pre-amplifiers and the high-voltage supplies for the PM tubes and the calibration lamp. The four optical channels are aligned to cover nearly identical fields of view. Most of the electronic circuitry of the MFA is contained in the electronic assembly. Principal exceptions are power supplies for operating sensors, calibration lamp, and signal pre-amplifiers which must be located near the sensors.

3. OPERATIONAL CONSTRAINTS

The experiment has to be performed from an orbiting platform in order to eliminate the disturbing effects of the Earth's ozone. The experiment method is to point the wide field of view, three-channel radiometer straight down toward the dark Earth. The radiometer senses the meteor radiation against the Earth's background (nightglow), and the radiometer electronics record electrical quantities proportional to the meteor observables, background intensity, and meteor intensity. The data will be telemetered to the ground station. From these measured quantities, the abundance of meteors and their masses and velocities will be determined.

Aside from the three radiometer sensor channels, the experiment package includes an in-flight calibration lamp and a fourth radiometer channel designed to protect the radiometer sensor channel against damage from excessive background illumination levels. The in-flight calibration lamps are intended to check for major changes in sensor channel calibration during flight. T 's check, which is planned to be performed every five minutes during the data-taking experiment period, is completely automated.

There are no orbital constraints on the experiment. The experiment will be performed during nighttime with the MFA apparatus automatically controlling the duty cycle. The experiment will not be performed during full moon or when there is significant aurora activity. Spacecraft pointing accuracy must be ± 10° or better of experiment optical axis toward nadir.

4. MODE OF OPERATION

There are no special skills or training requirements for the MFA experiment. In-flight activity consists of deploying the optical sensor package making sure the cable-to-electronics package is securely connected at both ends; activate the experiment by means of switch and ascertain t'at pilot light is on; inform pilot that experiment is on and that spacecraft must be oriented toward the center of Earth; maintain this attitude within ± 10° for the duration of the experiment (approximately 20 minutes during night orbit); and deactivate experiment and withdraw sensor package into spacecraft.

5. CREW SUPPORT

There are no special skills or training required for the MFA experiment. Crew activities are those as indicated in the previous section.

6. SPACECRAFT SUPPORT

The Sensor Assembly must be mounted such that an unobstructed 30° field of view in the direction of the Earth is provided. The Electronic Assembly box can be placed in any convenient location inside the spacecraft. Weight and size of the MFA assemblies are:

Sensor Assembly: 8.75" x 6.25" x 6.25" Weight: 8.3 lbs.

Electronics Assembly: 7.5" x 7.5" x 6.625" Weight: 6.2 lbs.

Power: Stand-by - 3.0 Watts

Average - 7.5 Watts

Maximum - 9.5 Watts

7. DEVELOPMENT SCHEDULE

Experiment can be developed in 15 months after go-ahead.

8. COSTS

FY 69 - $400K

FY 70 - $150K

FY 71 - $30K

EXPERIMENT DATA SHEET

T-017 METEOROID IMPACT AND EROSION

1. SPECIFIC OBJECTIVE

To measure the flux of near-earth meteoroids having masses between about 10^{-14} and 10^{-8} grams.

The experiment will give visual verification of the Pegasus 0.0015-inch thick aluminum penetration data and extend this data into the small particle region that may cause erosion of spacecraft and optical surfaces.

2. GENERAL DESCRIPTION

The experiment will expose smooth vycor glass surfaces to the near-earth environment. The experiment hardware consists of ten panels hinged together by torsion springs. The springs are preloaded to fold the hardware into a packaged configuration. Each panel contains 12 specially prepared impact plates. These plates are predominately highly polished vycor glass. Upon release the spring-loaded panels deploy exposing the vycor glass to the environment.

3. OPERATIONAL CONSTRAINTS

The experiment is passive. It must be deployed outside of the spacecraft in an area where the exposed surfaces are not shadowed by the spacecraft. Spacecraft orientation is not a requirement; however, the experiment must not be deployed such that it is not looking directly at the Earth.

4. MODE OF OPERATION

The experiment must be deployed and attached outside of the spacecraft. While exposed to the space environment, the experiment is completely passive. Upon completion of the mission, the experiment must be folded, retrieved and subsequently returned to Earth for analysis.

5. CREW SUPPORT

Astronaut is required to deploy and attach the experiments. He is also required to retrieve the experiment. Training procedures have been established and several astronauts have actually deployed and retireved the experiment in a simulated near-zero g environment. The experiment was to be flown in the Gemini Program and the astronaut duty cycle and skills were established at that time.

6. SPACECRAFT SUPPORT

The experiment is passive. Packaged configuration: 6" x 16" x 3"; Deployed configuration: 60" x 16" x 3"; Weight: 13 pounds.

7. DEVELOPMENT SCHEDULE

Experiment is on the shelf awaiting integration into the spacecraft.

8. COSTS

FY 69 - $100K (for integration).

EXPERIMENT DATA SHEET

T-021 METEOROID VELOCITY

1. SPECIFIC OBJECTIVE

The meteoroid penetration flux-velocity experiment will measure the impact velocity (magnitude and direction) and the penetration depth into soft aluminum of meteoroids in near-earth orbit with mass greater than $10^{-11.5}$ grams. The velocity is measured during flight and the impact plates are recovered for ground analysis.

2. GENERAL DESCRIPTION

The instrument consists of two thin-film (2500Å thick) capacitors suspended three inches apart with a soft aluminum impact plate immediately behind the second film. The conducting surfaces of the capacitors are approximately 2500Å thick and sectioned into 1-inch by 12-inch orthogonal strips (x and y). A meteoroid impact and perforation produces a plasma in the vicinity of the capacitor. The ions are collected on the negatively charged capacitor surface and produce a signal that is interpreted by a logic network as an x location on the front surface. The electrons are collected on the positive side, and the resulting signal is interpreted as the y location on the rear surface. The perforation point is then identified within 1-inch square on the front and rear thin-film capacitors and defines the particle trajectory. The aluminum impact plate is located just behind the second capacitor. Each plate is 6x12 inches and is held in place by the structural framework. For ease of construction, handling, and recovery, the detectors are fabricated in 1-ft. square modules that are arranged in a 3x4-ft. rectangle for the flight configuration.

3. OPERATIONAL CONSTRAINTS

There are no operational constraints; however, the experiment must be located on the spacecraft such that it will not be shadowed by any spacecraft components, and it will not be looking directly at the Earth. Spacecraft orientation is not required.

4. MODE OF OPERATION

The experiment is passive and protected during launch. After insertion into orbit the protection is jettisoned and the experiment is turned on, checked out, and prepared for data collection. When a meteoroid "hit" occurs, the time of flight between capacitors and trajectory is recorded on a central data storage and telemetered to a ground station approximately every four hours. Prior to the completion of the mission, the impact panels must be recovered by an astronaut and stored in protective containers for subsequent return to Earth for analysis.

5. CREW SUPPORT

An EVA astronaut will be required to recover the impact plates.

6. SPACECRAFT SUPPORT

As presently being developed, the experiment requires 10 watts of power continuously and weighs approximately 100 pounds. Volume of the experiment is about 3.0 ft^3. Returned weight is estimated to be about 10 pounds if three one-square-foot impact plate modules are returned. For analysis purposes, a minimum of three modules must be returned.

7. DEVELOPMENT SCHEDULE

Experiment is under development and a flight-qualified unit can be available in 18 months.

8. COSTS

FY 69 - $500K

FY 70 - $200K

METEOROID FLUX AND VELOCITY

1. SPECIFIC OBJECTIVE

   a. Flight qualification of instrument planned to measure the meteoroid and asteroid environment in the region of the solar system beyond the Earth's orbit.

   b. Obtain data on the number and velocity of meteoroids in near-Earth space that are a potential hazard to spacecraft.

2. GENERAL DESCRIPTION

The instrument uses reflected or scattered solar radiation from the meteoroid or asteroid for detection, size, and velocity determination. The passage of the body is measured by three independent non-imaging optical systems. The entrance and exit times of the particles through each of three fields of view completely determine the range and the true velocity components of the particle.

3. OPERATIONAL CONSTRAINTS

There are no particular spacecraft orientation requirements; however, the instrument location on the spacecraft and spacecraft orientation should be such that the instrument points away from the Earth for at least 50% of the mission. A 10° field of view is required. Instrument cannot operate during time of full moon.

4. MODE OF OPERATION

Once the instrument is turned on, it will operate automatically and continuously until the mission is completed. Data are stored and can be telemetered to the ground or recorded by an astronaut.

5. CREW SUPPORT

Only requirement for crew support is to turn instrument on and to record the data, if this mode of operation is selected. Ground command could turn instrument on and telemeter data so it is possible that no crew support would be required.

6. SPACECRAFT SUPPORT

Launch the instrument. Weight: 5 lbs.; Volume: 2,000 $in.^3$; Power: 2.0 watts continuous, designed for 28 VDC regulated ±1%; Telemetry: 400 bits per readout of once per hour.

7. DEVELOPMENT SCHEDULE

Instrument can be developed 30 months after go-ahead.

8. COSTS

FY 69 - $250K

FY 70 - $400K

FY 71 - $100K

ORBITAL FATIGUE

EXPERIMENT DATA SHEET

1. Specific Objective - to verify the adequacy of ground based fatigue testing by corroboration with fatigue tests conducted in orbit.

2. General Description - a series of fatigue test specimens (estimated at 24) will be exposed to the space environment for long durations. These specimens will then, one by one, be placed in a fatigue tester for measurement of fatigue life in-situ. This means that the fatigue tester will be deployed internal to the spacecraft.

   The test specimens are approx. .1" X .5" X 6". The fatigue tester will have an envelope of 15" long X 4" wide X 2" thick and will weigh about 35 pounds. Total weight of the specimens will be about 3 pounds not including the exposure and deployment hardware.

3. Operational Constraints - location of specimen and tester deployment should be away from spacecraft contamination.

4. Mode of Operation - Manned intermittent, attached.

5. Crew Support - the astronaut is required to retrieve the test specimen, place it in the fatigue tester and deploy the tester outside the spacecraft. When turned on, the fatigue tester will function automatically until specimen failure. The astronaut is required to retrieve the failed specimen for return to earth and to repeat with the next specimen. Time required for astronaut to retrieve exposed test specimen, mount in tester and deploy tester is approximately 15 minutes. Automated testing time (astronaut not required) can be from 1 to 10,000 minutes.

6. Spacecraft Support - provisions are required for long duration exposure and retrieval of test specimens and for exposure and retrieval of the fatigue tester. Fatigue tester operation will require an average of 100 watts and a maximum of 200 watts. Tested samples must be stored and returned to earth. Total weight about 40 lbs plus deployment requirements. Return weight about 5 lbs, including 1/3 ft^3 container. Data read-out requires 1 channel at 1 reading per minute and one channel at 1 reading every 30 minutes.

7. Development Schedule

8. Cost

FY 69	FY 70	FY 71	FY 72	FY 73	FY 74
50K	60K	100K	(200K)	(200K)	(100K)

( ) flight hardware development

9. Spacecraft Interface - as noted in Item 6

10. Test Program - will be minimized because of ground based research program using some fatigue tester.

EXPERIMENT DATA SHEET

T-031 SPACECRAFT SURFACES

1. SPECIFIC OBJECTIVES

The object is to determine the long-term effects on the optical properties of various types of thermal control surfaces after exposure to combined solar ultraviolet radiation, high-energy particles, and other components of the environment which may be present at low orbital altitudes. Simulation of the combined effects in the laboratory is difficult or impossible and exposure via remote automated instrumentation of such surfaces does not reveal changes which may occur in sufficient detail. For example, changes in directional reflectometer characteristics, whether directional or in diffuse reflectance at particular wavelengths, cannot be detected by presently available remote instrumentation. Crushing and pulling are also not detectable by such means.

2. GENERAL DESCRIPTION

Several coupons containing a selection of thermal control surfaces are to be attached to the outer surface of the spacecraft before launch or after insertion into orbit. As soon as possible after obtaining orbit, our EVA astronaut would make measurements on selected samples with a solar reflectometer and with a color camera. Another similar measurement would be made before the end of the mission following which the astronaut would detach one or more of the coupons and place them in a sealed container for return to Earth and subsequent analysis of same.

The reflectometer will consist of a pistol-grip type device containing internally a liquid source, appropriate filters, detectors and an integrating sphere. It will be attached by cable to its tape recorder -- power supply container - holster which is strapped to the astronaut's waist.

3. OPERATIONAL CONSTRAINTS

Measurements with the reflectometer should be made while the sample is in sunlight to eliminate the possibility of contamination due to cryopumping of evolving water.

4. MODE OF OPERATION - See 2 and 3 above.

5. CREW SUPPORT

The astronaut must become familiar with the operational and handling characteristics of the experiment. This will involve a detailed briefing at MSFC, as well as practice with the spectral reflectometer, the container, etc., in the neutral buoyancy facility and in the zero 'g' aircraft.

6. SPACECRAFT SUPPORT

The total weight of the pistol-grip type reflectometer and accompanying holster containing a recorder is 12 kg with a combined volume of 24 liters. The retrieval box weighs 2-6 kg and occupies 36.8 liters. The template is thin, weighing .1 kg with horizontal dimensions of 28 x 44 cm. The sensor package (pistol grip) will use a steady power of 10 watts while the recorder requires steady power of 14 watts.

7. DEVELOPMENT SCHEDULE

Two engineering prototypes of hand-held solar reflectometers are nearing completion. Flight hardware could be completed 6 to 9 months from go-ahead on development.

8. COST

Flight hardware, documentation and testing of reflectometer estimate is $150K from go-ahead. Recovery boxes and samples being prepared in-house.

9. SPACECRAFT INTERFACES

Interface between reflectometer, sample recovery box, and template dependent on whether experiment is combined with similar Air Force Materials Laboratory experiment.

SPACE STATION EXPERIMENT PROGRAM

FOR

ADVANCED TECHNOLOGY

July 9, 1969

Langley Research Center
Langley Station
Hampton, Virginia

INTRODUCTION

Because the design and operation of any future space station is significantly impacted by the experiments to be carried out, and since the scheduled start of the phase B design effort for the 1975 space station is in early 1969, the Deputy Associate Administrator for Manned Space Flight requested through the Office of Advanced Research and Technology that the Langley Research Center be responsible for establishing a Space Station Experiment Program in Advanced Technology for the integrated payload planning activity of the Advanced Manned Mission Program. As a result, the Langley Research Center formed an Ad Hoc Integration Group to define Advanced Technology Experiments. The personnel assignments are shown in table I.

The integration group was divided into several working groups to define representative experiments for Advanced Technology in the following disciplinary areas:

Space materials, structures, and mechanisms

Guidance, stability, and control

Environmental control/life support

Space power

Fluid systems

Remote sensing

Centrifuge

Crew aids

In the resulting study, Functional Program Elements (FPE) and experiments have been defined according to the procedures established by the integrated payload planning activity of the Advanced Manned Missions Program for the Payloads Office, Code MTX.

It should be noted that this experiment definition activity does not define all the experiments that could be considered for each functional program element but simply represents in some detail a class of experiments that will support the phase B Space Station Design Study. It is suggested that the proposed experiments will provide the requirements necessary to design a space station facility capable of handling a wide variety of experiment objectives.

SPACE STATION MISSION SIMULATION MATHEMATICAL MODEL

Also in support of the integrated payload planning activity, the Langley Research Center has developed a Space Station Mission Simulation Mathematical Model under contracts NAS1-5874 and NAS1-7105. This model permits the assessment and analysis of requirements, planning, scheduling, and overall integration functions related to space-station experiment programs to be made by automatic computing equipment.

For the purpose of the present exercise, inputs have been provided to that part of the mathematical model known as the Planning Model (Langley Program No. R-2017) in accordance with the format listed on the accompanying sample. Experiment/Event Data Sheet (see table II). Entries have been supplied, where available, for each operational phase of each experiment. In order to limit the bulk of this presentation, the format has been condensed to a simple listing of items corresponding to the numbering system of table II. Details relating to the mathematical model may be obtained from Charles P. Llewellyn, ext. 3666, or Karen D. Brender, ext. 3544, at the Langley Research Center.

TABLE I.- AD HOC INTEGRATION GROUP

Axel T. Mattson, Chairman
Richard C. Dingeldein, Asst. Chairman
Irene J. Manning, Secretary

WORKING GROUPS

SPACE MATERIALS, STRUCTURES, AND MECHANISMS		
Edward L Hoffman, Head	LRC	Structures Research Div.
John S. Mixson	LRC	Dynamic Loads Div.
Jerry G. Williams	LRC	Applied Materials and Physics Div.
GUIDANCE, STABILITY, AND CONTROL		
Ralph W. Will, Head	LRC	Applied Materials and Physics Div.
Jacob H. Lichtenstein	LRC	Aeronautical and Space Mechanics Div.
Aaron J. Ostroff	LRC	Flight Instrumentation Div.
ENVIRONMENTAL CONTROL/LIFE SUPPORT SYSTEM		
William M. Piland, Head	LRC	Aeronautical and Space Mechanics Div.
Lenwood G. Clark	LRC	Applied Materials and Physics Div.
Charles G. Saunders	LRC	Flight Instrumentation Div.
SPACE POWER		
Robert C. Wells, Head	LRC	Flight Vehicles and Systems Div.
Atwood R. Heath, Jr.	LRC	Structures Research Div.
CREW WORK AIDS		
Gary P. Beasley, Head	LRC	Aeronautical and Space Mechanics Div.
William Letko	LRC	"
Otto F. Trout, Jr.	LRC	Applied Materials and Physics Div.
FLUID SYSTEMS		
Ian O. MacConochie, Head	LRC	Flight Vehicles and Systems Div.
John C. Aydelott	LeRC	Spacecraft Technology Div.
Franklin W. Booth	LRC	Flight Vehicles and Systems Div.
Pendleton M. Jackson, Jr.	LRC	"
REMOTE SENSING		
John A. Dodgen, Head	LRC	Flight Instrumentation Div.
Richard E. Davis	LRC	"
Wilfred D. Hesketh	LRC	"
Anthony Jalink, Jr.	LRC	"
Leonard P. Kopia	LRC	"
Samuel H. Melfi	LRC	"
W. E. Sivertson, Jr.	LRC	"
CENTRIFUGE EXPERIMENTS		
Ralph W. Stone, Jr., Head	LRC	Aeronautical and Space Mechanics Div.
H. George Hausch	LRC	Flight Vehicles and Systems Div.

TABLE II.- EXPERIMENT/EVENT DATA SHEET

Experiment Title

1. The identification number of the experiment .... __________
2. The total duration, in days, of the event; -1 for mission duration .... __________
3. The number of days active each period; (item 3 > 0) .... __________
4. The expected number of active periods; not specified for mission duration event .... __________
5. The number of days inactive each period; (item 5 ≥ 0) .... __________
6. Code for period:
   0 - period begins with inactive cycle (if item 5 > 0)....... __________
   1 - period begins with active cycle.
7. The forced start date within the mission if the event execution is fixed in time.................................. __________
8. Number of skill types required/day; (1 ≤ item 8 ≤ 3).......... __________
9. First skill type required; (1 ≤ item 9 ≤ 35).................. __________
10. The number of hours required of 1st skill type per day; (0 ≤ item 10 ≤ 24).. __________
11. Second skill type required; (0 ≤ item 11 ≤ 35)................ __________
12. Hours required for 2nd skill type .... __________
13. Third skill type required; (0 ≤ item 13 ≤ 35)................. __________
14. Hours required for 3rd skill type .... __________
15. Position latitude (not used by p.m.).......................... __________
16. Position longitude (not used by p.m.)......................... __________
17. Light-dark code number (not used by p.m.)..................... __________
18. Peak ac power required each day in active cycle (watts).. __________
19. Continuous ac power required (watts).......................... __________
20. Duration of peak ac (hours); ≤ 24.0........................... __________

TABLE II.- Continued

21. Duration of peak dc (hours); ≤ 24.0 .... ________
22. Peak dc power required each day in active cycle (watts) .... ________
23. Continuous dc power required (watts) .... ________
24. Weight required on the logistics spacecraft .... ________
25. Volume required on the logistics spacecraft .... ________
26. Special equipment code .... ________
    0 - No special equipment required.
    1 - Telescope module present.
    2 - Animal module present.
27. Predecessor/successor datum. See item 40 .... ________
28. Predecessor/successor datum. See item 40 .... ________
29. Predecessor/successor datum. See item 40 .... ________
30. Code for required spacecraft orientation .... ________
    -1 - Belly down.
    0 - No requirement.
    1 - Special (inertial).
31. Communications - voice hours/day .... ________
32. Communications - TV hours/day .... ________
33. Communications - digital data, 10^6 bits/day .... ________
34. Percent of digital data not transmitted (not used by p.m.) ..... ________
35. Weight of experimental material to be returned .... ________
36. Volume of experimental material to be returned .... ________
37. Interruptibility code .... ________
    -1 - Not interruptible.
    0 - Data loss.
    1 - Interruptible with no data loss.
38. Optimistic estimate of number of active periods .... ________
39. Pessimistic estimate of number of active periods .... ________

TABLE II.- Concluded.

40. Predecessor/successor option.................................. ________

If item 40 = 0:

If item 27 and/or item 28 is filled in and item 29 is the delay time, then it is a rigid chain and the chain will not start if any experiment/event cannot be worked (i.e., it schedules chain like one event).

If item 40 = 1:

One or more or items 27, 28, and 29 are predecessors you cannot start this event until the predecessors have been started.

If item 40 = 2:

One or more of items 27, 28, and 29 are predecessors and event cannot be started until the predecessors are finished.

(Item 3 and item 5) × item 4 = item 2.

NOTE:

(Item 3 and item 5) × item 4 = item 2.

If you want decimal number, put it in as decimal. Every place that requires a decimal is indicated by dot.

FUNCTIONAL PROGRAM ELEMENT I

1. Discipline: Advanced Technology

2. Program Element: Large Expandable Space Structures

3. Requirement:

   (a) Verify deployment and operation of lightweight space structures under actual operating conditions for use on future space missions.

   (b) Provide technology base for design and development of large expandable space structures.

   (c) Evaluate man's capability in support of deployment and alinement of large space structures.

4. Justification:

Many proposed space missions require structural configurations that are too large and fragile for realistic ground qualification of their operational feasibility and reliability. Ground qualification is not possible because the structures cannot support their own weight in the deployed condition and because zero "g" vacuum environment, or structural dynamics, cannot be adequately simulated for the large structures. In addition, the technology required for the structures is too far beyond current technology to permit development in a single step or to permit acceptance for prime missions without prior space qualification. Therefore, deployment in space of proposed configurations should first be studied with smaller-scaled models or simplified versions of the concepts in order to advance the large structures technology to a suitable base for future mission acceptance.

5. Component Experiments:

Experiment A - Lightweight Solar Cell Array

Experiment B - Parabolic Antenna

6. Description:

The lightweight solar cell array consists of two wings with areas of 1,250 square feet each that are to be deployed in orbit and undergo structural and electrical evaluation experiments. Parts of the arrays may be used to supplement the power capacity of the space station. The antenna experiment consists of a 15-foot-diameter model of a structural design applicable to antennas as large as 300 feet in diameter. The antenna and its deployment boom are to be evaluated structurally. The antenna-surface accuracy as well as man's capability to adjust the surface are also to be studied. The antenna may be used to increase the communication capacity of the space station after the experiments are completed.

7. Special Considerations:

Extravehicular activity (EVA) will be required to retrieve films of the deployment of the structures, to adjust the antenna surface, and to perform maintenance and repair tasks. The solar array must be pointed toward the sun and the antenna requires pointing toward specific ground stations. Experiments should be designed for deployment from the space station. Orbit altitude and inclination are not critical. Both experiments require return of film to earth.

BIBLIOGRAPHY

1. Anon: A Study of an Intermediate Orbital Workshop System (IOWS), Vol. 2 Experiment Program. NASA LRC, August 1968.

2. Anon: Analysis and Preliminary Design of Engineering Experiments for Manned Earth-Orbital Missions. Report No. 65-928-65 (Contract NAS1-4667), International Business Machines Corporation, August 1965.
   Part 1 - Space Flight Requirements for Satellite Recovery.
   Part 2 - Four Experiment Designs for the Manned Earth-Orbiting Laboratory.

3. Anon: Apollo X Final Report, Extended Apollo Systems Utilization Study. Volume 3B- Experimental Programs. Report No. 64-1860-3 (NAS9-3140), North American Aviation, Inc., November 1964.

4. Anon: Derivation of a Comprehensive Engineering Experiment Program for Manned Earth-Orbital Missions. Report No. 65-928-64 (Contract NAS1-4667), International Business Machines Corporation, August, 1965.

5. Anon: Experiment Requirements Document Apollo Applications Program (AAP). Report ED-2002-71 (NAS8-21004), Martin Marietta Corporation, April 1967.
   Volume I - Index.
   Volume III - Space Environment.
   Volume V - Astronomy.
   Volume VI - Communications/Navigation

6. Anon: Feasibility Study of Large Space Erectable Antennas. Report No. GDC DCL 67-002 (NASw 1438), General Dynamics, January 1968.
   Volume III - Summary, Parabolic Expandable Truss Antenna Experiment.
   Volume IV - Study, Parabolic Expandable Truss Antenna Experiment.

7. Anon: Final Report - Large Space Structure Experiments for AAP. Report GDC-DCL 67-009 (NASA Contract 8-18118), Convair Div. of General Dynamics, November 30, 1967.
   Volume I - Summary
   Volume II - Analysis and Evaluation of Space Structure Concepts
   Volume III - Crossed-H Interferometer for Long Wave Radio Astronomy
   Volume IV - Focusing X-Ray Telescope - A Large Space Structure for X-Ray Astronomy
   Volume V - Parabolic Antenna

8. Anon: ORL Experiment Program. (NASw-1215), International Business Machines Corporation, February 1966.
   Volume B, Part VI - Communications and Navigation/Traffic Control.
   Volume B, Part XI - Astronomy/Astrophysics.

9. Anon: Space Research- Directions for the Future, Report of a Study by the Space Science Board. Publ. 1403, National Academy of Sciences - National Research Council, Washington, D.C., 1966.

10. Anon: Summary of Results of Engineering Research Program for Manned Earth-Orbital Missions. Report No. 65-928-63 (Contract NAS1-4667), International Business Machines Corporation, August 1965.

11. The Needs and Requirements for a Manned Space Station.
Vol. I: Summary Report.
Vol. II: Astronomy.
Vol. III: Earth Resources.
Vol. IV: Meteorology.
Vol. V: Biology.
Vol. VI: Long-term Flight.
Vol. VII: Research and Development in Advanced Technology.
Vol. VIII: Orbital Operations and Logistics.
Prepared by Space Station Requirements Steering Committee. November 15, 1966. NASA, Langley Research Center.

12. Anon: A Proposal for Parabolic Expandable Truss Antenna Experiment Mounted on SIV Workshop. Report No. GDC PIN 68-220, Convair Division of General Dynamics, April 1968.

13. Anon: OLSCA Orientation Linkage for a Solar-Cell Array. Tech. Rept. AFAPL-TR-68-76, Hughes Aircraft Co., July 1968.

14. Apperson, J. L.; McAfee, F. W.; Norsen, D. A.; and Weikel, R. C.: Final Report - Phase II, Large Area Solar Array. Report D2-113355-7, (JPL Contract 951934), The Boeing Co., October 1968.

15. Fager, J. A.: Large Space Erectable Communication Antennas. Report SD 9, 19th Congress of the International Astronautical Federation, New York, New York, October 1968.

16. Ketchum, J. W.; McAfee, F. W.; Apperson, J. L.; and Weikel, R. C.: Final Report, Large Area Solar Array. Report D2-113355-4, (JPL Contract 951653) The Boeing Co., October 1967.

17. Lauderback, Paul Wayne: An Analysis of Low Orbital Drag Constraints of Orbit- and Sun-Oriented, Solar-Cell Arrays. Advances in Energy Conversion Engineering, Papers presented at 1967 Intersociety Energy Conversion Engineering Conference, ASME, August 1967, pp. 339-344.

18. Schuerch, H. V., and Hedgepeth, J. M.: Large Low-Frequency Orbiting Radio Telescope. NASA CR-1201, 1968.

19. Shepard, N. F. et al: Feasibility Study 30 Watts Per Pound Roll-Up Solar Array Final Report. Report No. 68 SD 4301, (JPL Contract 951970), General Electric Co., June 1968.

20. Staff of Space Station Office Manned Spacecraft Center: Manned Orbital Laboratory Research and Applications Requirement Study. Volume III., NASA, September 1963.

21. Wechsler, J. W.: Orbital Astronomy Support Facility (OASF) Study. Volume V - Research and Technology Implications for Orbital Astronomy, DAC-58145. Douglas Missile and Space Systems Division., June 1968.

22. Wolbers, H. L.: Report on the Development of the Manned Orbital Research Laboratory (MORL) System Utilization Potential, Task Area 1 - Analysis of Space Related Objectives, Books 1 and 2. (NAS1-3612), Douglas Missile and Space Systems Division, September 1965.

EXPERIMENT DATA SHEET I A

Lightweight Solar Cell Array

1. Specific Objective:

The purpose of this experiment is to develop the technology of a large-area, lightweight, solar cell array and space-qualify the array as a power source for future spacecraft. The structural dynamics of the array will be investigated under conditions of (1) array deployment, (2) array orientation under routine station operations, and (3) array orientation under station transient operations such as resupply vehicle docking and departure. Array loads under thermal shock associated with entry into and emergence from the earth's shadow, will also be determined. Power output of the array will be monitored to determine the compatibility of the solar cell installations with lightweight structures under actual flight conditions. In addition, supplementary power can be supplied to the station.

2. Description:

The array consists of two wings, each composed of thirteen panels, with a total area of 2,500 ft^2 per array as shown in figure 1. Only six panels of the array have solar cells, thus giving a power output of 6 kW. The remaining twenty panels each have mass simulation as though celled and are structurally similar to the panels containing cells. The array is mounted on a two-axis orientation system and can be alined to face the sun without regard to spacecraft orientation. The outer twelve panels of each wing will be discarded at the completion of the structural dynamics and power tests to reduce aerodynamic drag. The remaining two fully-celled panels will supply supplementary power of 2 kW to the station.

3. Operational Constraints:

Orbit inclination - not a factor

Altitude - maximum attainable within station capability

Stabilization - ±10° continuous in sunlight

Pointing - Station-pointing will be restricted while the experimental array is being deployed in order to provide adequate illumination to photograph and observe the operation. Station pointing may also be restricted once the array is extended to prevent shadowing of either this array or the main array used for station power.

Orbit keeping - To offset the aerodynamic drag of the area, 300 lb of propellant are needed in the 30-day period for a 200 n. mi. orbit. This drops to 10 lb in a 400 n. mi. orbit.

Acceleration - Steady-state accelerations < 0.02 g.

EVA may be required to photograph deployment of the array or to retrieve film from remote cameras.

NOTE: The sun-pointing and stabilization capability will be provided by the solar-cell array orientation system.

4. Mode of Operation:

The folded array with its own orientation system will be attached to the main station structure. In orbit, the deployment of the array will be automatic after initiation by the crew. Orientation of the array with the sun is automatic. Outer panels of the array will be jettisoned on astronaut command at the end of the observation period of one month. Data will be recorded automatically except that housekeeping information and selected critical data will be monitored by the crew for the deployment, initial solar orientation, and vehicle docking and departure phases of operation.

5. Crew Support:

Deployment Phase	- One man to activate and monitor accelerations and strains: One man to observe and film the deployment sequence: 30 min/man
Routine Operations Phase	- One man to monitor strains, accelerations, temperature, and power: 15 min/day
Docking and Departure Phases	- One man to monitor strains and accelerations: 15 min/event
Jettison Phase	- One man to monitor strains and accelerations and one man to film the sequence: 15 min/man

Crew skills require an electrical-mechanical technician and a photographer, however, any crew member could suffice with adequate preflight training.

6. Spacecraft Support:

Weight	- 2,480 lb
Packaged Size	- 160 in. diameter by 170 in. high

Power for deployment and operation of the solar array will be furnished from its own power system. One hundred data channels for recording of array information are required and may be returned to earth with either telemetry or tape.

Film taken during deployment and other events is to be returned to earth (three pounds of film). Magnetic tape containing data may be returned to earth or telemetered back on a convenience or availability-of-equipment basis.

7. Development Schedule:

Preliminary design and fabrication of portions of the array have been completed on JPL contracts. This work has proved out the feasibility of fabricating lightweight structures from advanced materials such as beryllium.

Simulated zero-"g" deployment has been done in ground tests on a mock-up of parts of the array in the same program. All work done to date has been based on the use of the array on an unmanned spacecraft. Redesign is required to meet the differing manned spacecraft requirements and it is estimated that three years would be required to deliver the array.

8. Cost:

Total Experiment	20.5 M
FY 71	8.5 M
FY 72	10.0 M
FY 73	2.0 M

9. Spacecraft Interface:

The spacecraft must have windows from which a crew member can observe the deployment and reactions of the array to spacecraft disturbances. Provisions must be made for transmitting the data from the experiment site to the spacecraft recording equipment. Provision should also be made to connect the array power system to the spacecraft power system so that the power available from the array after the conclusion of the experiment can be utilized. The structure of the spacecraft at the points of attachment to the solar array structure must withstand all loads imposed by the array.

10. Test Program:

The flight test program for the lightweight solar-cell array experiment consists of measurements of strains, acceleration, temperatures, and power (when applicable) on the array as well as photographic recording of events.

Specific test phases are listed below:

PHASE	TITLE
1	Array Deployment
2	Normal Array Operation
3	Logistic Vehicle Docking
4	Logistic Vehicle Depart
5	Outboard Panels Jetti

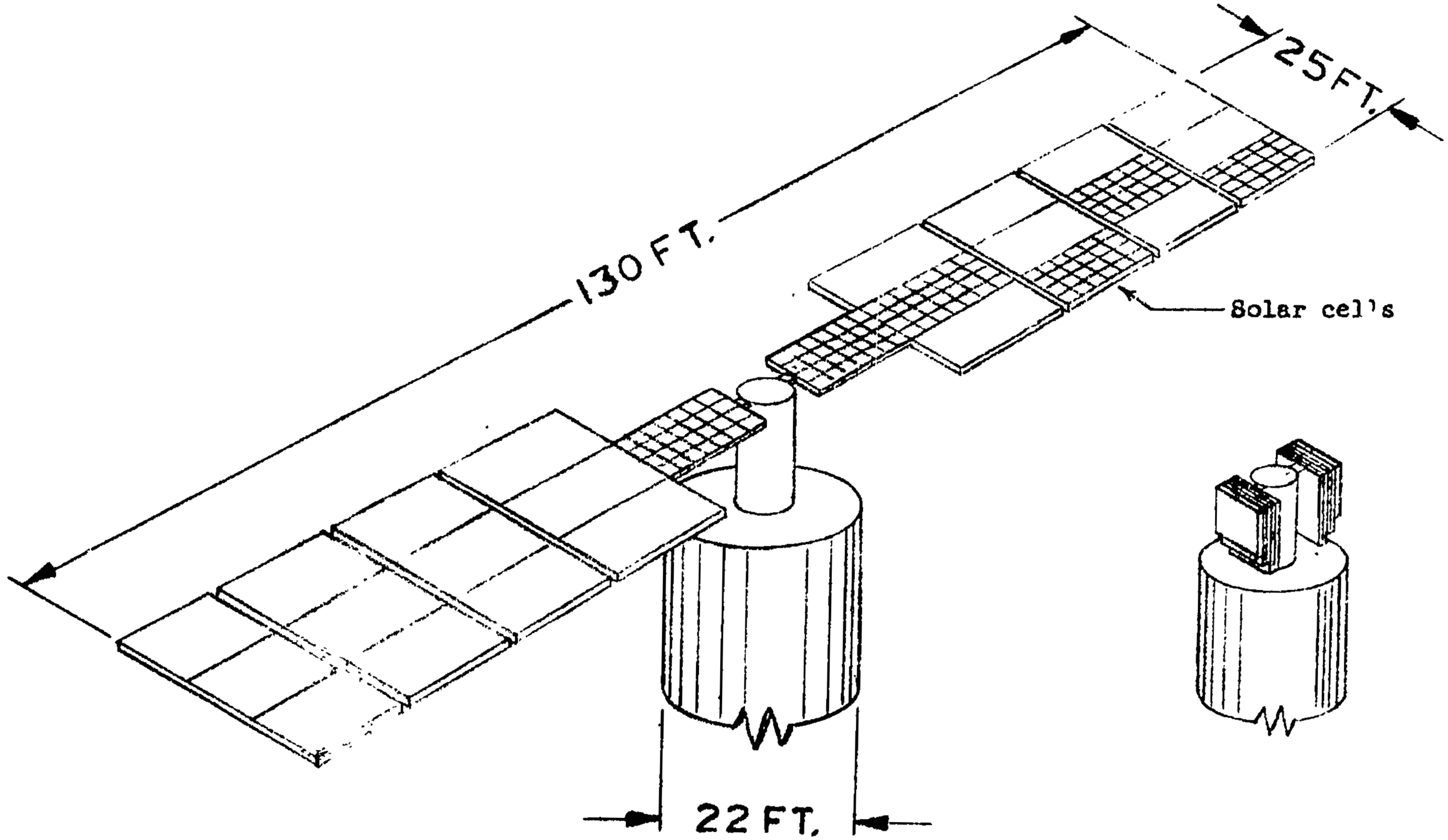


Figure 1.— Lightweight solar cell array.

EXPERIMENT/EVENT DATA SHEET IA

TITLE: LIGHTWEIGHT SOLAR CELL ARRAY

ITEM No.	PHASE: 1 ARRAY DEPLOYMENT	PHASE: 2 NORMAL ARRAY OPERATIONS	PHASE: 3 LOGISTICS VEHICLE DOCKING	PHASE: 4 LOGISTICS VEHICLE DEPARTURE
1	IA-1 (601001)	IA-2 (601011)	IA-3 (601021)	IA-4 (601031)
2	1	30	1	1
3	1	30	1	1
4	1	1	1	1
5	0	0	0	0
6	1	1	1	1
7				
8	2	1	2	2
9	3	3	3	3
10	0.5	0.25	0.25	0.25
11	2	0	2	2
12	0.5	0	0.25	0.25
13	0	0	0	0
14	0	0	0	0
15				
16				
17				
18	0	0	0	0
19	0	0	0	0
20	0	0	0	0
21	0	0	0	0
22	0	0	0	0
23	0	0	0	0
24	2480			
25	198			
26	0	0	0	0
27		601001	601011	601021
28	0	0	0	0
29	0	0	0	0
30	1	0	0	0
31	0	0	0	0
32	0	0	0	0
33	14	15	14	14
34				
35				
36				
37	-1	1	0	0
38				
39				
40	0	2	2	2

EXPERIMENT/EVENT DATA SHEET I A - CONCLUDED

TITLE: LIGHTWEIGHT SOLAR ARRAY

ITEM No.	PHASE: 5 OUTBOARD PANELS JETTISONED	PHASE:	PHASE:	PHASE:
1	I A-5 (601041)			
2	1			
3	1			
4	1			
5	0			
6	1			
7				
8	2			
9	3			
10	0.25			
11	2			
12	0.25			
13	0			
14	0			
15				
16				
17				
18	0			
19	0			
20	0			
21	0			
22	0			
23	0			
24				
25				
26	0			
27	601031			
28	0			
29	0			
30	0			
31	0			
32	0			
33	14			
34				
35				
36				
37	-1			
38				
39				
40	2			

EXPERIMENT DATA SHEET I B

Parabolic Antenna

1. Specific Objective:

The purpose of this experiment is to develop the technology and demonstrate the feasibility for the deployment, alinement and operation of parabolic antenna designs suitable for the size range of 100 - 300 feet in diameter. Study of the deployment characteristics of a lightweight extendible boom for positioning the antenna relative to the space station is also an integral part of the experiment. Technical problems which must be solved are associated with deployment mechanisms, parabolic-surface measurement and adjustment, structural distortions due to temperature gradients, and disturbances induced by the space station. Techniques for overcoming these problems will be developed and demonstrated on a 15-foot diameter antenna separated 20 feet from the space station. Incorporation of this experiment on a manned station will also provide evaluation of the requirement for man, and the capabilities of man in the adjustment and operation of large antennas. Upon completion of this experiment the antenna will be available to increase the communications capacity of the space station.

2. General Description:

A 15-foot-diameter parabolic antenna will be mounted on the space station through a three-degree-of-freedom gimbal system. The concept is shown schematically in figure 1. A boom will extend the packaged antenna and its gimbal platform away from the space station by approximately 20 feet. The 15-foot diameter antenna and the feed mast will automatically deploy on command by the astronaut

Deployment will be monitored by visual observations from the space station, by photography, and by response indicators on the space station control panel. Figure 2 illustrates the deployment sequence.

3. Operational Constraints:

The antenna will be deployed and tested in a zero-gravity field. EVA will be required to measure and adjust the antenna surface and to retrieve film. Special orbit altitude and inclination are not requirements. Pattern measurements for the antenna will require pointing toward a ground-based receiving station. Favorable lighting conditions are required for the photographic, observation, and EVA phases of the experiment. Photographic records will be returned to earth.

4. Mode of Operation:

The parabolic antenna and extendible boom are packaged and launched with the space station. The experiment package is automatically deployed on astronaut command after orbit is achieved. Experimental measurements are monitored by the astronaut and EVA is utilized in film retrieval and antenna alinement/adjustment tasks. The experiment may be sequenced on a noninterference basis; antenna pattern measurements must be made while the space station is over a ground receiving station.

5. Crew Support:

Astronaut prelaunch training must be conducted in the areas of parabolic antenna theory; equipment usage; malfunction detection, analysis, and repair; safety procedures; RF test measurements; EVA structural tasks; pointing tests; and mission simulation and familiarization. The astronaut will monitor a control panel, record data, and participate through EVA task assignments. Total expected EVA time for the experiment is approximately four hours.

6. Spacecraft Support:

The experiment, which will be launched in a packaged condition with the space station, should weigh about 300 lb and require a volume of 100 cu ft (5' x 4.5' x 4.5'). Power requirements should average 165 watts, with a maximum load of 225 watts. Deployment data will be recorded on film and returned to earth. On-board instruments will record and store for convenient transmission the following: temperature, strain, acceleration, and gimbal angle data as well as recordings of astronaut comments and spacecraft orientation during antenna pattern measurements. The spacecraft control system is required to stabilize and assist in slewing and pointing the antenna. Some spacecraft activities may need to be restricted during measurements of antenna vibrations, temperatures, and electronic patterns.

7. Development Schedule:

The experiment is considered to require three years from go-ahead to delivery of flight units. Phase A and B (one year) would include experiment definition, breadboard experiments, design, and development of components. Phase C (one year) would include fabrication and testing of mock-ups, prototypes, and support equipment. Phase D (one year) would include fabrication, test, and delivery of flight units and spares.

8. Cost:

Total Experiment	3.1 M
FY 1970	.7 M
FY 1971	1.7 M
FY 1972	.7 M

9. Spacecraft Interface:

Since this experiment is expected to be launched with the main station, the spacecraft/experiment interface must carry the structural loads of handling and launch as well as provide launch vibration isolation, power to operate the deployment mechanism, and electronic linkage with the antenna for control and data transmission functions. A large part of the experiment involves observation by astronauts inside the spacecraft, therefore windows must be provided. The deployed antenna is a relatively large structure and must not shadow other on-board pointing experiments or operating equipment such as solar panels and vice versa. Complementary effects of antenna/space station dynamics must also be considered.

10. Test Program:

The flight test program for the expandable parabolic antenna experiment consists of five distinct phases covering pertinent areas of antenna technology. It is expected that extensive ground-test programs will be carried out to develop and select candidate techniques for flight demonstration and evaluation. The test phases are listed below, and are discussed separately in the following paragraphs:

PHASE	TITLE
1	Structure Deployment
2	Vibration and Temperature Effects
3	Surface Contour Measurement and Adjustment
4	Pointing Exercises
5	Electronic Pattern Measurements

Phase 1 - Structure Deployment.- Expansion of large, accurately-dimensioned structures from small packages requires complex mechanisms. These mechanisms must be demonstrated to be reliable in space operations. In this phase of the test program the deployment of the boom, feed, and reflective dish is initiated and observed by the astronaut, and the operation is recorded photographically and by means of displacement, velocity and acceleration sensors, and strain-gages. Deployment is anticipated to be entirely automatic, however, the man is required to insure complete deployment and to initiate corrective action (either EVA or IVA) if deployment is not satisfactorily completed. Additional ground evaluation of the recorded operation will be performed to compare actual space operation with designed operation. Part of this experiment phase involves extension of a long boom supporting the antenna mass. It is expected that the experience gained in deployment of this antenna boom will be applicable to boom deployment problems of long-wave radio-astronomy antennas, nuclear power sources, and artificial gravity systems.

Phase 2 - Vibration and Temperature Effects.- Disturbances caused by the crew or control system operations, and temperature gradients due to sunlight/shadow operation, are expected to cause structural deformations that degrade the quality of the reflective dish/feed operation. In this phase of the experiment,vibration and temperature disturbances will be intentionally introduced and the response of the antenna structural components will be measured and compared with predicted responses. Compensating mechanisms intended to minimize the response to the disturbances will be operated and evaluated. The magnitude of these disturbances of the reflective dish will influence the accuracy attempted in the surface contour adjustments, therefore different operation modes may be required for different degrees of contour accuracy.

Phase 3 - Surface Contour Measurement and Adjustment.- The surface contour accuracy required varies from .002 in. for astronomy to .125 in. for some communications uses. In this phase of the experiment, surface contour measurement and adjustment methods of increasing accuracy will be used to determine the limits of accuracy attainable. The measurement method must produce a print-out of the surface contour, recommended adjustments, best-fit parabaloidal surface, and optimum focal point. Test sequence of this phase begins with the antenna fully-deployed, vibration-isolated, and temperature-compensated. A contour measurement system is then put into operation to determine the initial shape of the reflector dish. The recommended adjustments are then made by the astronaut, and the contour resurveyed. When the best contour is obtained, phases 4 and 5 of the test program are performed. As improved measurement systems are developed they will replace previous systems and be evaluated on the antenna.

Phase 4 - Pointing Exercises.- This phase consists of antenna rotations to acquire earth targets, orbiting satellites, or deep-space targets. The objective is to determine the ability of the control system to rotate the antenna and to hold the antenna pointed accurately in the desired direction. The effect of vibrations, thermal variations, and gimbal operation on the ability to hold direction will be evaluated.

Phase 5 - Electronic Pattern Measurements.- The electronic parameters of the antenna to be measured in this phase of the experiment determine the overall quality of the antenna design. Typical parameters to be measured include maximum gain, beam width, lobe patterns, noise temperatures, and signal/noise ratio. Test procedure consists of measurement of antenna signal while slewing the antenna with respect to the station transmitting (or receiving) the antenna signal. The angle between the antenna-pointing direction and the line of sight between antenna and station must also be measured. Further analysis of the recorded signal can be performed on the ground.

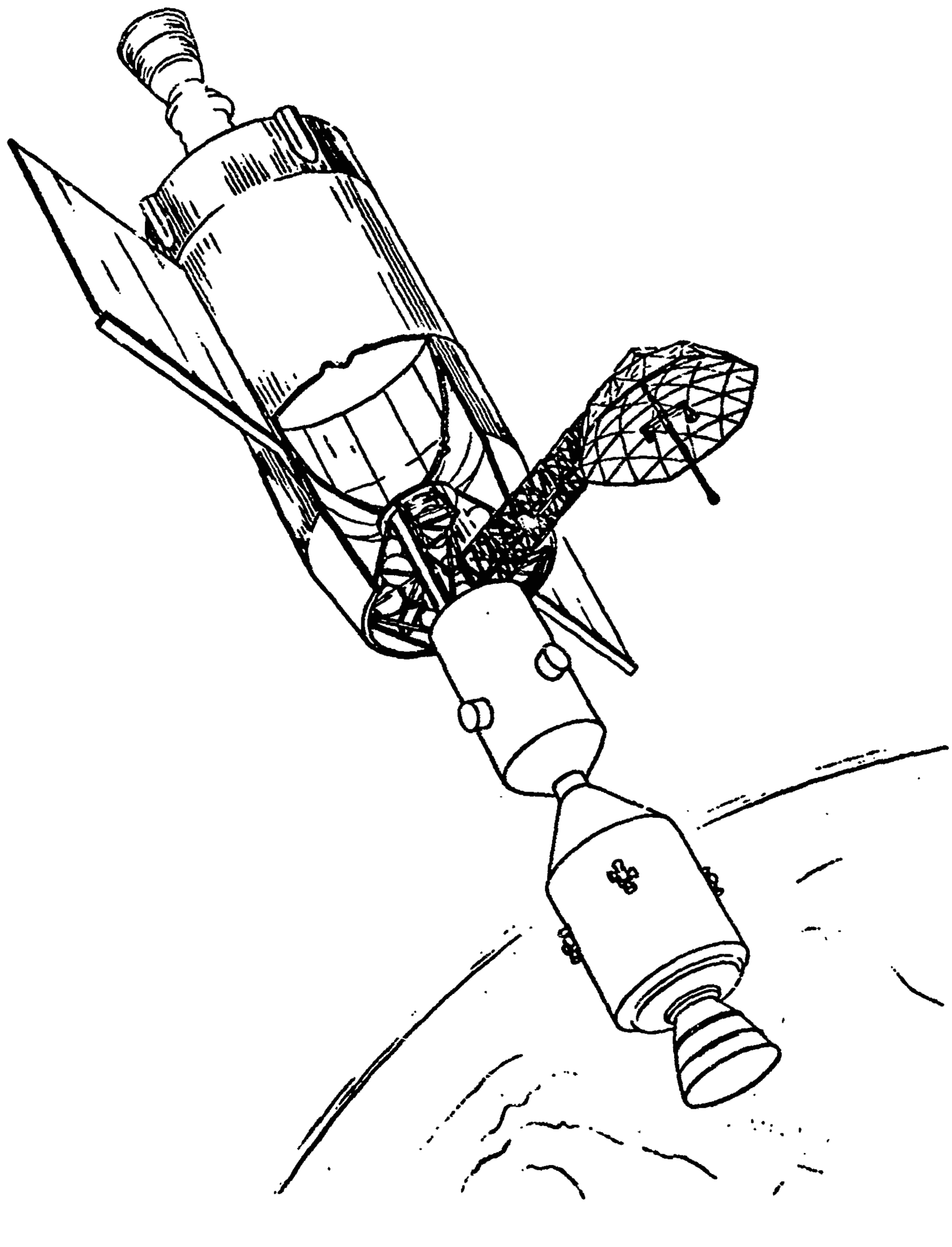
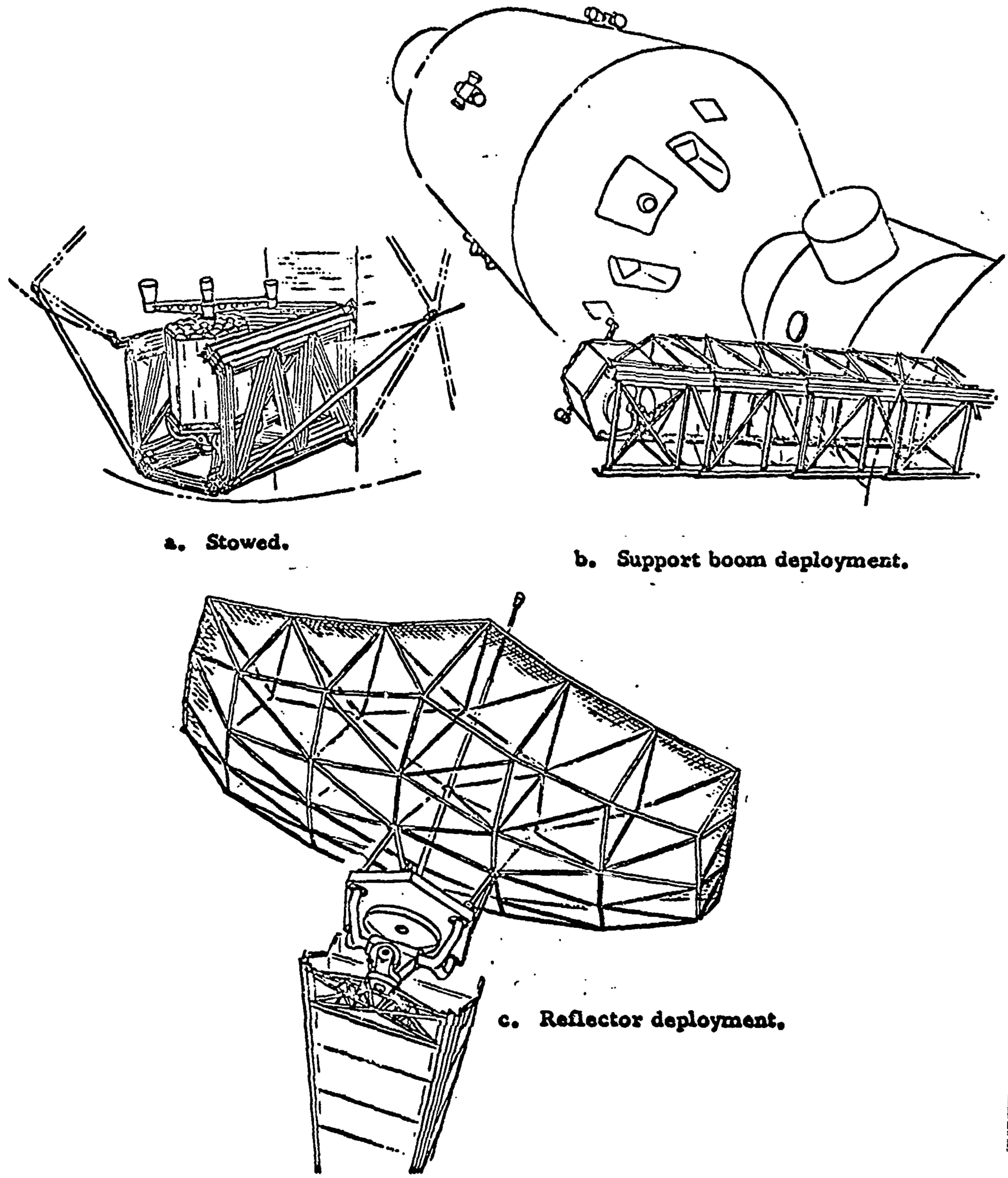


Figure 1.- Parabolic antenna experiment.



a. Stowed.

b. Support boom deployment.

c. Reflector deployment.

Figure 2.- Antenna deployment sequence.

EXPERIMENT/EVENT DATA SHEET IB

TITLE: PARABOLIC ANTENNA EXPERIMENT

ITEM No.	PHASE: 1 STRUCTURE DEPLOYMENT	PHASE: 2 VIBRATION AND TEMPERATURE EFFECTS	PHASE: 3 SURFACE CONTOUR MEASUREMENT & ADJUSTMENT	PHASE: 4 POINTING EXERCISES
1	IB-1 (601002)	IB-2 (601012)	IB-3 (601022)	IB-4 (601032)
2	1	1	3	1
3	1	1	1	1
4	1	1	3	1
5	0	0	0	0
6	1	1	1	1
7				
8	2	1	3	2
9	16	9	4	16
10	2	2	1	1
11	16		16	16
12	2		3	1
13	0		16	
14	0		3	
15				
16				
17				
18	0	0	100	100
19	0	0	0	0
20	0	0	2	1
21	0.5	2	0.5	0.5
22	20	15	65	65
23	0	0	0	0
24	0	0	0	0
25	0	0	0	0
26	0	0	0	0
27		601002	601012	601022
28				
29				
30	0	1	0	1
31	0.1	0.1	0.5	0.5
32	0	0	1	0
33	5	5	25	10
34				
35				
36				
37	0	0	0	0
38				
39				
40	0	2	2	2

EXPERIMENT/EVENT DATA SHEET IB - CONCLUDED

TITLE: PARABOLIC ANTENNA EXPERIMENT

ITEM No.	PHASE: 5 ELECTRONIC PATTERN MEASUREMENTS	PHASE:	PHASE:	PHASE:
1	IB-5 (601042)			
2	3			
3	1			
4	3			
5	0			
6	1			
7				
8	2			
9	4			
10	1			
11	16			
12	1			
13				
14				
15				
16				
17				
18	100			
19	0			
20	2			
21	0.5			
22	65			
23	0			
24	0			
25	0			
26	0			
27	601032			
28				
29				
30	1			
31	0.5			
32	0			
33	10			
34				
35				
36				
37	0			
38				
39				
40	2			

FUNCTIONAL PROGRAM ELEMENT II

1. Discipline: Advanced Technology

2. Program Element: Space Experiments Hangar

3. Requirement:

(a) Provide a large multiuse structure with an access hatch of sufficient size to accommodate satellites, experiment modules, logistics vehicles, or large equipment.

(b) Provide a structure of sufficient size to accommodate and mount various experiments and related test equipment.

(c) Extend space station capabilities by providing a combination pressurized/vacuum workspace for the performance of experiments, testing, manufacturing, and inspection which cannot be suitably performed in the station.

(d) Extend man's capability to support extravehicular activities (EVA) and work in a vacuum environment for longer periods of time.

4. Justification:

Some experiments considered under the Advanced Technology Discipline require the large unobstructed volume of a hangar or may be accomplished with greater safety or efficiency by using the hangar. The hangar, with its large enclosed workspace, would provide a safer working environment for some experiments, possibly reduce the amount of EVA, reduce manhours required to accomplish tasks normally requiring EVA, and provide a safer environment to practice new EVA concepts. The hangar would also provide an emergency shelter if the space station were endangered and would be useful in performing experiments that could not be conducted in the space station because of the possibility of compromising the station integrity or environment purity.

5. Component Experiments:

Experiment A - Orbital Assembly and Operation Startup

Experiment B - Advanced Crew Work Aids

Experiment C - Remote-Exposure Experiment and Satellite Retrieval

6. Description:

The space experiments hangar is envisioned to be 260 inches in diameter, with a cylindrical section 360 inches long and a hemispherical dome on each end. The hangar will be launched separately from the space station but will rendezvous and dock with the station. After docking, provisions are made for manual assembly of reinforcing structures to rigidize hangar/space station combination. The hangar is separated from the station by an airlock. An additional airlock is provided at the opposite end of the hangar.

During launch, rendezvous, docking, and assembly, the hangar would provide its own altitude and stabilization control system. After assembly is completed this system would require integration with the station's stability and control system to allow for satisfactory hangar/station control.

The hangar door exposes the entire inside area of the hangar for entry. A hydraulically operated breach-block cam-roller mechanism is used to latch the door and a hydraulic system is provided to swing the hangar door open and shut.

Storage tanks and a pumping system are provided to store the hangar atmosphere whenever the hangar is unpressurized. An air purification system is provided for removal of water vapor, CO_2, and contamination. A ventilation system is provided for atmospheric circulation within the hangar.

Docking ports are provided on the hangar for logistics vehicles. After mating to the station the protruding parts of the docking ports are installed using EVA. Rails are provided for moving modules and supplies from the docked logistics vehicles to the hangar interior.

Numerous attachment points are provided on both the inside and the outside of the hangar so that experiments, equipment, crew aids, work stations, and modules can be attached without modifying the basic structure of the hangar. In addition, feedthroughs are provided so that new experiments can be added without modifying the hangar structure or disturbing the hangar atmosphere.

Windows are provided to facilitate docking operations and make observations.

A retractable docking mechanism is provided so that vehicles can be docked in the open hangar and quickly moved inside.

7. Special Considerations:

Determination of the type structure the hangar will have - inflatable, expandible, or rigid - must be made and the system designed accordingly. The type of assembly required to provide the hangar/station reinforcing must be extensively considered. The type of stability and control system necessary to satisfy initial hangar requirements for launch rendezvous, docking, and assembly, and including necessary integration with the station systems must be considered.

BIBLIOGRAPHY

1. Schulte, L. O., Editor: Air Lock Experiment for Saturn S-IVB, SA209. Report SM51894P, Douglas Aircraft Co., Inc., 1966.

2. Youngblood, G. J.; and Davidson, J. R.: Apollo Extensions Systems Conceptual Design Study of an SIVB Orbital Workshop. Report on NASA Contract NAS8-20073, Brown Engineering Co., Inc., BECO 8-20073-ABX-006-2, September 1965.

3. Loats, Harry L., Jr.; Hay, George M.; and Morris, Edwin: Study of the Astronauts Capabilities to Maintain Life Support Systems and Cabin Habitability in Weightless Conditions. Final Report NASA Contract NAS1-7887, ERA 68-1, Environmental Research Associates, 1968.

4. Loats, Harry L., Jr.; and Bruchey, William J.: A Study of the Performance of an Astronaut During Ingress Maneuvers Through Airlocks and Passageways NASA CR-971, 1968.

5. Roth, Emanuel M., editor: Compendium of Human Responses to the Aerospace Environment. Vol. III, NACA CR-1205(III), November 1968.

6. Machell, Reginald M.: Summary of Gemini Extravehicular Activity. NASA SP-149, 1967.

7. McCarty, H. A., Program Manager: Extravehicular Engineering Activities (EVEA) Program Requirements Study. Final report on NASA Contract NAS8-18128, Space Division, North American Rockwell Corp., SD-68-304, May 1968.

8. Gemini Summary Conference. NASA SP-138, February 1967.

9. Wortz, E. C.: A Study of the Astronaut's Extravehicular Capabilities in Weightless Conditions. Final report on NASA Contract NAS1-7571, AiResearch Manufacturing Co., 1968.

10. Trout, Otto, F., Jr.: An Investigation of Leakage of Large-Diameter O-Ring Seals on Spacecraft Air-Lock Hatches. NASA TN D-4394, March 1968.

11. ORL Experiment Program. Vol. B, parts VI, VIII, X, XIII. Final Report on Contract NASw-1215, February 1966, International Business Machines Corp.

12. Report on Second National Conference on Space Maintenance and Extravehicular Activities. NASA-Wright Patterson AFB, Las Vegas, Nevada, August 1968.

13. Wortz, E. C.: Study of Astronaut Capabilities to Perform Extravehicular Maintenance and Assembly Functions in Weightless Conditions. NASA CR-859, 1967.

14. Trout, Otto F., Jr.; Beasley, Gary P.; and Jacobs, Donald L.: Simulation of Gemini Extravehicular Tasks by Neutral Buoyancy Techniques. NASA Prospective TN.

15. Anon: A Study of An Intermediate Orbital Workshop System (IOWS). Vol. 2, Experiment Program. NASA-LRC, August 1968.

16. Anon: Analysis and Preliminary Design of Engineering Experiments for Manned Earth-Orbital Missions. Report No. 65-928-65 (contract NAS1-4667), International Business Machines Corporation, August 1965. Part 1 - Space Flight Requirements for Satellite Recovery. Part 2 - Four Experiment Designs for the Manned Earth-Orbiting Laboratory.

17. Anon: Apollo X Final Report, Extended Apollo Systems Utilization Study. Vol. 3B - Experimental Programs. Report No. 64-1860-3 (NAS9-3140), North-American Aviation, Inc., November 1964.

18. Anon: Derivation of a Comprehensive Engineering Experiment Program for Manned Earth-Orbital Missions. Report No. 65-928-64 (contract NAS1-4667), International Business Machines Corporation, August 1965.

19. Anon: Experiment Requirements Document Apollo Applications Program (AAP). Report ED-2002-71 (NAS8-21004), Martin-Marietta Corporation, April 1967. Volume I - Index. Volume III - Space Environment. Volume V - Astronomy. Volume VI - Communications/Navigation.

20. Anon: Summary of Results of Engineering Research Program for Manned Earth-Orbital Missions. Report No. 65-928-63 (contract NAS1-4667), International Business Machines,Corporation, August 1965.

21. Anon: The Needs and Requirements for a Manned Space Station. NASA, November 1966.
Vol. 1 - Summary Report
Vol. 2 - Astronomy
Vol. 3 - Earth Resources
Vol. 4 - Meteorology
Vol. 5 - Biology
Vol. 6 - Long-Term Flight
Vol. 7 - Research and Development in Advanced Technology.
Vol. 8 - Orbital Operations and Logistics

Prepared by Space Station Requirements Steering Committee. NASA-Langley Research Center, November 15, 1966.

22. Rittenhouse, J. B.; and Singletary, J. B.: Space Materials Handbook, Supplement 2 to Second Edition. AFML-TR-64-40, Supplement 2, 1968.

23. Staff of George C. Marshall Space Flight Center: The Meteoroid Satellite Project Pegasus First Summary Report. NASA TN D-3505, 1966.

24. Staff of Space Station Office-Manned Spacecraft Center: Manned Orbital Laboratory Research and Applications Requirement Study. Vol. III, September 1963.

25. Wolbers, H. L.: Report on the Development of the Manned Orbital Research Laboratory (MORL) System Utilization Potential, Task Area 1 - Analysis of Space Related Objectives, Books 1 and 2. NAS1-3612, Douglas Missile and Space Systems Division, September 1965.

EXPERIMENT DATA SHEET IIA

Orbital Assembly and Operational Startup

1. Specific Objective:

The objective includes experimental verification of manned orbital assembly of large modular units by the concept of first docking the modules together and then adding the structural reinforcing elements, protruding equipment, and EVA crew work aids by manual extravehicular operations.

2. General Description:

The experiment begins with hard docking of the hangar module to space station (fig. 1). After the docking operation, structural reinforcement elements will be installed between the space station and the hangar using EVA so that the hangar and space station are combined into a rigid structure and bending loads are no longer carried through the docking cone. Next, the astronauts will install handrails to the docking ports of the hangar, install the protruding portions of the docking ports, and other essential hardware. The astronauts will make electrical, communication, and fluid connections to the space station, perform an actuation cycle on the hangar door, pressurize the hangar, and check the structure for leaks. After docking and assembly, the hangar will operate as an integral part of the space station.

3. Operational Constraints:

During the assembly task the statior [illegible] ngar relative attitudes and attitude rates would require strict con[illegible] xperiment can be conducted at any orbital altitude or inclinat[illegible]

4. Mode of Operation:

The experiment would require astronaut performance both in vacuum and shirt-sleeve environments. The experiment tasks would be conducted on a time-available basis.

5. Crew Support:

Extravehicular operations by the crew are a necessary part of the modular assembly concept of the activation of the hangar. Except in the case of the installation of the structural bracing to rigidize the space-station-hangar combination, the remainder of extravehicular operations to complete the EVA crew aids and docking ports can be completed after checkout of the hangar mechanical system. Approximately 80 manhours will be required to perform assembly and checkout.

To assure the success and efficient performance of the EVA's in support of the orbital assembly operation, extensive simulation development of crew aids, procedures, timelines, and crew training is required prior to launch.

Preflight simulation of crew procedures and evaluation of the IVA's and EVA's in support of each of the experiments conducted in or on the hangar will also be required.

6. Spacecraft Support:

The space station must provide electricity, fluids, communications, and telemetry for the hangar. In addition, these are also required for each of the experiments in the hangar. The spacecraft attitude control system, when combined with the hangar control system, must be capable of controlling the hangar-space-station combination.

7. Development Schedule:

The development schedule is shown in Figure 2.

8. Costs:

Total Experiment $23.0M

Basic Structure	$20.0M
Atmospheric Storage and Purification System	1.5M
Electrical, Fluid, and Communication Equipment	1.0M
Development and Testing of Pressure Vessel, Hatch Actuator, Mechanism, Crew Aids, etc.	0.5M

The cost does not include installation of experiments, preparation for launch, or crew training.

9. Spacecraft Interface:

(a) Hangar will be docked and attached permanently to station.

(b) Assembly members are attached to station.

(c) An airlock is located between the hangar and station.

(d) Electrical, fluid and communications connections are made to hangar from the station.

(e) Hangar and station attitude control systems will be integrated after assembly and will be controlled from station.

10. Test Program:

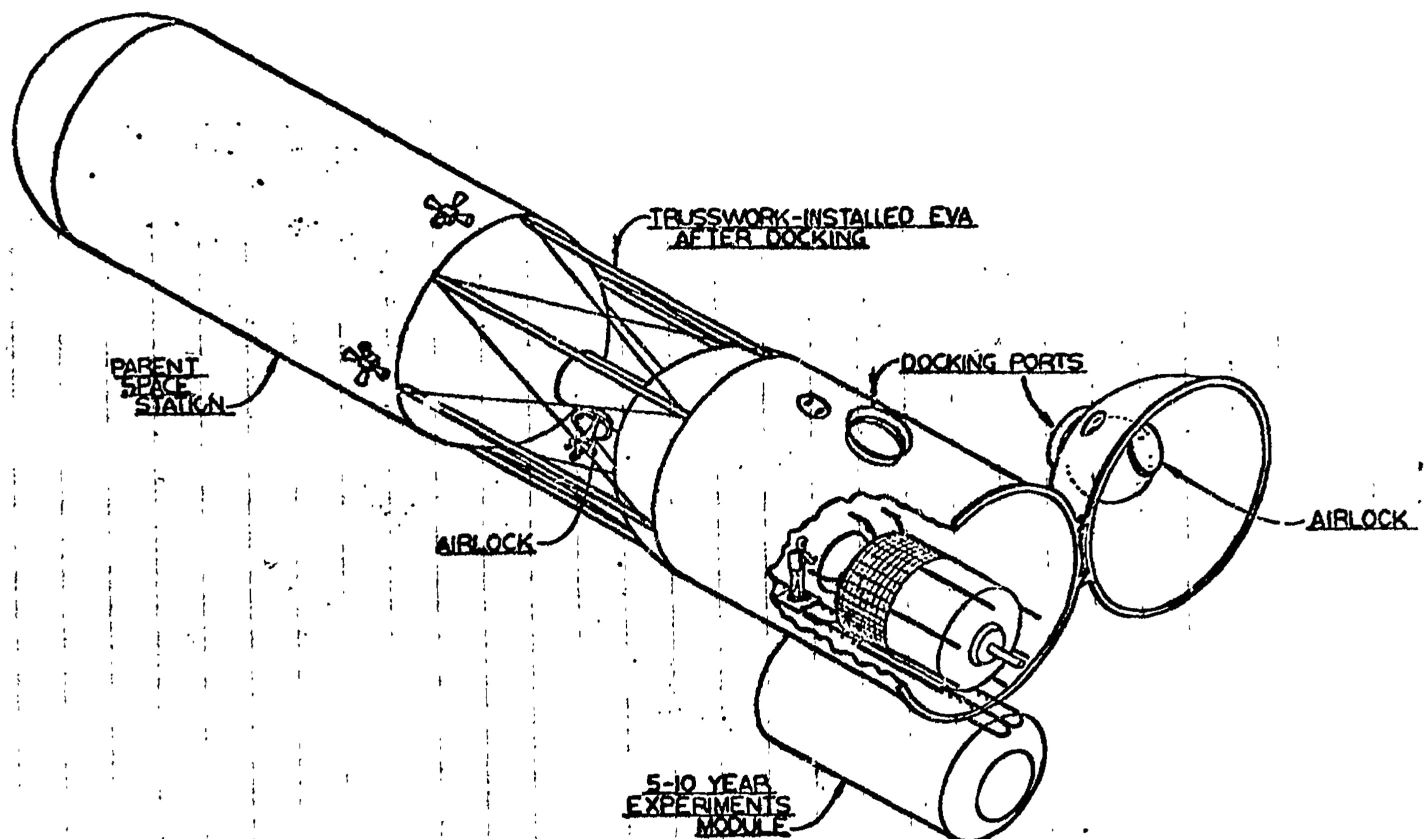
(a) Docking and assembly to station.

(b) Rigidizing by installation of reinforcement.

(c) Evaluation of hangar door mechanism.

(d) Evaluation of pressurization and pumping system.

(e) Assembly of crew aids and docking port covers.



PRELIMINARY
LRC 2-13-69

Figure 1.- Space experiments hangar.

T101

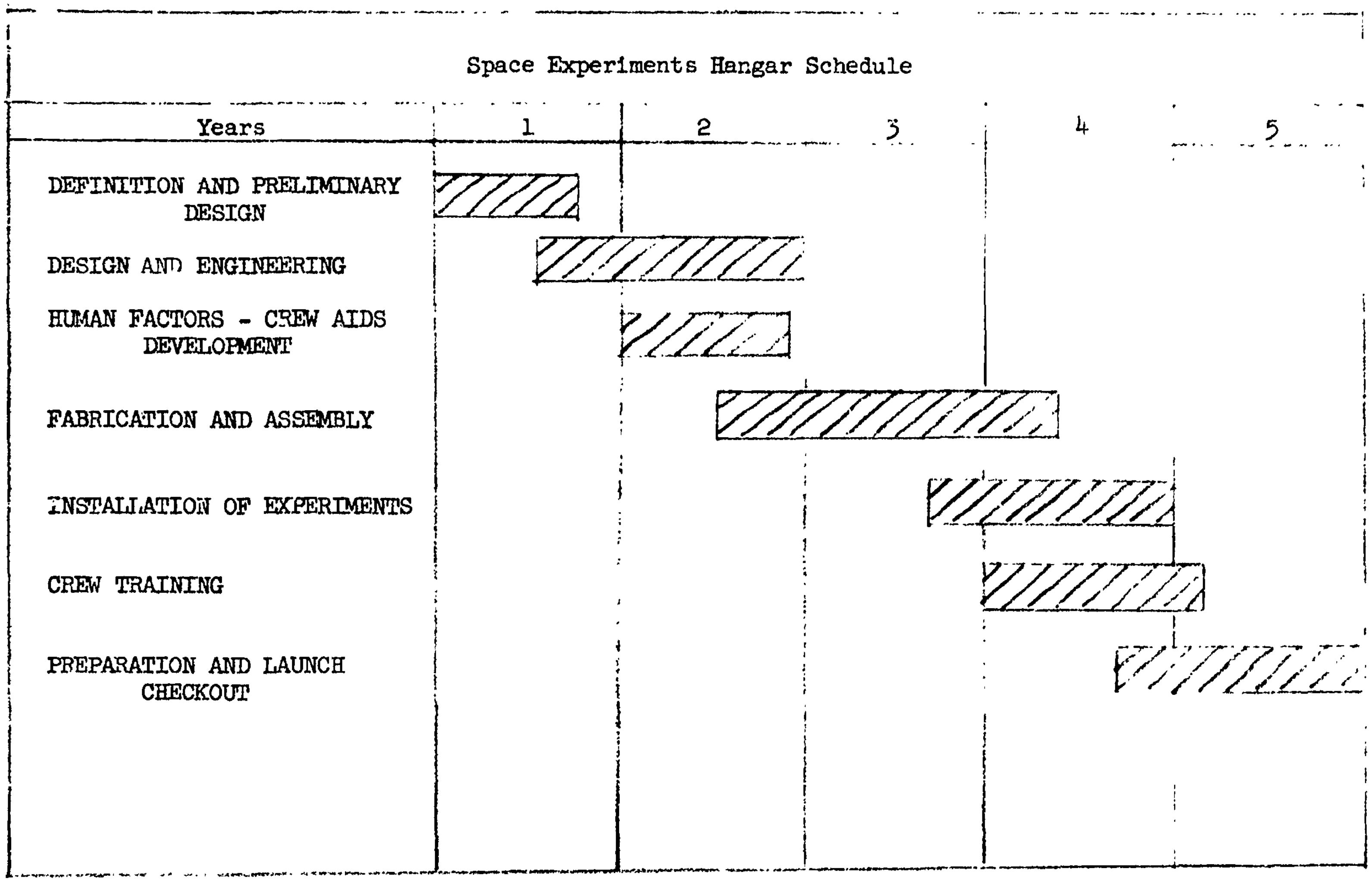


Figure 2.- Hangar development schedule.

T102

EXPERIMENT/EVENT DATA SHEET II A

TITLE: ORBITAL ASSEMBLY AND OPERATIONAL START-UP

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	II A-1 (602001)			
2	8			
3	8			
4	1			
5	0			
6	1			
7				
8	3			
9	16			
10	4			
11	16			
12	4			
13	16			
14	2			
15				
16				
17				
18	1000			
19	200			
20	2			
21	0			
22	0			
23	0			
24				
25				
26	0			
27				
28				
29				
30	0			
31	4			
32	4			
33	0			
34				
35				
36				
37	1			
38				
39				
40	0			

EXPERIMENT DATA SHEET IIB

Advanced Crew Work Aids

1. Specific Objective:

The objective includes verification and in-space evaluation of advanced concepts of crew work aids for performing intravehicular and extravehicular tasks. In addition to the evaluation of specific crew work aids, the experiment will provide an evaluation of the applicability of ground simulation in the preflight development of crew work aids and procedures (fig. 1).

2. General Description:

The experimental program will include the evaluation and use of advanced concepts for crew work aids previously developed during ground simulation tests for extravehicular and intravehicular operations. A typical example of these are portable, adjustable platforms and handrails for inside or outside stations (fig. 2). Each of the crew work aids will be instrumented to measure force inputs, and when comparative tests are performed the astronaut's energy expenditure will be measured by indirect calorimetry from the subject's oxygen consumption and CO_2 output. Task time lines, energy expenditure, forces exerted, and astronaut capabilities will be compared with preflight simulation data developed in preparation for the flight. Most of the crew work aid concepts can be evaluated in the hangar before use on EVA's. They will include the use of restraint systems, traction aids, manual locomotion aids, work platforms, tools, and fasteners for accomplishing complex work tasks, structural assembly, and satellite

3. Operational Constraints:

Astronaut participation using pressurized suits is required for this experiment. Zero gravity is required but orbital altitude and orientation do not affect the experiment.

4. Mode of Operation:

The experiment is performed in the hangar in both a pressurized shirt-sleeve condition and unpressurized with suits, as well as outside in vacuum conditions. Since the experiment events can be conducted over an extended time period and can be separated from one another, they can be integrated with other experiments.

5. Crew Support:

Thorough preflight simulation training in the procedures and use of the crew work aids by neutral buoyancy techniques is necessary in preparation for the flight. No special training other than the above is required for the experiments. Approximately 80 manhours will be required to complete the experiment. A maximum of two astronauts will be involved at any one time.

6. Spacecraft Support:

The space station must provide electrical power for lighting, instrumentation and telemetry for force and energy expenditure measurements, TV for monitoring the tests, and life support when the tests are run EVA. The hangar must provide storage for the crew work aids. The power, weight, and volume requirements are undefined at the present time.

7. Development Schedule:

No schedule has been established, however, development of crew work aids should proceed simultaneously with development of the hangar.

8. Cost:

Total Experiment $1.6M	
Crew Work Aids	$1.0M
Astronaut Training	0.5M
Installation on Hangar	0.1M

9. Spacecraft Interface:

None

10. Test Program:

The test program would consist of installing the crew work aids and using them with experiment work panels or in actual repair tasks. The test program is to be defined concurrent with the development of the advanced crew work aids.

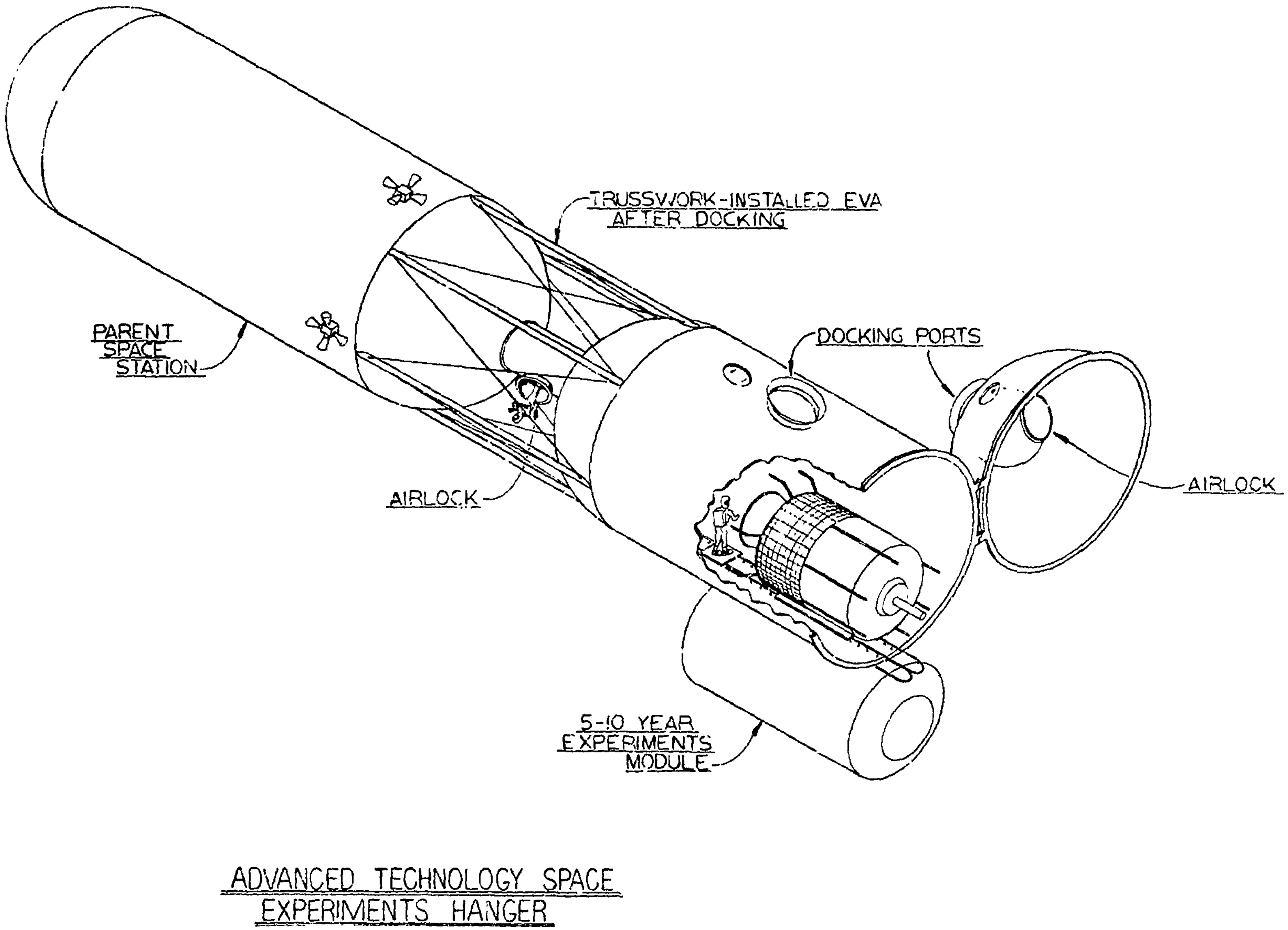


Figure 1.- Space experiments hangar.

T107

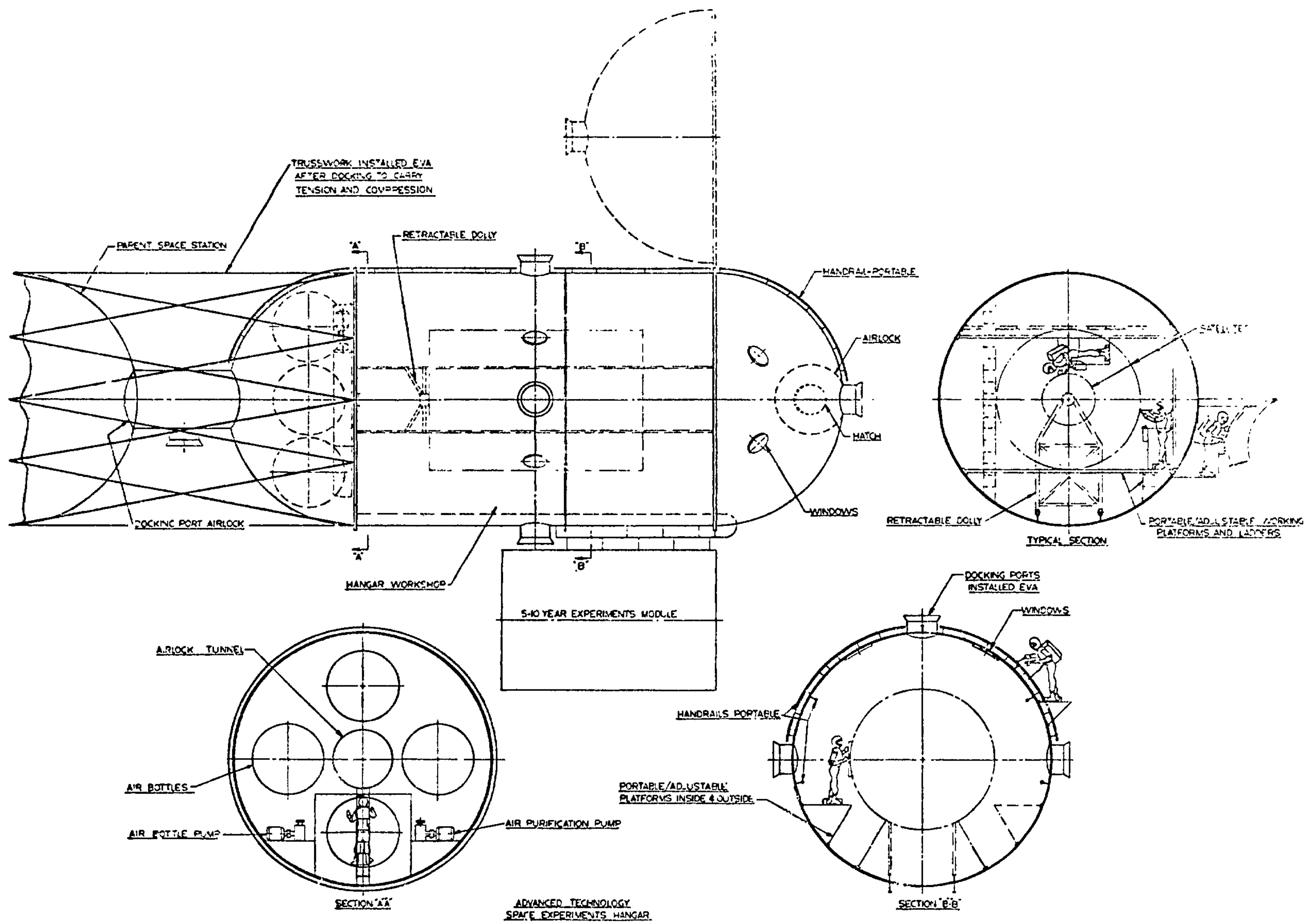


Figure 2.- Space hangar layout and crew work aids.

T108

EXPERIMENT/EVENT DATA SHEET IIB

TITLE: ADVANCED CREW WORK AIDS

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	IIB-1 (602002)			
2	10			
3	10			
4	1			
5	0			
6	1			
7				
8	2			
9	16			
10	4			
11	16			
12	4			
13				
14				
15				
16				
17				
18	500			
19	200			
20	4			
21	0			
22	0			
23	0			
24	500			
25	100			
26	0			
27				
28				
29				
30	0			
31	4			
32	4			
33	5			
34				
35				
36				
37	1			
38				
39				
40	0			

EXPERIMENT DATA SHEET IIC

Remote-Exposure Experiments and Satellite Retrieval

1. Specific Objective:

The purpose of this experiment is to determine the long-range effects of the space environment on spacecraft surfaces, materials, and mechanisms for correlation with and validation of ground-based experiments. Exposure of the spacecraft surfaces and materials should not be in the near vicinity of the contaminated atmosphere surrounding the manned spacecraft. Therefore, data should be obtained by rendezvous with, or retrieval of, other satellites.

2. General Description:

Primarily, the experiment consists of spectral measurements of spacecraft surfaces, color photography of surface damage, and recovery of small satellites or samples for detailed studies of materials and mechanisms. Onboard material exposure experiments are planned for AAP and the space station laboratory (Space Physics - Airlock Experiment); however, these experiments are handicapped by limited exposure times and contamination from the space station. Many materials of interest are on satellites currently in space and others will be launched in the time period before 1975. Their recovery promises the quickest return of meaningful data on long-term effects of the space environment on material properties.

Satellites currently of interest include Pegasus III; Vanguard 1; Explorer 7, 16, and 26; Telstar 1 and 2; OGO 1; and OSO 1 and 2. Of these, Pegasus III and OSO 2 are considered the best choices for early retrieval of material specimens for the following reasons:

1. Wide range of structural materials used.
2. Consideration included in designs for retrieval of meteroid penetration and thermal coating panels.
3. Long exposure to the environment.
4. Operationally useless.
5. Favorable orbit inclination relative to station.
6. Small ΔV required for rendezvous.
7. Low radiation hazard for observation spacecraft.

In addition, it is proposed to launch a special materials satellite in the near time period (before 1975). A wider spectrum of materials and specially designed attachments to aid in recovery would characterize such a materials satellite.

The basic experiment approach would involve:

1. Rendezvous of the ferry spacecraft with the satellite.
2. Selected in-situ measurements and photographic documentation.
3. Detachment of selected specimens.
4. Return of the ferry spacecraft to the space station with the specimens, or in the case of small satellites such as OSO 2, return of the entire satellite to the space station hangar.
5. Material property determination through onboard experimentation.
6. Return to earth of selected specimens for more thorough evaluation.

For inspection and retrieval of material samples from tumbling or spinning satellites or retrieval of the satellites themselves, it may be necessary to develop a small self-contained reaction-jet stabilization unit. The stabilization unit would be launched from the ferry spacecraft to attach itself to the target satellite. After a suitable time delay for attachment rigidization, the stabilization unit would be activated. Following stabilization of the satellite, EVA could be accomplished.

3. Operational Constraints:

The following table lists 1965 data concerning several candidate satellites. Also shown is the estimated tissue dose per 4-hour sortie from Van Allen protons, which must be considered.

Candidate satellite	Inclination, deg	Apogee/Perigee, nm	Dose/Sortie, rad
Vanguard 1	34.24	2125/352	175.5
Explorer 7	50.30	577/301	2.4
Explorer 16	52.03	635/407	4.5
Telstar 1	44.79	3045/510	77.0
Tiros 1	48.40	422/372	1.3
OSO 1	32.84	319/294	0.6
OSO 2	32.86	326/298	
Pegasus III	28.87	288/279	

It is assumed that the space station would be launched into an orbit favorable to rendezvous in a ferry spacecraft with the satellites of interest.

Materials that could become contaminated or otherwise affected by the hangar environment or atmosphere must be packaged before being returned to the hangar. Once in the hangar the packages should be pressurized with an inert gas to further prevent spurious changes to material properties.

4. Mode of Operation:

The general mode of operation would be for two astronauts, in a ferry spacecraft, to rendezvous with the target satellite. One astronaut (EVA) would photograph selected samples with a color camera and take reflectance measurements with a hand-held reflectometer. Samples of particular interest, such as panels with meteoroid damage or failed mechanisms, would be removed for further examination aboard the space hangar or return to earth. Small satellites would be towed to the space station hangar for in-depth disassembly and examination. Direct EVA by the astronaut would be used to obtain samples attached to outer surfaces of the hangar or attached to a specific materials satellite in close orbit with the space station.

5. Crew Support:

Astronauts will require training in rendezvous techniques, EVA, and operation of measurement and recovery equipment. Measurement or recovery of surfaces of specific satellites would be a one-time occurrence for each satellite. Measurements or recovery of samples attached to the outer surface of the hangar or a specific materials satellite would be recurrent with decreasing frequencies.

6. Spacecraft Support:

The hangar will be used as the base of operations for the experiment. Satellites or samples that are retrieved will be returned to the hangar for study by the astronauts. Power to operate instruments for recording data will be provided by the space station. For data telemetry to earth, equipment aboard the space station will be used.

7. Development Schedule:

Instruments to measure materials in a vacuum environment will require some development and ground testing. A hand-held reflectometer is currently under development with a prototype due for delivery early in 1969. Development and launch of an unmanned materials satellite, including the selection of material samples to be attached to the satellite, will require approximately 4 years.

8. Costs:

Total costs can vary considerably with the number of satellites to be recovered, therefore, costs are to be determined following more detailed studies.

9. Spacecraft Interface:

This experiment is not expected to be launched with the main station, therefore, communication links between the ferry spacecraft and the main station as well as the space hangar are required. As noted in item 6, power and data recording are required.

10. Test Program:

The satellites selected for examination in this experiment include OSO 2, Pegasus III, and a proposed Materials Technology Satellite. As new satellites are launched in the time period between now and that of the space station launch, some substitution may occur. A general outline of the proposed test program for three satellites is as follows:

1. OSO 2: Two astronauts in a ferry spacecraft would rendezvous with OSO 2 and stabilize it if necessary. One astronaut (EVA) would photograph specific surface areas and measure reflectance using a hand-held reflectometer. The ferry spacecraft would be attached to OSO 2 and

returned to the hangar for more detailed reflectance measurements and removal of parts of interest for return to earth.

2. Pegasus III: Two astronauts in a ferry spacecraft would rendezvous with Pegasus III and stabilize it if necessary. One astronaut (EVA) would photograph the 48 surface samples of Pegasus III and measure reflectance of specific samples using a hand-held reflectometer. Surface samples showing meteroid damage or other interesting features would be removed from Pegasus III for more detailed studies in the hangar and subsequent return to earth.

3. Materials Technology Satellite: This satellite would be launched approximately 1 year prior to the launch of the space station in order to accumulate sample exposure time. It would be launched into an orbit to be a near companion to the space station, yet distant enough not to be contaminated by the near-space-station environment. Data from some materials experiments on the materials satellite would be telemetered directly to earth. Other materials samples would be returned to the hangar to determine effects of exposure on mechanical properties. The satellite would be periodically visited by the astronauts during which time reflectance of samples would be measured and samples showing meteoroid damage removed for transport back to the hangar. New samples would be left in order to obtain a time-base degradation of coatings and materials. Following the initial rendezvous with the materials satellite, it is proposed that additional visits would be made after 1, 3, 6, 12 and 24 months for additional reflectance measurements, color photographs, and retrieval of samples showing meteoroid damage or other interesting features.

EXPERIMENT/EVENT DATA SHEET IIC

TITLE: REMOTE - EXPOSURE EXPERIMENTS AND SATELLITE RETRIEVAL

ITEM No.	PHASE: 1 RETRIEVAL OF OSO-2	PHASE: 2 PEGASUS III PANEL RETRIEVAL	PHASE: 3 MATERIALS TECHNOLOGY SATELLITE	PHASE:
1	IIC-1 (602003)	IIC-2 (602013)	IIC-3 (602023)	
2	4	2	732	
3	4	2	2	
4	1	1	6	
5	0	0	120	
6	1	1	1	
7				
8	3	3	3	
9	16	16	16	
10	12 (WITH OVERTIME)	12	12	
11	7	7	7	
12	12	12	12	
13	16	16	16	
14	12	12	12	
15				
16				
17				
18	0	0	0	
19	0	0	0	
20	0	0	0	
21	0	0	0	
22	0	0	0	
23	0	0	0	
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40	0	0	0	

FUNCTIONAL PROGRAM ELEMENT III

Guidance, Stability, and Control

1. Discipline: Advanced Technology

2. Program Element: Guidance, Stability, and Control

3. Requirement:

   (a) Develop technology required for the stabilization and control of rotating (artificial gravity) spacecraft.

   (b) Extend spacecraft fine-pointing capabilities to the level required for large orbital telescopes (0.01 arc sec).

   (c) Evaluate advanced guidance components in fine-pointing space environment.

4. Justification:

A requirement for artificial gravity capability will necessitate the development of control technology for rotating spacecraft configurations. The complex dynamics of such concepts preclude complete evaluation of deployment, spinup, and stabilization techniques in ground tests or simulation. The artificial gravity capability must, therefore, be demonstrated in the space environment.

Astronomical observations will require fine-pointing of the spacecraft, on the order of 0.01 arc sec, for extended periods of time. An extremely low-friction control-moment gyro (CMG) system capable of providing these pointing accuracies cannot be adequately evaluated in ground tests due to the gravity loads on the CMG gimbals. Stabilization of an experiment package in the 0.01 arc-sec range would test the advanced CMG hardware and establish the feasibility of providing control for large astronomical telescopes. A the conclusion of the experiment this package would become a laboratory component experiment.

The laboratory developed for the fine-pointing experiment would provide an excellent test bed for advanced guidance components needed for future space applications. Accuracy and drift measurement on devices such as electrostatic gyros and low-"g" accelerometers must be made in the space environment.

5. Component Experiments:

   Experiment A - Rotating Spacecraft Control

   Experiment B - Evaluation of a Fine-Pointing Control System

   Experiment C - Evaluation of Advanced Guidance Components

6. Description:

The artificial gravity spacecraft control experiment will involve the deployment, rotation, and stabilization of the space station module on the end of a long cable or truss system with a logistics vehicle or last-stage booster as a counterweight. A large control-moment gyro wobble-damper will damp the system wobbling motions, with passive techniques such as viscous ring dampers or cable-mounted spring-and-dashpot-type devices evaluated as alternative or supplementary stabilization techniques. Continuous monitoring of the space station and counterweight motions, cable forces, and control-system outputs will permit evaluation of the effectiveness of rotating spacecraft stabilization techniques.

The fine-pointing control experiment and advanced guidance component evaluation involves a separate laboratory module which is stabilized by a low-friction CMG system with a fine-pointing star sensor. This module can operate either in soft-spring gimbal isolation mode, or in a free-flying mode. The module will be brought into the space hangar for systems alinement, checkout, and maintenance. Then the module will be isolated from the station using extravehicular activity (EVA), and stabilized with respect to stellar reference for pointing-system evaluation. Once the stability level is determined, advanced guidance components will be installed in the module for accuracy and long-term drift evaluations.

7. Special Considerations and Provisions:

For the rotating spacecraft experiment, the space station itself must be designed for a gravity environment. All zero-gravity experiments must be interrupted for rotation operations and their associated equipment must be secured prior to rotation.

The soft-gimbal mode of the fine-pointing laboratory operation requires the space station to maintain an inertial orientation for periods up to several days. The free-flying mode requires only that the space station remain within reasonable sight and communication distances of the module.

BIBLIOGRAPHY

1. Report on the Optimization of the Manned Orbital Research Laboratory (MORL) System Concept. September 1964, Volume XIII (SM-46084), NAS1-3612, Douglas Aircraft Company.

2. Space Station Stabilization and Control Study. December 1963, AB-1210-0020, NAS1-2946, Sperry-Rand Corp.

3. A System Study of a Manned Orbital Telescope. October 1965, D2-84042-1, NAS1-3968. The Boeing Company.

EXPERIMENT DATA SHEET IIIA

Rotating Spacecraft Control

1. Specific Objective:

The objective of this experiment is to develop the technology required for the stabilization and control of rotating (artificial gravity) spacecraft configurations. This would provide an artificial gravity capability on board the station for physiological conditioning and biomedical studies at various "g" levels and rotation radii, as may be required for future long-duration flights. This experiment will entail the deployment, rotation, and stabilization of the space station module on the end of a long cable or truss system, with a logistics vehicle or last stage of the booster as a counterweight. Various methods of damping the wobbling motions of the laboratory-counterweight system during all rotating modes of operation will be evaluated. A candidate primary system is a large double-gimballed control-moment gyro (CMG) used as an active wobble damper. Alternative or supplementary passive techniques such as viscous ring dampers in the counterweight or dashpot-type cable damping devices may also be investigated.

No tests or other developments in rotating spacecraft stabilization are anticipated prior to 1975. Technology in this area may be required for extended-duration space station or manned planetary missions.

2. General Description:

A proposed configuration shown in figure 1 has a laboratory module weight up to 100,000 pounds, a counterweight of 26,000 pounds (SIV-B), and an 8-crossed-cable configuration 273 feet long. It provides about 1/3 "g" at a 70-foot rotation radius when rotated at 4 rpm. Gravity level is variable up to 0.6 "g" by changing cable length or spin rate. The deployment, spinup, despin, and retraction maneuvers are highly complex and will require extensive manned monitoring and adjustment of the control gains and filters as the system moments of inertia and flexibility characteristics change with separation distance. Spinup and despin operations will be accomplished by spin jets on the laboratory and counterweight. A large doubled-gimballed CMG in the laboratory module, with its associated control computer and two-axis sun sensors or inertial measuring unit (IMU), will be used to damp wobbling motions of the system. Counterweight passive damping devices (such as viscous ring dampers and cable-mounted spring-and-dashpot damping mechanisms) will also be investigated.

3. Operational Constraints:

The rotating spacecraft experiment will interfere with all on-board zero-gravity experiments and observational experiments requiring pointing. All such experiments must be completed or interrupted, and their associated equipment and apparatus must be secured prior to spinup operations.

4. Mode of Operation:

Spinup, deployment, and wobble-damping will be automatic, with provisions for manual override and adjustment during all modes of operation.

5. Crew Support:

In addition to securing all zero-gravity experiment apparatus, an extra-vehicular activity (EVA) mission will be required to attach the deployment mechanism and cables to the counterweight module. Manned checkout of the CMG wobble damper will be performed. Close monitoring and possibly manual operation of the spinup jets and deployment mechanism will be required. A second crew member will be needed during spinup operations to evaluate the performance of the gyroscopic wobble damper, and possibly to adjust system gains and filter compensation loops. Control consoles displaying station and counterweight attitude errors and cable-slacking indications will be provided for these monitors. Manual override and adjustment capability for all modes of rotating operation will also be provided on these consoles. Additional evaluation of manual control techniques for rotating spacecraft control may be performed after steady-state spin is achieved. In addition to the stabilization experiment, it may be desirable to instrument one or more crew members for biomedical studies in the gravity environment.

6. Spacecraft Support:

The spin axis of the station-counterweight system should point toward the sun to simplify solar-array mechanization and to utilize solar sensors in the rotating-control system. Data return to the station should include continuous readout of the laboratory and counterweight motions, the cable forces, and separation distance. A summary of the weight, power, and envelope data is given below:

Weight, Mass, and Envelope Data:

Weights: Deployment mechanism - 1,000 lb

Fuel (150 lb thrust jets)

Spinup - 1,000 lb

Despin - 1,000 lb

Wobble-damper system - 500 lb

Volume: Deployment mechanism - 700 cu ft
Wobble-damper system - 20 cu ft

Power: Deployment mechanism - 112 watts peak
Wobble-damper system - 500 watts peak
200 watts continuous

7. Development Schedule:

No detailed development support program may be defined at this time. However, several long-lead items must be developed for ground tests and extensive simulation required in support of this experiment. The gyroscopic wobble damper will require 18 months to 2 years to develop. A computer program for simulation and hardware test purposes representing the cable-coupled spacecraft dynamics is available but modal data will have to be developed. Ground testing of the wobble damper in a dynamic simulation to verify the system control laws and filter implementation will require 6 months to 1 year.

8. Cost:

~ 40 M

9. Spacecraft Interface:

The primary space-station interface requirement for this experiment will be the basic physical design of the station module for a gravity environment. Also provisions must be made for securing all zero-gravity experiment equipment:

10. Test Program:

The test program will consist of the deployment, rotation, stabilization, and despin of the laboratory - counterweight system while measuring spacecraft and control-system parameters to evaluate the control effectiveness.

Measurements made on a continuous basis during this experiment will include:

a. Laboratory attitude errors. (two-axis sun sensor or IMU)

b. Laboratory rates (rate gyros)

c. Counterweight attitude errors (two-axis sun sensor or IMU)

d. Counterweight rates (rate gyros)

e. Cable forces (strain gages)

f. Wobble-damper gimbal angles

g. Jet fuel used during spinup and despin

h. Cable separation distance

<u>Duration</u>: Spinup - 1 hr
Rotation and wobble-damper evaluation - 10 hrs minimum
Despin - 1 hr

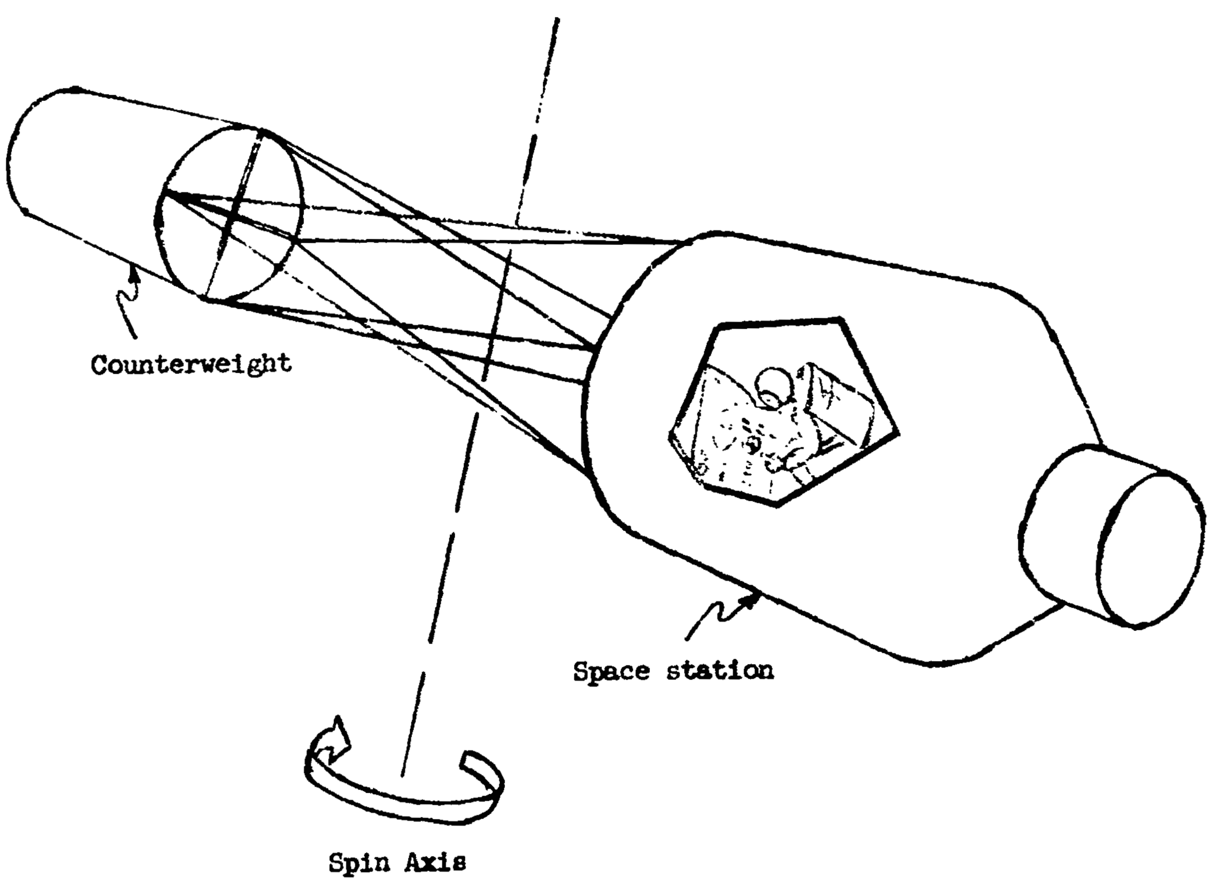


Figure 1.- Rotating spacecraft control experiment.

EXPERIMENT/EVENT DATA SHEET III A

TITLE: ROTATING SPACECRAFT CONTROL EXPERIMENT

ITEM No.	PHASE: 1 SECURE ZERO GRAVITY FOR ROTATING SPACECRAFT CONTROL EXPERIMENT	PHASE: 2 ROTATING SPACECRAFT CONTROL	PHASE:	PHASE:
1	III A-1 (603001)	III A-2 (603011)		
2	1	1		
3	1	1		
4	1	1		
5	0	0		
6	1	1		
7				
8	1	2		
9	16	4		
10	8	7		
11	0	3		
12	0	7		
13	0	0		
14	0	0		
15				
16				
17				
18	0	700		
19	0	0		
20	0	18		
21	0	15		
22	0	500		
23	0	0		
24	0			
25	0			
26	0	0		
27		603001		
28	603011			
29				
30	0	1		
31	0	4		
32	0	3		
33		0		
34				
35				
36				
37	1	-1		
38				
39				
40	0	0		

EXPERIMENTAL DATA SHEET IIIB

Evaluation of Fine-Pointing Control System

1. Specific Objective:

The main objective of this experiment is to demonstrate the feasibility of stabilizing a laboratory to 0.01 arc sec. Fine-pointing capabilities of this magnitude are necessary for the large-telescope astronomy projects and as a test bed for advanced guidance components testing. Additional objectives are to determine the characteristics of a low-friction (0.05 ounce-inches breakout torque) control-moment gyro stabilization system under a zero-"g" environment, and to evaluate a softly-sprung gimbal isolation system.

2. General Description:

The experiment will be contained in an external module. The basic stabilization system will be a low-friction "control-moment gyro" system with twin-rotor, single-gimbal gyros about each of three axes as shown in figure 1. A sensor system using fine-pointing star sensors operating through two small (typically 12") telescopes will be used to furnish attitude information to the CMG system. These will also be used to evaluate the performance of the stabilization system.

The experiment module and its associated control system will be initially activated and checked out in the shirt-sleeve environment of the space hangar. After checkout, the module then will be flown to the location where it can be attached to the soft-spring gimbal system. At first, a hard dock between the station and module is necessary so the pair can be slewed until guide stars are within the range of the star sensors. At this point the two will be isolated for the fine-pointing experiment. All necessary power will be included on the module. A digital computer will be used for monitoring, with the ability to shut down system operation automatically. Periodic monitoring will be performed by the crew on the space station.

After completion of this experiment, the detached mode will be evaluated. The module will be flown remotely to a position approximately one-half mile from the space station. A gimbal star tracker will be used in a scan mode to lock on the guide stars. The module will then be slewed by a reaction-jet control system until the guide stars fall within the range of the coarse-pointing star tracker. The CMG control system will take over at this point. The module must contain its own control system for flying to and from the station, onboard power, thermal control system, guidance sensors, and digital computer for automatic operation of all systems during the fine-pointing experiment. The module design must include sufficient space and power for advanced guidance component tests.

3. Operational Constraints:

The main constraint on the experiment module is that the telescopes be able to view relatively bright stars (about +2 magnitude) for as much of the orbit as possible. If it is not possible to view two bright stars, one of the telescopes can accept a dimmer star with a resultant decrease in sensitivity, but the accuracy should not deteriorate beyond 4 arc sec in the roll axis.

The operational constraints imposed on the space station are considerably different for each of the possible operation modes. These are described as follows:

Soft-Spring Attached Mode - The space station should remain in very close alinement with the experiment module in an inertial-hold mode. Attitude differences should be within $1/4^{\circ}$ and the rate should be low enough not to introduce oscillations through the springs. It will be necessary to maintain this close coupling for about 48 hours to evaluate the soft-spring gimbal isolation system.

Detached Mode:

The only constraint in this case is that the distance between the station and module does not become too large; i.e., 10 miles or less.

4. Mode of Operation:

The experiment will be initially alined by the crew and is designed for operation with a minimum of attention. Once started, the experiment will be run continuously until completion.

As mentioned previously, there are two modes of operation, described as follows:

A soft-sprung mode in which the module is attached to the main laboratory at three points by a very soft gimbal system as shown in figure 2 in order to provide isolation between the two vehicles during observations. It can be hard-docked for repair and adjustment.

A detached mode which has no physical link between the two and consequently would require a completely separate control, stabilization, and transport system.

5. Crew Support:

The support crew should be trained to setup, aline, and checkout the equipment, and perform routine maintenance as required. The crew should also be able to monitor the experiment and make qualitative evaluation of the data. In the detached mode they may have to fly the module to a docking port or hangar.

For the alinement and checkout of the experiment, the crew should have members trained in the following disciplines: optics for sensors, control analysis for the gyro system, and electronics for computer, communications, etc.

6. <u>Spacecraft Support:</u>

The output from the sensors and the gyros will be telemetered to the main laboratory.

Permanent data records will be maintained on oscillographs and tape in the module and be returned with the shuttle.

The weight, power, and volume of the module are given in the following table:

Weight	Volume (External)	Volume (components)	Average power required
7,500 lb	624 cu ft	110 cu ft	580 watts

The module will be docked in the space operations hangar periodically in order to obtain the shirt-sleeve environment required for checkout and maintenance.

7. <u>Development Program:</u>

At present the key components are not available and their development would require a period of three to four years (low-friction CMG, for instance). During the development program, computer simulation studies of the overall system will be required.

8. <u>Cost:</u>

~ 50 M

9. <u>Spacecraft Interface:</u>

In both modes a requirement exists for retrieval of the module to the hangar location to facilitate maintenance operations and checkout procedures.

There will be a spacecraft interface in the attached mode which consists of the support structure for the soft-spring gimbal system.

10. Test Program:

While in the space hangar, power will be applied to all systems to perform operational checks and necessary adjustments. Typical items to be functionally checked include the CMG's, IMU, electronics, star sensors, and digital computer. Complete control-system tests will also be performed initially in the hangar. Other systems to be checked include munications, environmental and thermal control, propulsion system, and recording equipment.

The module will then be removed from the hangar and mounted in the soft-spring gimbal system. The entire station will be pointed to the desired stellar reference and the gimbals uncaged for evaluation of the fine-pointing system performance. When the pointing accuracy attained in this mode is determined, the module will be disconnected and flown away from the station for a fine-pointing evaluation in the free-flying mode.

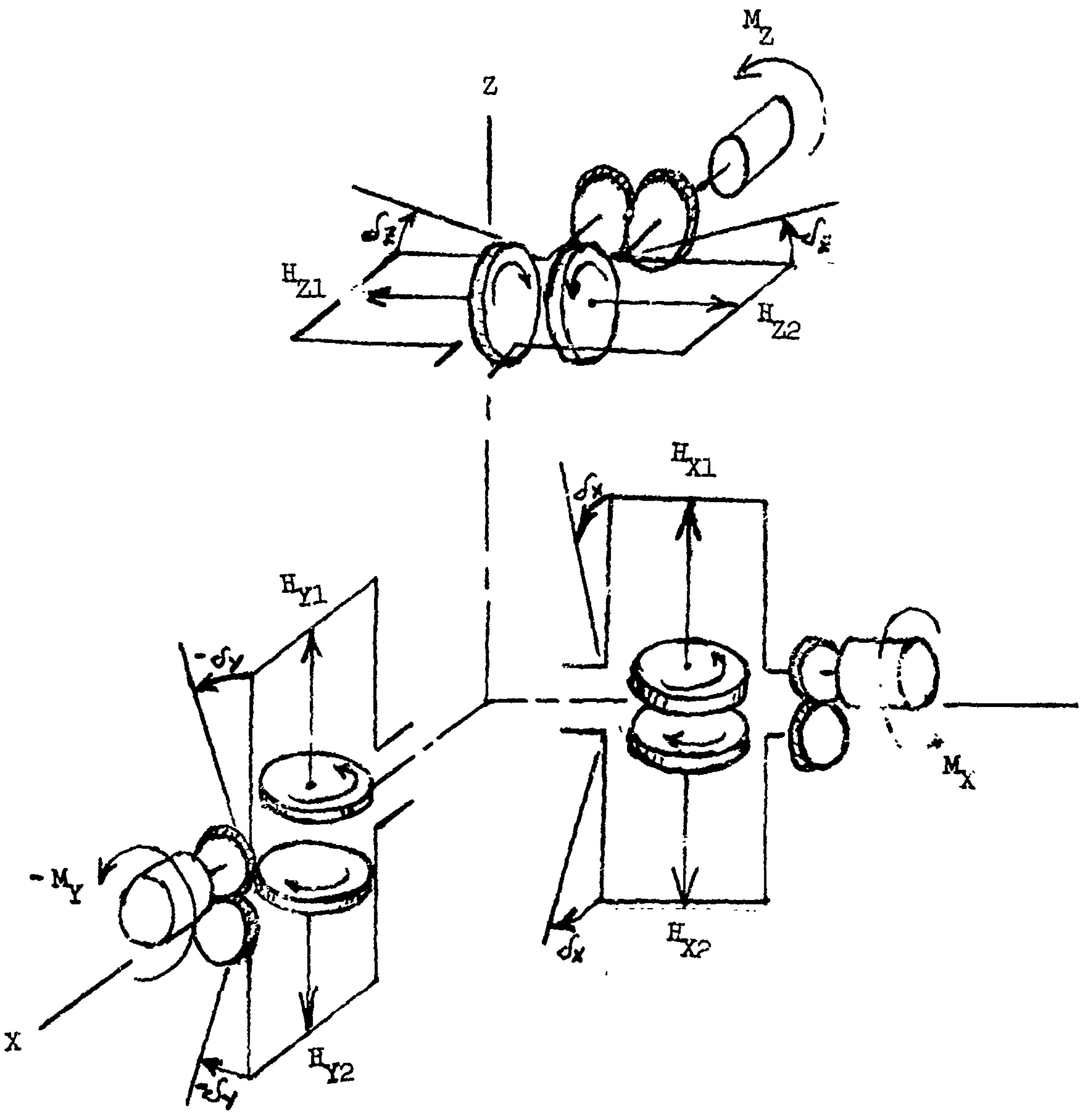
Typical measurements to be made during the fine-pointing evaluations are:

(a) Time history of the star-sensor output

(b) Time history of the CMG gimbal angles

(c) Time history of the CMG gimbal rates

(d) The gyro spin rates



Note: Each pair of gyros rotate as a couple in the directions shown in order to eliminate cross coupling and provide momentum changes about only one axis.

Figure 1.- Twin-rotor, 3-axis fine-pointing CMG system.

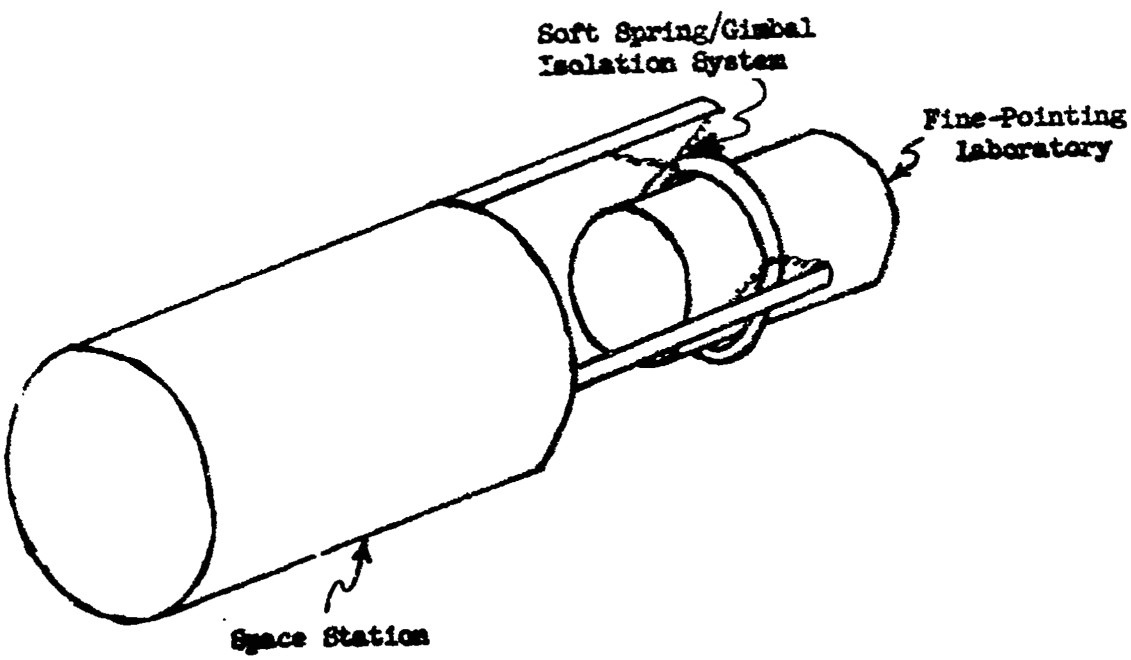


Figure 2.- Fine-pointing experiment shown in the soft-spring mode.

EXPERIMENT/EVENT DATA SHEET IIIB

TITLE: EVALUATION OF FINE-POINTING CONTROL SYSTEM

ITEM No.	PHASE: 1 ALINEMENT AND CHECKOUT	PHASE: 2 SOFT-SPRING GIMBAL ATTACHMENT	PHASE: 3 EVALUATION OF CONTROL SYSTEM — SOFT ATTACHED MODE	PHASE: 4 PLACEMENT OF DETACHED MODE
1	III B-1 (603002)	III B-2 (603012)	III B-3 (603022)	III B-4 (603032)
2	2	1	2	1
3	2	1	2	1
4	1	1	1	1
5	0	0	0	0
6	1	1	1	1
7				
8	2	2	1	2
9	3	27	27	27
10	8	8	4	8
11	3	27	0	27
12	8	8	0	8
13	0	0	0	0
14	0	0	0	0
15				
16				
17				
18	20	0	0	0
19	0	0	0	0
20	8	0	0	0
21	8	0	0	0
22	600	0	0	0
23	0	0	0	0
24		0	0	0
25		0	0	0
26	0	0	0	0
27		603002	603012	603002
28				
29				
30	0	1	1	0
31	0	5	0	5
32	0	5	0	5
33	0	0	1	0
34				
35				
36				
37	1	1	0	1
38				
39				
40	0	2	2	2

EXPERIMENT/EVENT DATA SHEET III B - CONCLUDED

TITLE: EVALUATION OF FINE-POINTING CONTROL SYSTEM

ITEM No.	PHASE: 5 EVALUATION OF CONTROL SYSTEM - DETACHED MODE	PHASE:	PHASE:	PHASE:
1	III B - 5 (603042)			
2	2			
3	2			
4	1			
5	0			
6	1			
7				
8	1			
9	27			
10	4			
11	0			
12	0			
13	0			
14	0			
15				
16				
17				
18	0			
19	0			
20	0			
21	0			
22	0			
23	0			
24	0			
25	0			
26	0			
27	603032			
28				
29				
30	0			
31	0			
32	0			
33	1			
34				
35				
36				
37	0			
38				
39				
40	2			

EXPERIMENT DATA SHEET IIIC

Evaluation of Advanced Guidance Components

1. Specific Objective:

The objective of this experiment is to test advanced guidance components which cannot be adequately tested in a one-"g" environment. The highly stabilized (.01 arc sec) module developed for the fine-pointing control system evaluation will be used in a free-flying mode as a test bed for advanced inertial guidance devices, such as cryogenic electrostatic gyros. The tests will evaluate the accuracy and drift characteristics of these components in a space environment and investigate their associated operational problems. Other experiments requiring extremely low accelerations might be isolated from the spacecraft disturbances by being run in this fine-pointing test bed.

2. General Description:

Numerous advanced inertial guidance components could be tested aboard the highly stabilized module. The cryogenic electrostatic gyroscope is considered typical of this class of components, and its testing requirements and procedures are representative for advanced guidance devices. These components have potential accuracies of better than .01 arc sec and extremely low drift rates. Another candidate experiment is the low "g" accelerometer with a range of 10^{-5} to 10^{-11} "g".

3. Operational Constraints:

The operational constraints are basically the same as for the "Fine-Pointing Control System Evaluation." The experiments will be almost completely automatic once they are set up, but are of several weeks duration and will require occasional monitoring. Orbit-keeping on the part of the main station may be required in order to remain within several miles of the module for communication and rendezvous.

4. Mode of Operation:

The mode of operation will be the same as available for the "Fine-Pointing Control Experiment", however because of the long test periods required, the preference may be for the detached mode.

5. Crew Support:

The crew support would generally be the same as the requirements for the "Fine-Pointing Control Experiment." In addition some training in the handling of cryogenic materials would be required. The crew would be required to remotely monitor selected component readouts to check the progress of the experiments.

6. Spacecraft Support:

Since these are component tests, the experiment package would not be very large. The cryogenic electrostatic gyro would probably define the worst-case requirements of 100 lb and volume of 1 to 12 cu ft. The power required is typically about 25 watts. This support is required from the remote laboratory and not the space station.

The main laboratory support would consist of the crew support and monitoring of the experiment.

7. Development Schedule:

The development time for the two experiments given as examples is about 4 to 6 years, and probably is representative of other typical experiments in this area.

8. Cost:

This will be determined as the program progresses.

9. Spacecraft Interface:

The forseeable interface for these experiments is the same as that for the fine-pointing experiment (IIIB). However, it would also entail the mounting and alinement of the experiments in the module while it is docked in the hangar.

10. Test Program:

This will have to be worked out for each experiment individually. Typically, accuracy and drift measurements of guidance components would require continuous stabilization of the test bed with respect to stellar reference for periods of several weeks,with periodic monitoring of the components.

EXPERIMENT/EVENT DATA SHEET III C

TITLE: ADVANCED GUIDANCE COMPONENTS TESTING LABORATORY

ITEM No.	PHASE: 1 COMPONENTS TESTING	PHASE:	PHASE:	PHASE:
1	III C-1 (603003)			
2	27			
3	7			
4	3			
5	2			
6	1			
7				
8	1			
9	3			
10	8			
11				
12				
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	0			
22	0			
23	0			
24	100			
25	12			
26	0			
27	603042			
28				
29				
30	1			
31	0			
32	0			
33	1			
34				
35				
36				
37	0			
38				
39				
40	2			

FUNCTIONAL PROGRAM ELEMENT IV

1. Discipline: Advanced Technology

2. Program Element: Environmental Control and Life Support (EC/LS) Systems

3. Requirement:

This element must be included in the overall experiment program to provide critical information with respect to the environmental requirements, the design criteria for EC/LS systems, and the technology which will allow and assist men to perform effectively on future space missions. This much-needed information will be gathered through:

(a) Investigations of the basic chemical and physical phenomena, and their occurrence and rate of occurrence in those gravity-sensitive elements of future EC/LS systems.

(b) Evaluations of advanced subsystem performance, reliability, and systems-fit in the space environment.

(c) Investigations of man-system and system-vehicle interfaces and demonstrations of man's ability to accomplish maintenance and repair operations.

4. Justification:

Flight qualification of advanced regenerative EC/LS systems must be accomplished in earth orbit to obtain confidence in the system prior to commitment to long-term flight. Qualification in earth orbit will provide the proper environment and sufficient experiment time in that environment for thorough performance and reliability assessment of gravity-sensitive elements of the system. These assessments together with studies of the man-system interface will provide a basis from which operational EC/LS systems for long-term missions can be designed and developed. Specific components of future EC/LS systems which must be tested include waste and water management subsystems and integrated oxygen recovery subsystems.

Because of medical and crew social requirements, personal hygiene and sanitation will be of primary importance during extended manned space missions. A major element in maintaining adequate personal hygiene is, of course, body cleansing. Provisions must be made whereby the crew can maintain bodily cleanliness as a psychological link to earth-bound habit patterns and attitudes. It is therefore necessary to thoroughly test techniques for body cleansing in the space environment to insure that these techniques will be adequate for future space missions.

5. Component Experiments:

The following list of experiment packages includes those critical components of future EC/LS systems which require zero-gravity validation and which presently show the most promise as operational subsystems for manned space missions following the 1975 space station:

A. Zero-Gravity Whole-Body Shower

B. Advanced Waste-and Water-Management Subsystem

C. Advanced Integrated Oxygen-Recovery Subsystem

In addition to the above list of EC/LS system experiments, the following additional experiments have been identified as being potential candidates for flight qualification. However, these additional experiments have not been defined as those listed above.

Clothing Washer/Dryer

Potability Sensor

Membrane Final Filter (CO_2 Purity)

Wet-Oxidation Waste-Management Subsystem

Bladderless Tank

Membrane-Diffusion CO_2 Collector

Chemisorbant Beds

Isotope Catalytic Oxidizer and/or Waste Managemen Subsystem

Waste/Propulsion System

Glycerol Synthesis From Methane

6. Description:

A. Zero-Gravity Whole-Body Shower

This experiment involves the flight test of a zero-gravity shower using an airstream to direct water over the body. The shower is a cylindrical stall approximately 30 inches in diameter and 80 inches high. The crewman enters this stall and uses the stirrups and restraint straps provided to retain orientation in the air/water stream while keeping his hands free for washing functions.

B. Advanced Waste-and Water-Management Subsystem

This experiment combines an advanced waste-management subsystem and an advanced water recovery unit into one experimental package for flight test. The waste-management subsystem consists of a wet-waste collector with a removable dry-waste shredder and an attached urinal. Waste collection is followed by a 30-minute sterilization phase at 250° F with periodic waste decomposition accomplished by vacuum pyrolysis at 1200° F for 12 hours. Waste residue is vacuumed from the collection chamber at the completion of the cooldown period. Cabin air is drawn through the collector to provide the zero-gravity transfer mechanism.

A urine/air separator and a pump are used for the collection and immediate transfer of urine to a water recovery unit. For this experiment the water recovery unit will be an advanced vapor diffusion concept. Vapor diffusion is an ambient-pressure distillation process in which water diffuses through a membrane surface and condenses on a porous metal condenser/separator surface. The semipermeable membrane prevents the passage of solids and other contaminants into the condenser. The water recovery unit can also be operated as a separate experiment if desired.

C. Advanced Integrated Oxygen-Recovery Subsystem

This experiment involves the flight testing of three-man capacity, advanced closed-loop oxygen recovery subsystem. In order to maintain a maximum of flexibility in this experiment, three options are considered. The two primary options involve the integration of a solid amine-CO_2 concentration unit with either (or both) a solid electrolyte or a Bosch-CO_2 reduction unit. A vapor-feed electrolysis unit is also proposed as a part of the solid amine/Bosch option. The third option involves the flight test of a single-step, fused-salt oxygen-recovery subsystem. The inclusion of the fused-salt concept into the integrated oxygen recovery experiment package will depend on the solving of certain inherent problems within the next two years. The fused-salt concept, while a desirable alternative for future missions, is not presently proposed for experiment development, but the option must remain open for its inclusion into this experiment package at a later date.

7. Special Considerations or Provisions:

(a) A near-zero gravity environment is required for these experiments.

(b) Integration of the whole-body shower experiment and the advanced waste and water management subsystem experiment into the crew personal hygiene compartment is desirable.

(c) Integration of the advanced oxygen-recovery subsystem experiment into the operational oxygen-recovery subsystem is desirable.

(d) Provision must be made in the thermal control system for the handling of heat loads generated by these experiments.

BIBLIOGRAPHY

1. Allen, J. L.: Report on the Development of the Manned Orbital Research Laboratory (MORL) System Utilization Potential. Task Area IV - MORL System Improvement Study, Book 1. SM-48815 (Contract No. NAS1-3612), Missile & Space Syst. Div., Douglas Aircraft Co., Inc., Dec. 1965.

2. The Needs and Requirements for a Manned Space Station
   Vol. I: Summary Report.
   Vol. II: Astronomy.
   Vol. III: Earth Resources.
   Vol. IV: Meteorology.
   Vol. V: Biology.
   Vol. VI: Long-term Flight.
   Vol. VII: Research and Development in Advanced Technology.
   Vol. VIII: Orbital Operations and Logistics.
   Prepared by Space Station Requirements Steering Committee. November 15, 1966. NASA, Langley Research Center.

3. Manned Spacecraft Center, Houston, Texas: RFP No. BG721-23-9-83P, "Design, Development, and Fabrication of an Environmental/Thermal Control and Life Support System for Installation in a Basic Subsystem Module". January 1969.

4. Neel, J. M., et al: Trade-Off Study and Conceptual Designs of Regenerative Advanced Integrated Life Support Systems (AILSS). Task II Report. Contract No. NAS1-7905, Hamilton Standard, Windsor Locks, Conn., 1968.

5. Runge, F. C., et al: Requirements Study For a Biotechnology Laboratory For Manned Earth Orbiting Missions. DAC-58155 (Contract No. NAS7-518), Missile and Space Systems Div., Douglas Aircraft Co., July 1968.

EXPERIMENT DATA SHEET IV A

Zero-Gravity Whole-Body Shower

1. Specific Objective:

The objective of this experiment is the flight testing of a whole-body cleansing unit in the weightless environment of space to determine the effectiveness of such a device for removing residual materials from the skin. In addition, this experiment will demonstrate that a whole-body shower device will be convenient and pleasant for the crew to use during extended stays in space and that such a device is much more effective than other body cleansing techniques. A further objective of this experiment is to provide an operational body-cleansing unit for space-station use.

2. General Description:

The experiment proposed herein involves the flight test of a zero-gravity shower using an airstream to direct water over the body. The shower (shown in figure 1) is a cylindrical stall approximately 30 inches in diameter and 80 inches high. The crewman enters this stall and uses the stirrups and restraint straps provided to retain orientation in the air/water stream while keeping his hands free for washing functions.

Water is introduced as a spray from a hand-held shower head. This spray is carried through the cylinder and out the end by the main airstream. A local water collector/blower circuit is used for the removal of the local accumulation of water and to assist in drying. Water flow, temperatures, and air flow are controlled by the crewman within the shower. The unit is provided with a sponge or a washcloth for local scrubbing.

3. <u>Operational Constraints</u>:

This experiment will require no specific orbital altitude or inclination and it will not require stringent stabilization accuracy. A near-zero-gravity environment is, however, required.

4. <u>Mode of Operation</u>:

The preferred mode of operation of this experiment requires that it be an integral part of the space station's personal hygiene compartment.

5. <u>Crew Support</u>:

Astronaut participation will obviously be required for the performance of this experiment. It is recommended that the shower be used at least three times a day until the device proves satisfactory, at which time it may be used operationally on a similar use schedule. The time required for a shower using this concept is estimated at 8 minutes for all operations, with 4 minutes of actual shower time.

Routine maintenance will be limited to periodic cleaning of the inside of the compartment and monthly replacement of two filters (if used operationally throughout the mission). The total maintenance time is estimated to be 2 man-hours per month.

Visual observations of the crew members using the shower will be required initially. Film, and, possibly, data-tape retrieval will be required.

6. <u>Spacecraft Support</u>:

The performance of this experiment requires the following spacecraft support:

Shower Weight: 195 pounds
Spares (if operational): 52 pounds
Power: 700 watts for 0.5 hours per day
Size: 48 cu ft
Telemetry: None required
Return Data: Possible film of initial uses of the shower, and data tape of measured parameters.

Water use for the shower is based on a flow rate of 0.5 gallons per minute, with four minutes of water use allocated for each shower.

7. Developme _chedule: See figure 2.

8. Cost: Total Experiment - 1 M

FY	COST $M
70	.15
71	.30
72	.40
73	.15

9. Spacecraft Interface:

This experiment would require integration into the operational crew hygiene system of the spacecraft. Operation of the shower will create an extra load on the atmospheric control subsystem because of the removal of the shower air heat and a small amount of atmospheric moisture introduced by the shower. Seventeen pounds of water at 105° F will be required for each shower. This water should be recovered by the water management subsystem of the station.

10. Test Program:

The test program for the whole-body shower will be conducted primarily by the crewmen using the device for a sufficient period of time to determine the adequacy of the shower. Initial shower uses will require visual monitoring for experimental, as well as safety, purposes. Measurements of selected shower system parameters (such as water flow rates and temperatures) will be required.

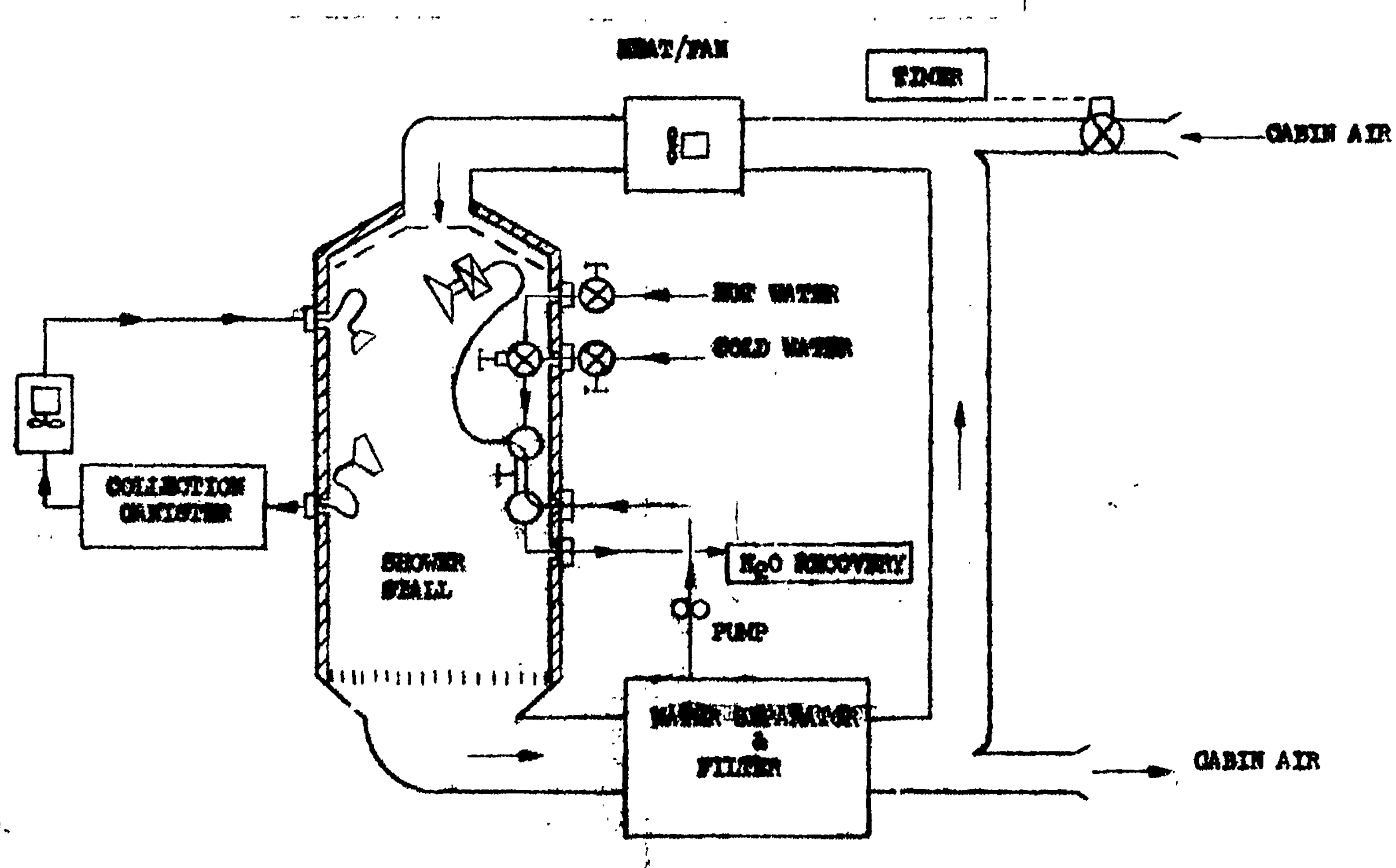


Figure 1.- Zero-gravity whole-body shower experiment.

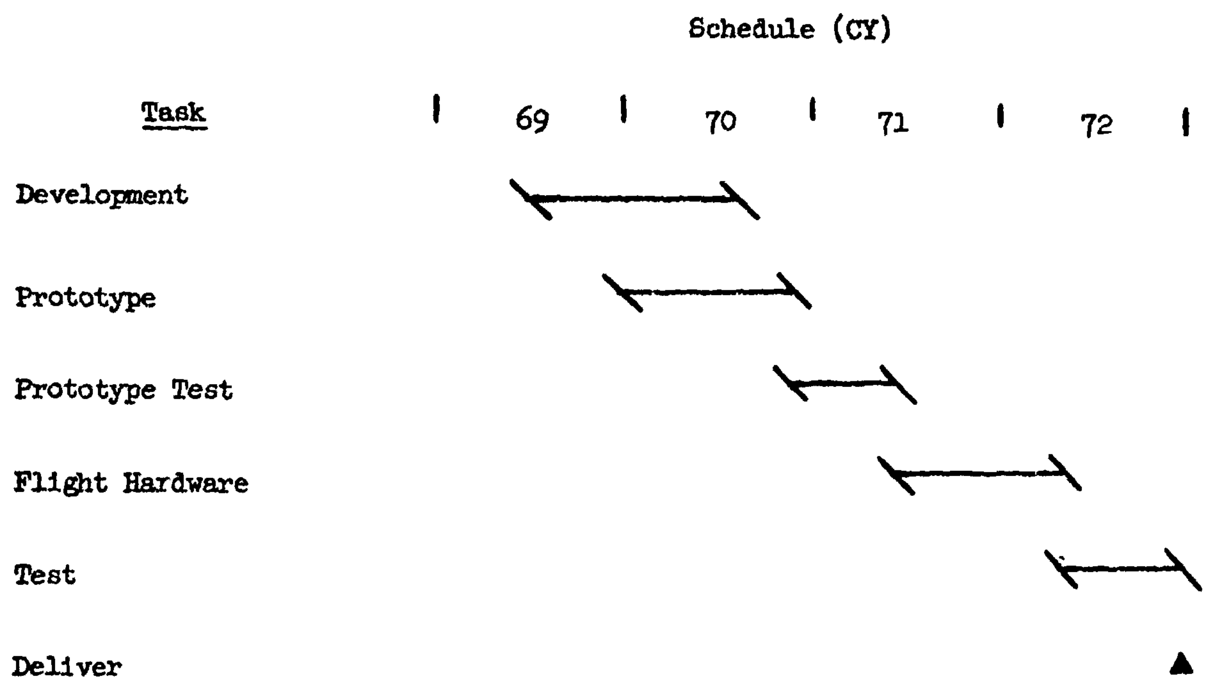


Figure 2.- Zero-gravity whole-body shower development schedule.

EXPERIMENT/EVENT DATA SHEET IV A

T152

TITLE: ZERO-GRAVITY WHOLE BODY SHOWER

ITEM No.	PHASE: 1 SHOWER USE	PHASE: 2 SHOWER MAINTENANCE	PHASE:	PHASE:
1	IV A-1 (604001)	IV A-2 (604011)		
2	10	1		
3	10	1		
4	1	1		
5	0	0		
6	1	0		
7				
8	1	1		
9	16	3		
10	0.5	0.15		
11				
12				
13				
14				
15				
16				
17				
18	0	0		
19	0	0		
20	0	0		
21	0.5	0		
22	700	0		
23	0	0		
24				
25				
26	0	0		
27		604001		
28				
29				
30	0	0		
31	0	0		
32				
33	0	0		
34				
35				
36				
37	1	1		
38				
39				
40	0	1		

EXPERIMENT DATA SHEET IV B

Advanced Waste-and Water-Management Subsystem

1. Specific Objective:

The objective of this experiment is to obtain the necessary zero-gravity operational an . performance data for flight verification of an advanced waste management subsystem wherein waste material is sterilized and processed to achieve a significant reduction in weight and waste storage volume. An additional objective of this experiment is to evaluate the performance of an advanced water recovery unit which is integrated into the urine collection aspect of the waste management subsystem.

2. General Description:

The advanced waste management subsystem shown in figure 1 consists of wet waste collector/vacuum decomposition unit with a removable dry-waste shredder and an attached urinal connected through a common process flow circuit. Following defecation or dry-waste shredding,processing is accomplished by first heating the wastes to 250° F for 30 minutes to insure sterilization. The vent valve is then opened and the water is flashed to space as a vapor. This process is repeated following each use of the unit, and at the end of a 24-hour period waste is pyrolytically decomposed by heating to 1200° F. This decomposition process continues for about 12 hours with the vacuum valve open and the gases vented to space. The collection chamber is then allowed to cool with the residue being vacuumed from the chamber at the completion of the cooldown period. Cabin air is drawn through the collector to provide the zero-gravity transfer mechanism and the air is treated to prevent odors, aerosols, and bacteria from escaping to the cabin. The plastic collection bag contains a hydrophobic patch, which will pass process flow air and retain solids and liquid. Incineration of the bags eliminates the need for replaceable filters which have inherent microbiological problems.

A urine/air separator, used in conjunction with a process-flow fan, and a pump are used for the collection and immediate transfer of urine to the water management subsystem. For this experiment, the water management subsystem will be an advanced-concept vapor-diffusion water-recovery unit.

Vapor diffusion is an ambient-pressure distillation process in which water diffuses through a membrane surface and condenses on a porous metal condenser-separator surface. The semipermeable membrane prevents the passage of solids and other contaminants (including micro-organisms) into the condenser. A schematic of this concept which uses the method of vapor compression for recovering the heat of condensation is shown in figure 2.

Waste water is received and stored in holding tanks where a pretreatment chemical is added. Two tanks are used; one receives waste water while the other discharges the treated water into a heated circulation loop that includes the vapor diffussion still. As the waste fluid flows through the evaporator portion of the still, the water evaporates and diffuses first through a semi-permeable membrane and then into a void space or gap. The vapor is then drawn off, compressed, and returned to a gap on the opposite side of the evaporator. There it condenses, giving up the heat of condensation to the evaporating fluid. Product water passes through a conductivity sensor as a final test and is delivered to a potable water storage tank.

3. Operational Constraints:

Orbital altitude, inclination, and pointing are not critical, however, a near zero-gravity environment is required.

4. Mode of Operation:

The experimental waste-management subsystem is planned to be used for waste collection over a 24-hour period. Waste processing will then take place during the next 24-hour period with water recovery from the collected urine being accomplished with the experimental vapor-diffusion water recovery unit. The equipment will be semiautomatic in operation and will be exercised on an intermittent basis for a sufficient period of time to determine its zero-gravity characteristics. The possibility then exists of using this equipment in an operational capacity.

5. Crew Support:

In addition to crew use of the experimental waste-management subsystem, crew support is required to initiate waste processing, to monitor equipment operation, to accomplish waste residue removal,and perform routine maintenance. The water recovery unit will require crew support for equipment startup, operation monitoring, shutdown, and maintenance.

Crew support requirements are estimated as follows:

Time (one man):

a) Waste Management: collection phase, 5 min/defecation
processing phase, 30 min/defecation

b) Water Recovery: 30 min per 24 hours

Skill: Electrical/Mechanical Technician

6. Spacecraft Support:

The following spacecraft support is required:

	Waste Management	Water Recovery	Total
Weight, lb	107	95	202
Power, watts	600	220	820

	Waste Management	Water Recovery	Total
Volume, cu ft	5	7	12
Data	To be determined	To be determined	

7. Development Schedule: (See figures 3, 4 and 5)

8. Cost:

Total experiment: 3.8 M

	70	71	72	73	74	75
WASTE MANAGEMENT SUBSYSTEM	.3	.4	.4	.3	—	—
WATER RECOVERY UNIT	.3	.3	.5	.3	.2	—
EXPERIMENT INTEGRATION	.1	.15	.2	.15	.1	.1

9. Spacecraft Interface:

This experiment package, as proposed, would require interfacing with the operational coolant fluid circuit. The process airflow circuit of the waste-management subsystem and the water circuit of the water-recovery unit do not require interfacing with the operational EC/LS system. However, additional radiator capacity may be required to support the heat loads generated by this experiment.

10. Test Program:

The flight test of the integrated waste and water management subsystem experiment will involve the operation of all subsystem components for a period of ten days. The crew will be required to start the experiment, use the waste management equipment, and perform scheduled maintenance over the test period. Measurements to determine the subsystem performance will be recorded for return to earth. Following the experiment, the subsystem may be used operationally for the remainder of the mission.

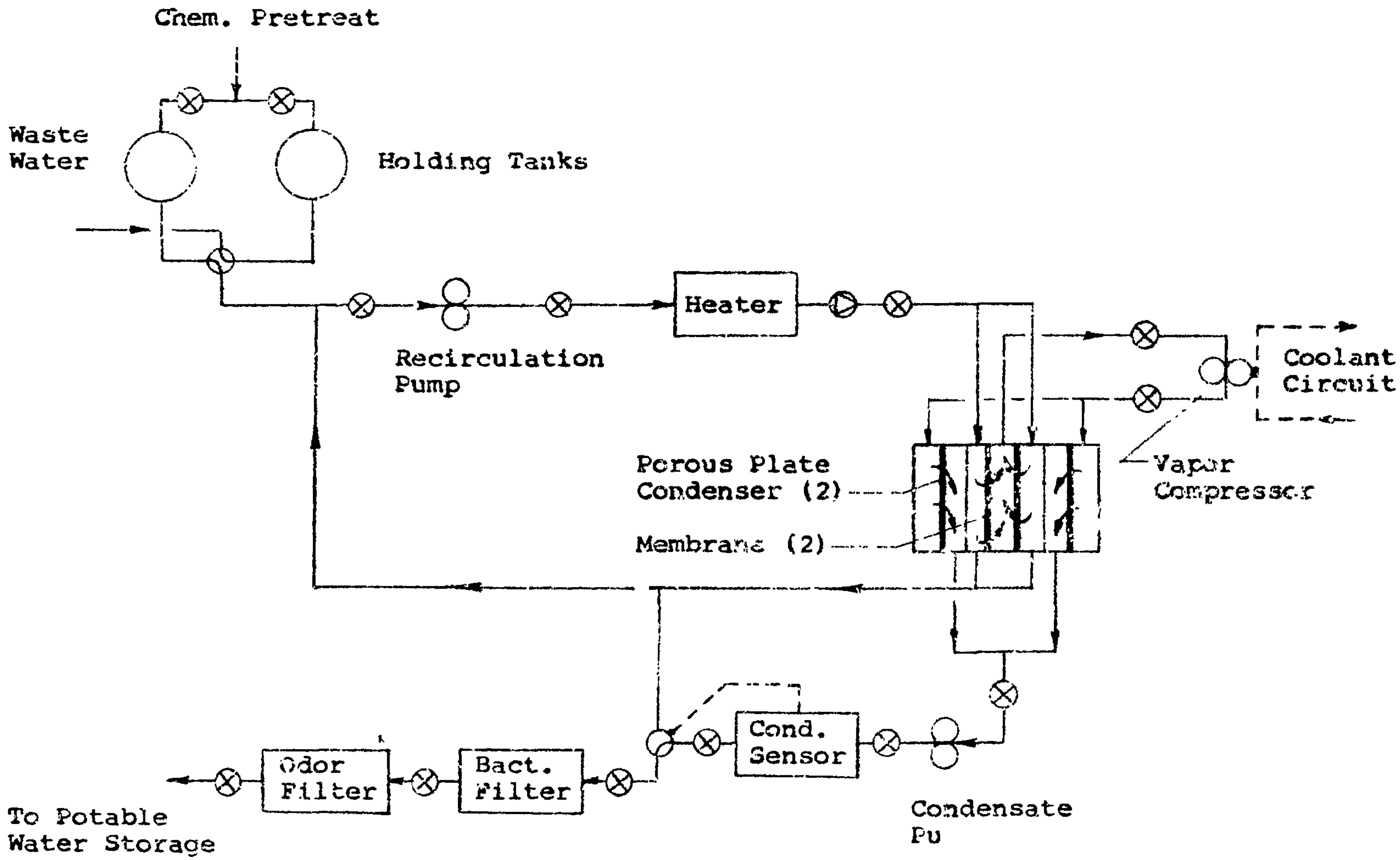


Figure 2.- Vapor diffusion/compression water-recovery unit.

T157

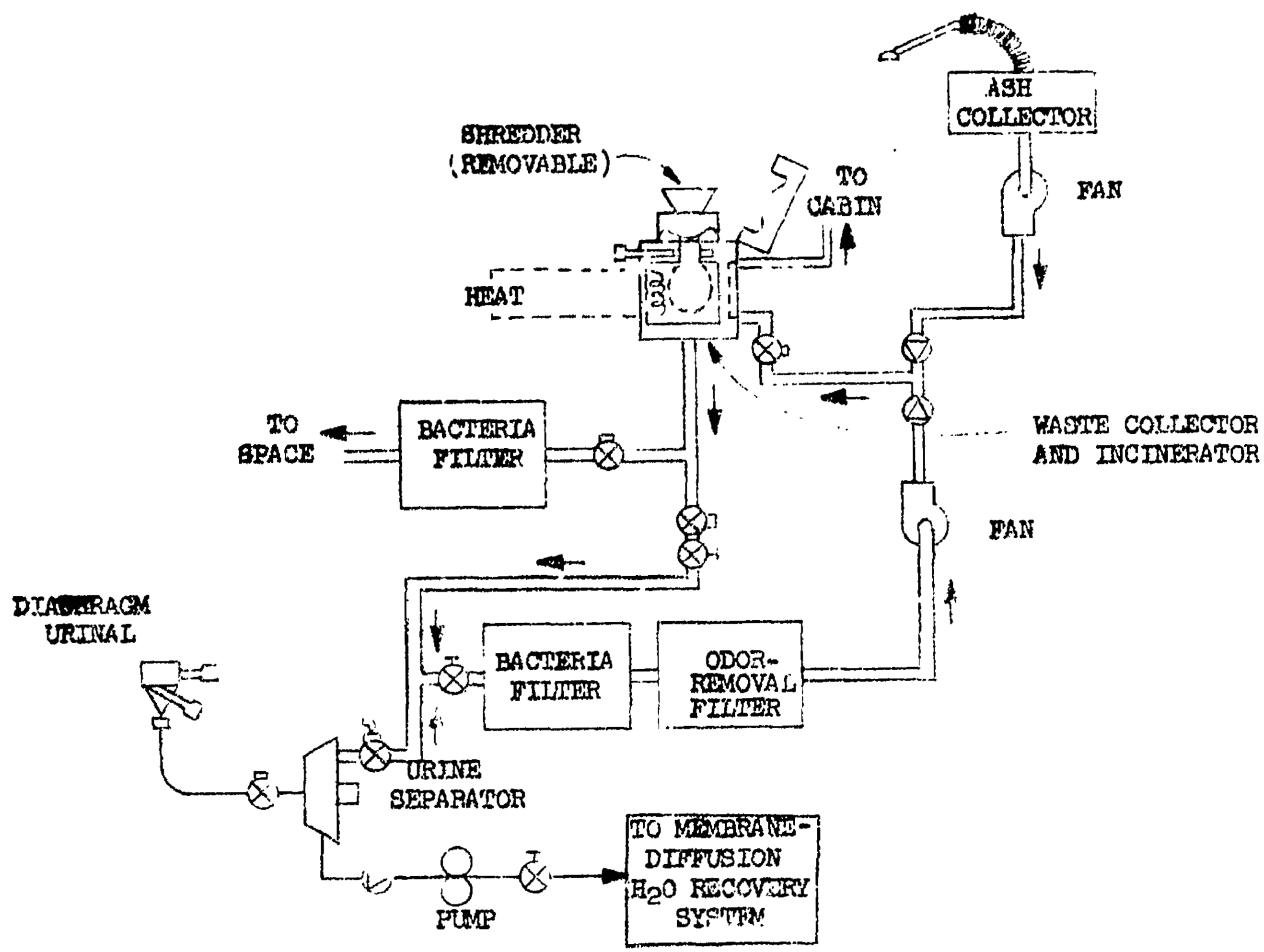


Figure 1.- Advanced waste-and water-management subsystem experiment.

T158

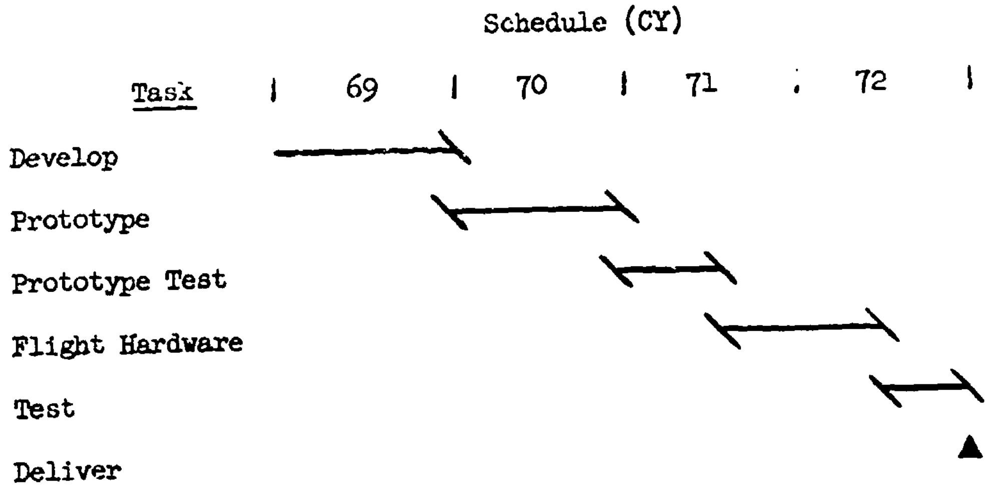


Figure 3.- Development schedule for integrated waste management subsystem.

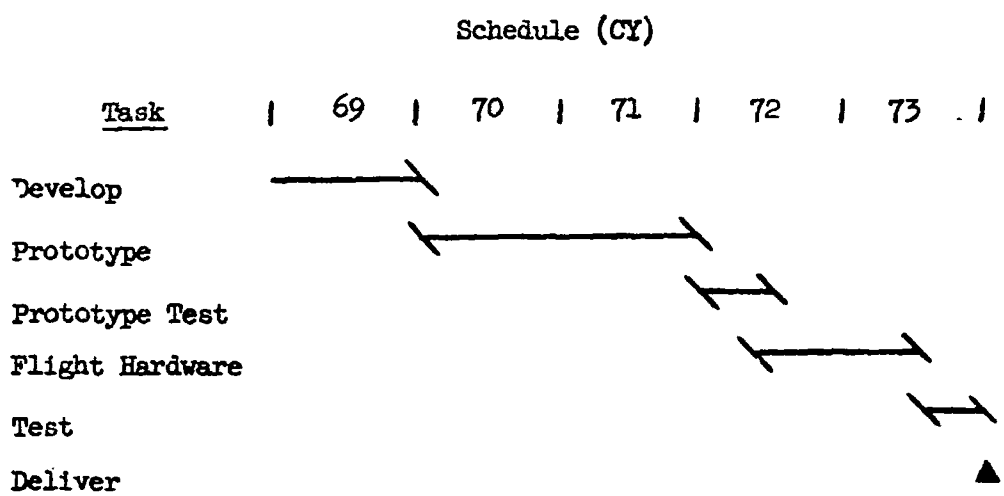


Figure 4.- Development schedule for water recovery unit.

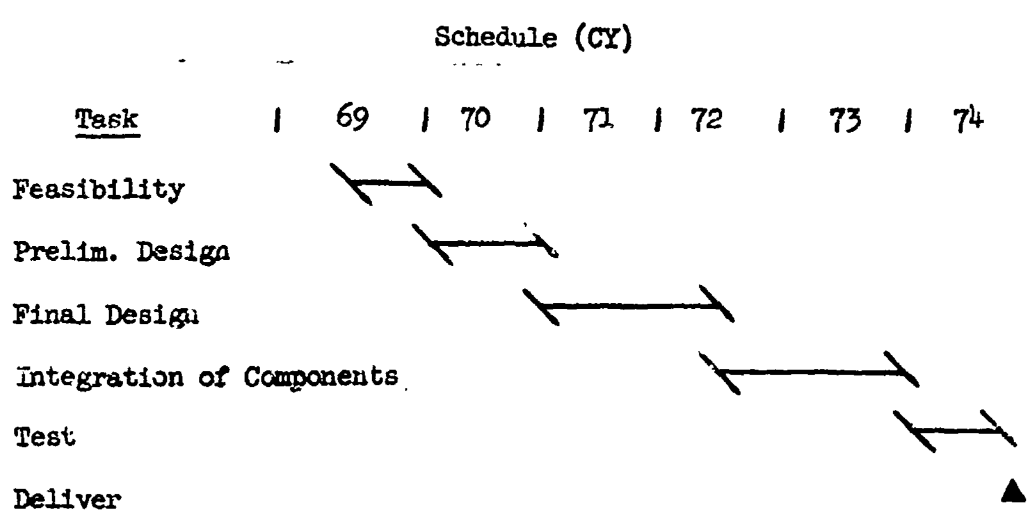


Figure 5.- Development schedule for experiment package.

EXPERIMENT/EVENT DATA SHEET IV B

TITLE: ADVANCED WASTE- AND WATER-MANAGEMENT SUBSYSTEM

ITEM No.	PHASE: 1 SYSTEM USE	PHASE: 2 SYSTEM MAINTENANCE	PHASE:	PHASE:
1	IV B-1 (604002)	IV B-2 (604012)		
2	10	10		
3	2	2		
4	5	5		
5	0	0		
6	1	1		
7				
8	1	1		
9	16	3		
10	1	1		
11				
12				
13				
14				
15				
16				
17				
18	0	0		
19	0	0		
20	0	0		
21	12	12		
22	200	620		
23	0	0		
24				
25	0	0		
26				
27		604002		
28				
29				
30	0	0		
31	0	0		
32				
33	0	0		
34				
35				
36				
37	1	1		
38				
39				
40	0	1		

EXPERIMENT DATA SHEET IV C

Advanced Integrated Oxygen Recovery Subsystem

1. Specific Objective:

The purpose of this experiment is to flight-test advanced closed-loop oxygen-recovery concepts applicable to future environmental control and life support (EC/LS) systems. These concepts will be designed for high performance and efficiency, operational simplicity, and long life. In order to assure that these advanced components will be available for space missions following the 1975 space station, a thorough flight-test program is required to evaluate any unforeseeable effects of a zero-or reduced-gravity environment on component performance and reliability. The advanced integrated oxygen recovery subsystem experiment proposed herein has the primary objective of obtaining these performance and reliability data to complete the technological development of this critical element of future EC/LS systems.

2. General Description:

The advanced integrated oxygen-recovery subsystem experiment package involves the flight test of those related components which presently show the most promise for use as operational components on missions after the 1975 space station. Because of uncertainties involved in forecasting technological breakthroughs in the immediate future and in order to maintain a maximum of flexibility in this experiment, three experiment options are considered. Figure 1 is a simplified schematic of these three options. The two primary options involve the integration of a three-man capacity solid amine-CO_2 concentration unit with either (or both) a solid electrolyte or a Bosch-CO_2 reduction unit. The solid electrolyte unit and the Bosch unit will each have a three-man capacity, and a vapor-feed electrolysis unit is proposed as a part of the solid amine/Bosch option. The third option involves the flight test of a three-man capacity, single-step fused-salt oxygen recovery unit. The inclusion of the fused-salt unit into the integrated oxygen recovery experiment package will depend on the solving of certain inherent problems within the next two years. The fused-salt process, while a desirable alternative for future missions, is not presently proposed for experiment development, but the option must remain open for its inclusion into this experiment package at a later date.

As is shown in figure 1, the advanced oxygen-recovery subsystem experiment should be considered for integration into the operational system which could operate at reduce [illegible] during experiment performance. However, an acceptable alt[illegible] this approach might be to flight-test these components as se[illegible] oxygen-recovery units either within the space station or in an experiment module launched separately from the station. Another alternative would involve the flight test of experimental units with the same capacity as the operational oxygen-recovery subsystem. With this approach the experimental hardware would serve as an "operational backup" for the mission, adding redundancy to insure overall mission success. Mission constraints not now foreseen will undoubtedly be the deciding factors for choosing the appropriate alternative to this experiment.

For the purpose of defining this experiment in greater depth, a package consisting of the first and second options previously discussed was used, and the units involved were assumed to be of three-man capacity and integrated into the operational oxygen-recovery subsystem.

3. Operational Constraints:

This experiment package will require no specific orbital altitude or inclination, and it will not require stringent stabilization accuracy. However, a near-zero gravity environment is required.

4. Mode of Operation:

This experiment should be integrated into the operational oxygen recovery subsystem of the space station. The performance of this experiment will involve continuous operation of each integrated option for a period of at least thirty (30) days with periodic monitoring by the crew.

5. Crew Support:

Astronaut participation will be required to perform initial start-up and checkout procedures of the experimental equipment, to periodically monitor selected parameters of the experiment performance, and to shut down the experiment at the conclusion of the test. The astronaut will also be required to retrieve selected components of the experiment for return to earth for detailed examination. The astronaut's ability to perform routine service and make periodic adjustments to the experiment hardware will be demonstrated.

Other specific crew support information -

Monitor: Periodic - 3 per day, 30 days, 10 min. ea.

Manual Operations: Initial setup and checkout - 1.0 hr
Shut down - 15 min.
Tape retrieval (at end of 30 days) 15 min.
Service - 30 min. ea. 3 days

Crew Skills: Electrical/Mechanical Technician

6. Spacecraft Support:

The performance of this experiment requires the following spacecraft

su p

Weight: 1,050 pounds

Power: 650 watts (peak) - Solid Amine/Bosch/Vapor Feed Electrolysis
700 watts (peak) - Solid Amine/Solid Electrolyte

Size: 210 cu ft (total)

*Telemetry (if used): To be determined

*Return data: Components (Size to be determined)
Tape (To be determined)

*Note: It is estimated that approximately 80 separate measurements will be required to support the total experiment package. Specific frequency ranges, etc., can be determined only after a preliminary design of the experiment is completed.

7. Development Schedule: (See figures 2, 3, 4, 5 and 6)

8. Cost: Total Experiment 6.8 M COST $M, by FY

	70	71	72	73	74	75
SOLID ELECTROLYTE UNIT	.5	.4	.4	.5	.6	.1
SOLID AMINE UNIT	.3	.3	.4	.4	-	-
BOSCH UNIT	.3	.4	.3	-	-	-
VAPOR FEED ELECTROLYSIS	.2	.3	.2	.3	-	-
EXPERIMENT INTEGRATION	.1	.1	.1	.2	.2	.2

9. Spacecraft Interface:

This experiment package, as proposed, would require interface with the operational oxygen recovery subsystem of the space station. The concept suggests that the experiment be tied to the cabin air-ducting system at a point near the operational oxygen-recovery unit. Note should be given to the fact that additional radiator capacity may be required to absorb the heat loads generated by the experiment. The level of additional heat load has not been determined.

10. Test Program:

The flight test of the advanced integrated oxygen recovery subsystem will involve the operation of all elements of the experiment at design capacity for a period of thirty days. During this test, periodic crew monitoring of the subsystem operation and sc! .led maintenance of specific components of the subsystem will be required. Measurements of the subsystem performance will be made over the entire thirty-day test and the data will be recorded for return to earth. Typical measurements will include temperatures, pressures, flow rates, and oxygen purity.

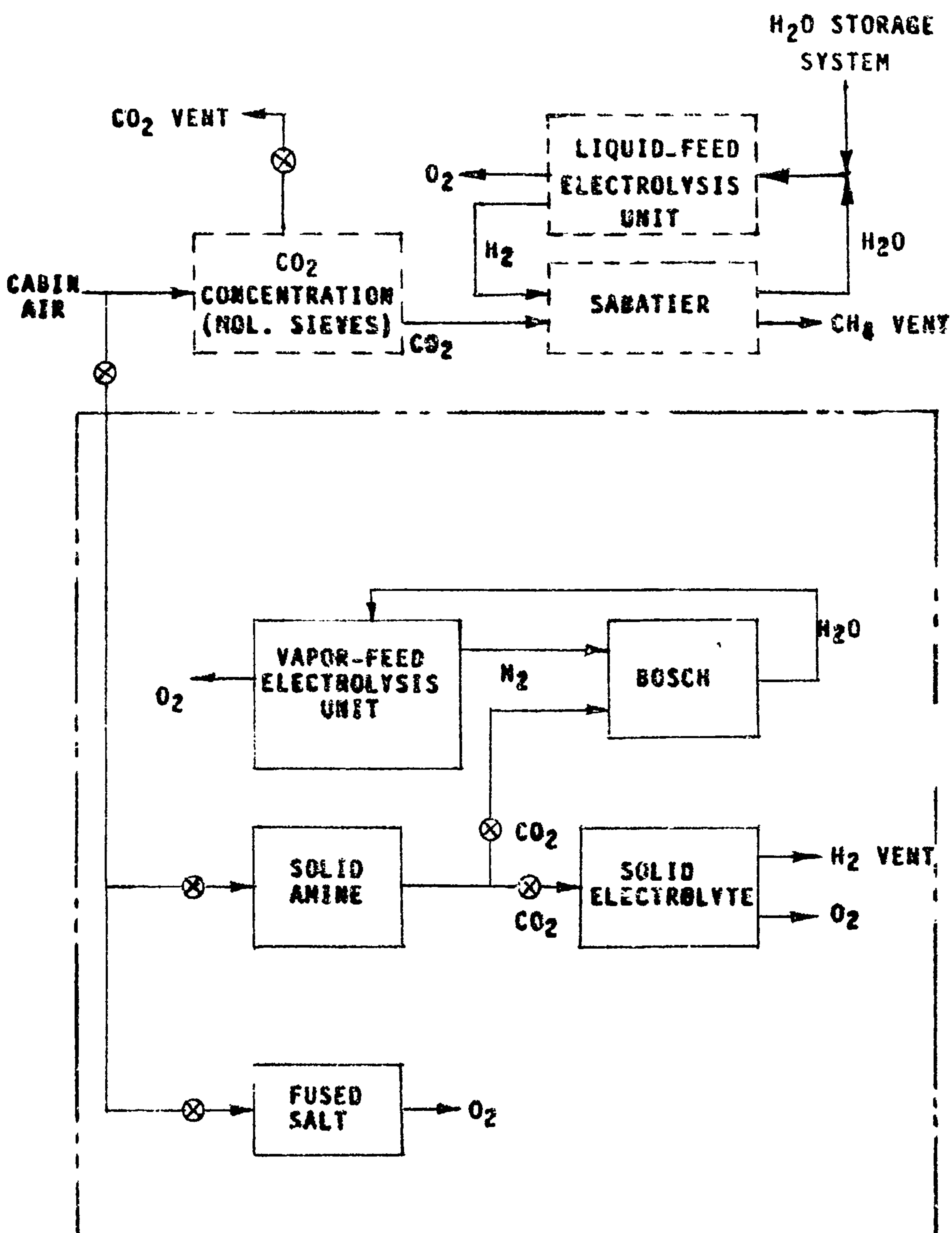


Figure 1.- Advanced Integrated O_2 Recovery Subsystem Experiment.

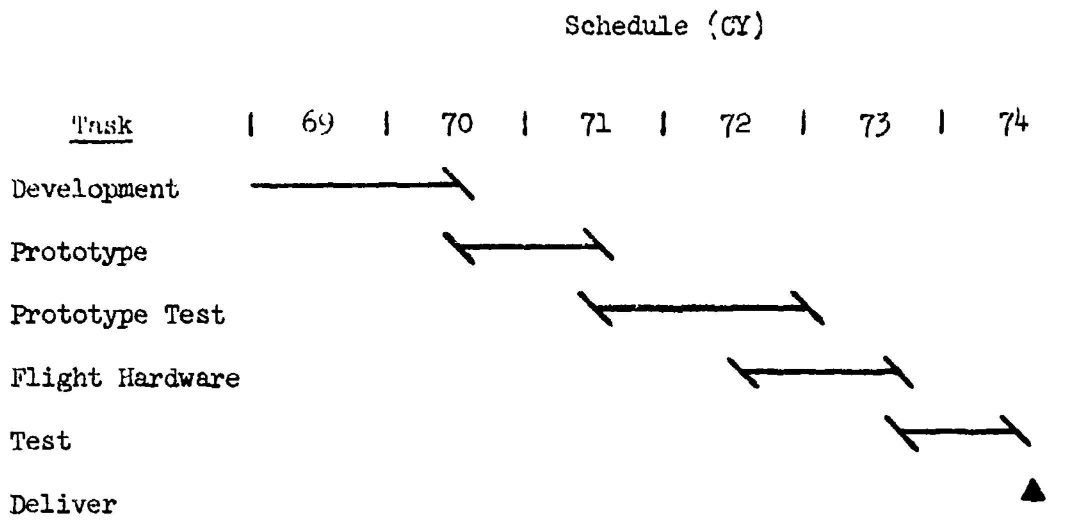


Figure 2.- Development schedule for solid electrolyte unit.

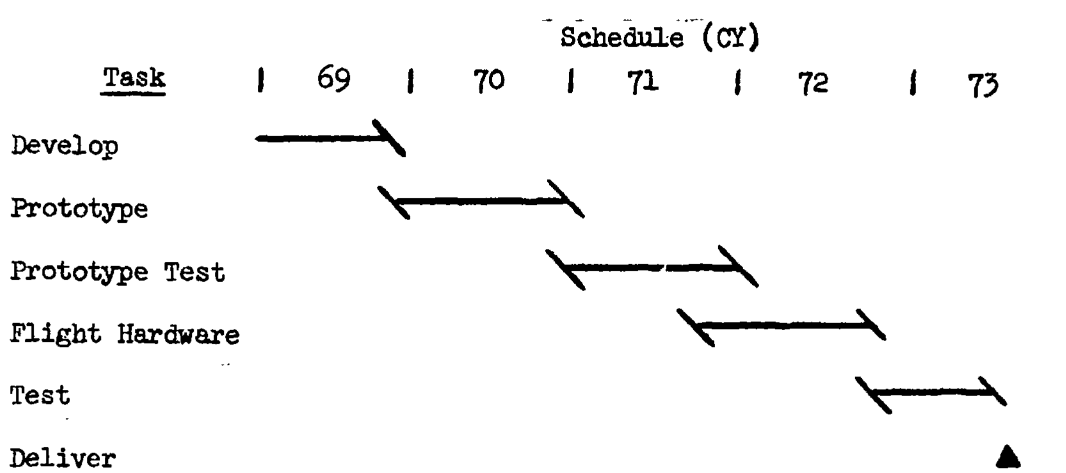


Figure 3.- Development schedule for solid amine unit.

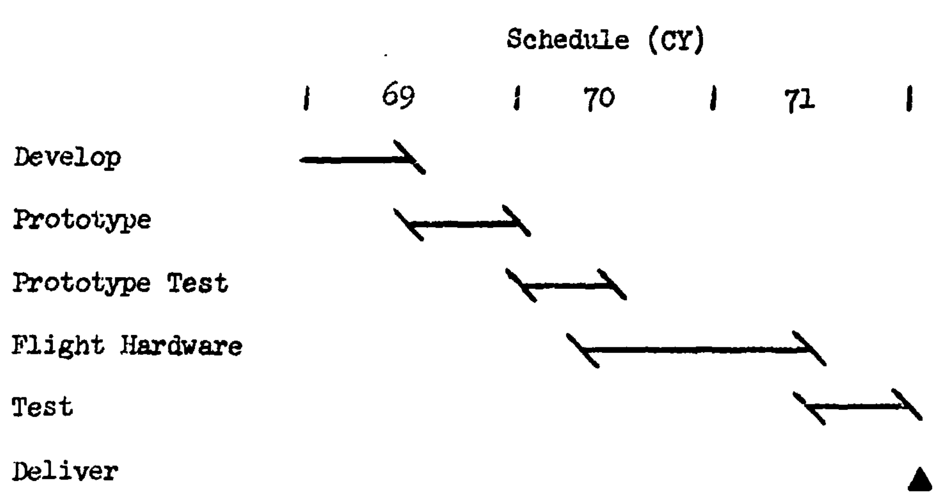


Figure 4.- Development schedule for Bosch unit.

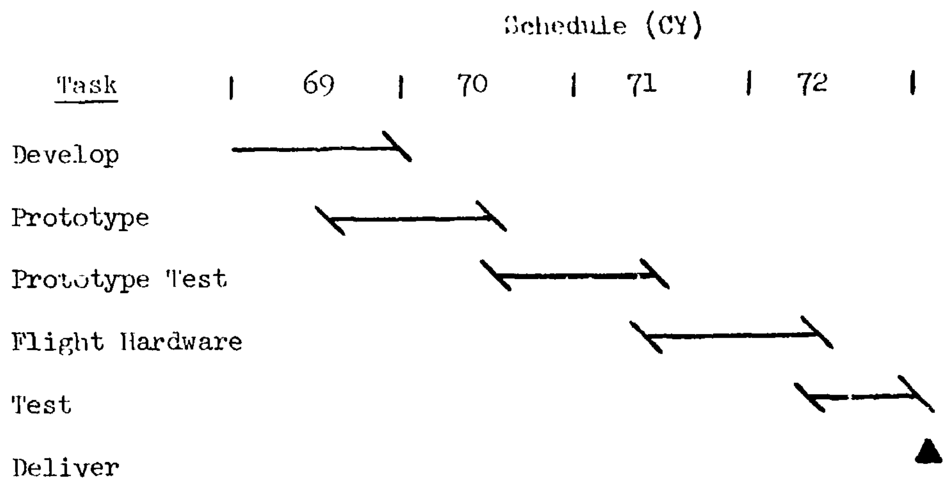


Figure 5.- Development schedule for vapor-feed electrolysis unit.

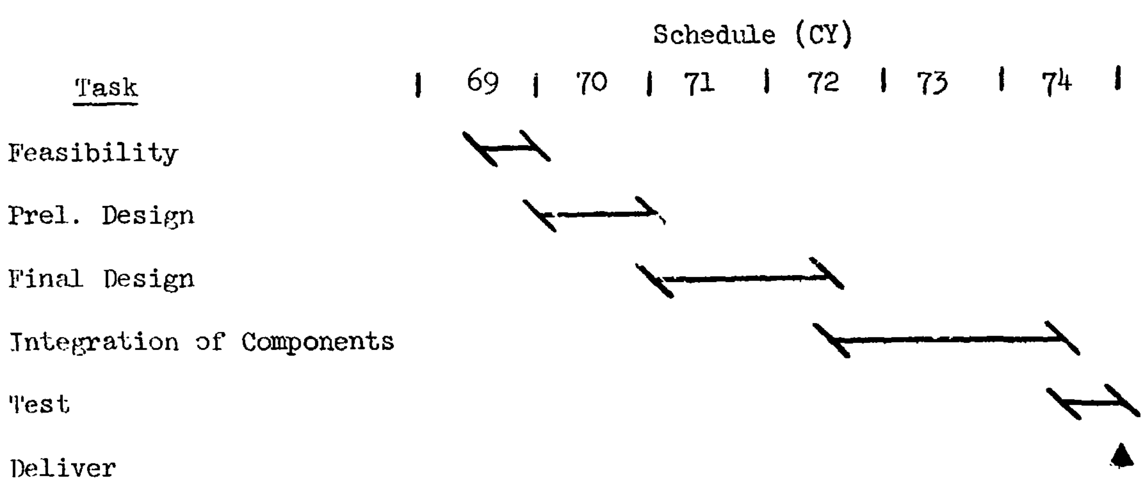


Figure 6.- Development schedule for experiment package.

EXPERIMENT/EVENT DATA SHEET IV C

TITLE: ADVANCED OXYGEN RECOVERY SUBSYSTEM

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	IV C-1 (604003)			
2	30			
3	30			
4	1			
5	0			
6	1			
7				
8	1			
9	3			
10	0.5			
11				
12				
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	24			
22	700			
23	0			
24				
25				
26	0			
27				
28				
29				
30	0			
31	0			
32				
33	0.5			
34				
35				
36				
37	-1			
38				
39				
40	0			

FUNCTIONAL PROGRAM ELEMENT V

1. Discipline: Advanced Technology

2. Program Element: Advanced Power Systems

3. Requirement:

A requirement exists to complete the technology program for Isotope-Brayton power systems to permit their use on future missions. Included requirements are:

(a) To develop safety criteria and procedures for applying large isotope sources to space vehicles.

(b) To establish in-flight startup, control, maintenance, and shutdown procedures for high-speed machinery for power generation.

(c) To conduct a systems evaluation of trade-off parameters, effectiveness of provided mechanisms, and effects of space environment on the large heat transfer surfaces required.

(d) To qualify the system for use in future long-term manned space flight.

4. Justification:

Advanced subsystems should be considered for experiments if their application can enhance the capability of the station to accomplish its intended mission and if their present development status precludes their selection as primary subsystems. The Isotope-Brayton power system meets the above requirements. The system, following evaluation and qualification, could remain in operation and be used as a backup or supplemental source of power. It could also serve as a replacement system for the anticipated baseline solar-array power system and permit retraction of the array from the deployed position. Significant operational advantages which would accrue to the station in the latter case would include:

(a) Freedom of space station orientation.

(b) Minimum collision hazard during EVA and rendezvous and docking operations.

(c) Minimum interference with both close-proximity experiments and tethered experiment modules.

(d) Minimum interference with multiple and conflicting fields-of-view requirements.

(e) Reduced resupply requirements.

(f) Increased power capability when operating in the earth's shadow.

(g) Potential for furnishing part of the total energy requirements from waste heat loops.

5. Component Experiments:

(a) Isotope-Brayton Power System

6. Description:

The experiment will consist of two complete Plutonium 238 Isotope-Brayton power systems launched in a cylindrical interstage attachment between the upper stage and the station. The power system will be launched in a nonoperating mode with provision made to dissipate the heat by a combination of evaporative and radiative cooling until orbit is achieved. Once in orbit, isotope heat will be directly radiated to space until the station has been manned, all primary systems have been checked out and placed in operation, and the experiment schedule permits implementation of this experiment. At this time the radiative-heat dump doors will be closed, the startup sequence initiated, and the system thoroughly checked and evaluated. Electrical power generated during the startup and evaluation phases will be dissipated in parasitic load radiators. Following this, the system is available to supply power to the station either in a supplemental or replacement mode.

If launch weight and overall length restraints preclude launch of the experiment with the station, numerous alternate design approaches are available. Separate launch of the Isotope-Brayton power system in a hard-docked logistics module should be considered as the preferred alternate.

7. Special Considerations:

The experiment does not impose constraints on the station for orbital parameters and does not establish stabilization or pointing requirements. It does not require support from the station for power except for that required in instrumentation. Consideration must be given in the design phases, however, to optimize the station with respect to integrated radiator requirements, considering both the power system and the environmental control/life support system. Major importance must be placed throughout the design in meeting the safety requirements associated with launch and recovery of large isotope sources, and integrated crew dose rates must consider the contribution of both natural sources and the power system.

BIBLIOGRAPHY

1. Anon: Study of Separately Launched Multiuse Space Electrical Power System. Report GESP-7007-1 (NAS9-7444), General Electric Co., October 1968, Vol. I - Summary.

2. The Needs and Requirements for a Manned Space Station. Vol. VI: Long-Term Flight. Prepared by Space Station Requirements Steering Committee. November 15, 1966. NASA, Langley Research Center.

3. Anon: Preliminary Design of a Pu 238 Isotope-Brayton Cycle Power System for MORL (NAS1-4479). Douglas Aircraft Corporation, September 1965.
   Report SM 48832 - Vol. I - Technical Summary (Confidential-Restricted Data).
   Report SM 48834 - Vol. III - Preliminary Program Plan (Confidential-Restricted Data).
   Report SM 48835 - VOl. IV - Technical Appendix - Book 1 - Nuclear System (Confidential-Restricted Data).

EXPERIMENT DATA SHEET VA

Isotope-Brayton Power System

1. Specific Objective:

The objective of this experiment is to complete the technology development required to permit the selection of an Isotope-Brayton power system for those future missions where its applicable power range and inherent features are advantageous. It is a further objective to furnish an experimental system which can, upon successful operational demonstration, enhance the capability of the station either by providing alternative modes of operation or serving as a supplemental source of power. Specific objectives of the experiment are:

(a) To develop safety criteria and procedures for applying large isotope sources to space vehicles.

(b) To establish in-flight startup, control, maintenance, and shutdown procedures for high-speed rotational machinery for power generation.

(c) To conduct a systems evaluation of trade-off parameters, effectiveness of provided mechanisms, effects of space environment on large heat transfer surfaces.

(d) To qualify the system for use in future long-term manned space flight.

2. General Description:

As proposed, the experiment will be installed in a cylindrical module launched with the station as an interstage attachment between the upper stage and the station (fig. 1). Length of the module is dependent on what portion of the station is available for use as a radiator surface. The total length required for radiator surface is approximately 25 ft assuming a station diameter of 22 ft. The minimum length interstage structure to house the components is 7 ft. Total length is based on radiator requirements of approximately 1300 sq ft which is appropriate to a 15-kW electric (kWE) system. Two Isotope-Brayton engines would be installed in the interstage structure, each rated at 7.5 kWE. Each engine would consist of the following components:

Isotope heat dump doors in the structure.

Isotope heat source complete with protective random reentry heat shield and radiation shield.

Brayton-cycle gas loop.

Gas management and startup system.

Parasitic load resistors.

Electrical controls and protective devices.

Power conditioning equipment.

Redundant radiator loops.

The total isotope inventory would be installed on the station prior to launch and ground cooling provided to remove the heat. A combination of evaporative and radiative cooling would be employed during the ascent portion of flight and radiative cooling would be used once orbit was obtained. Immediate operation of the system is not required and initial operation may be delayed for any period of time required. Sequentially, each engine would be placed on-line by closing the heat dump door, raising the temperature of the heat source heat exchanger, and activating the automatic controls for startup. Electrical energy generated would be dissipated in the parasitic load resistors until the engine was thoroughly tested as a subsystem and all pertinent operating parameters established. Subsequent to this, power generated would be used to power other experiments or to supplement space station power through tie breakers.

Numerous alternative approaches are available in defining the experiment. The Isotope-Brayton engine could be launched as part of a logistics vehicle which would rendezvous with and rigidly dock to the station. The experiment could be designed around a single engine with as little as 3 kWE output, or output of the two engines could be increased to 20 kWE. Consideration could be given also to launching the isotope separately on logistics vehicles and installing in orbit. Recovery of the isotope upon mission completion could be included in the manned recovery vehicle in lieu of providing the integral reentry vehicle. No attempt has been made to define the alternatives available.

3. Operation Constraints:

The experiment does not impose constraints on the station with respect to orbital altitude, inclination, or stabilization, and does not impose a requirement for pointing. Successful transition of the experiment to operational status may in fact relieve the requirements imposed on the station by other subsystems. Consideration must be given, however, to stowage of external modules adjacent to the space radiator operating at temperatures up to 275° F.

4. Mode of Operation:

The experiment as proposed will be an integral part of the station. Initiation of the experiment will require a combination of manned participation and automatic sequencing to start the machinery and evaluate its performance. Once operation has been initiated, the experiment is capable of continuous operation for long periods of time in a power-producing mode.

5. Crew Support:

Participation of the crew will be required in placing the machinery on the line, evaluating performance and automatic control sequencing, and thereafter periodically confirming proper operation. Use of the system to power real loads will require manual switching of the proper electrical distribution system. Anticipated time to achieve stable initial operation is 4 hours. Initial evaluation of performance would require approximately 15 minutes per hour for a period of several days, decreasing gradually to 5 minutes per hour for a period of several weeks. While thorough familiarization of an engineer-astronaut with the system would be a requirement, no special training problems are anticipated.

6. Spacecraft Support:

The experiment will impose a weight penalty of 7500-9000 lb on the station and will require a minimum length of 7 feet for a 22-foot diameter module. Additional length, however, is required to provide the 1300 sq ft radiator surface area. The total length requirement of 25 feet can use any combination of prime station length and experiment extension length. The experiment does not require power from the station. Data storage and transmission facilities for approximately 350 engineering measurements taken three times per orbit should be provided.

7. Development Schedule:

The advanced technology program being pursued by NASA and AEC in the area of Brayton-cycle components and engines, reentry vehicles, isotope fuel forms, and encapsulation techniques, etc., will culminate in a ground system test in 1972. Power system development should be considered to be complete through phase C at this time. Phase D for the power system, however, can only be accomplished as part of an integrated system design, beginning with the phase B effort for the station. Phase D for the power system is then synonymous with the phase D station schedule.

8. Cost:

Estimated total cost to flight is $200,000,000, including purchase of 85 kilowatts thermal (kWT)(2 flight units and 1 backup) of Plutonium 238 at $500 per watt. Since the Plutonium 238 constitutes a national resource and since safety considerations dictate its safe return to earth and recovery, it is considered more proper to cost the isotope on a rental basis. For a 10-year mission, cost should be based on use of 1/9 the inventory plus a fee necessary for reprocessing and recovering the isotope. Cost of isotope is then reduced from $42,500,000 to approximately $10,000,000. Estimated expenditure rate to produce a flight system is $30-40,000,000 per year beginning in 1971.

9. Spacecraft Interface:

The experiment imposes a major interface problem on the station with respect to optimization of the radiator surface area. It also imposes an interface requirement to consider nuclear safety throughout design of the station.

10. Test Program:

The flight test program will be divided into three basic phases. Measurements taken will include temperatures, pressures, power, voltage, and current. The proposed phases are as follows:

(a) Initial startup.- Isotope doors will be closed to allow the heat source heat exchanger to come up to temperature. Automatic startup sequence will be initiated and closely monitored until the system reaches stable operating conditions.

(b) Early operational evaluation.- The system will be monitored periodically to insure proper operation. Switching of dummy electrical and thermal loads will be initiated to insure proper operation of automatic controls.

(c) Normal operational evaluation.- The system will be monitored periodically to insure proper operation. Switching of real electrical and thermal loads will be initiated under manual control of the astronaut.

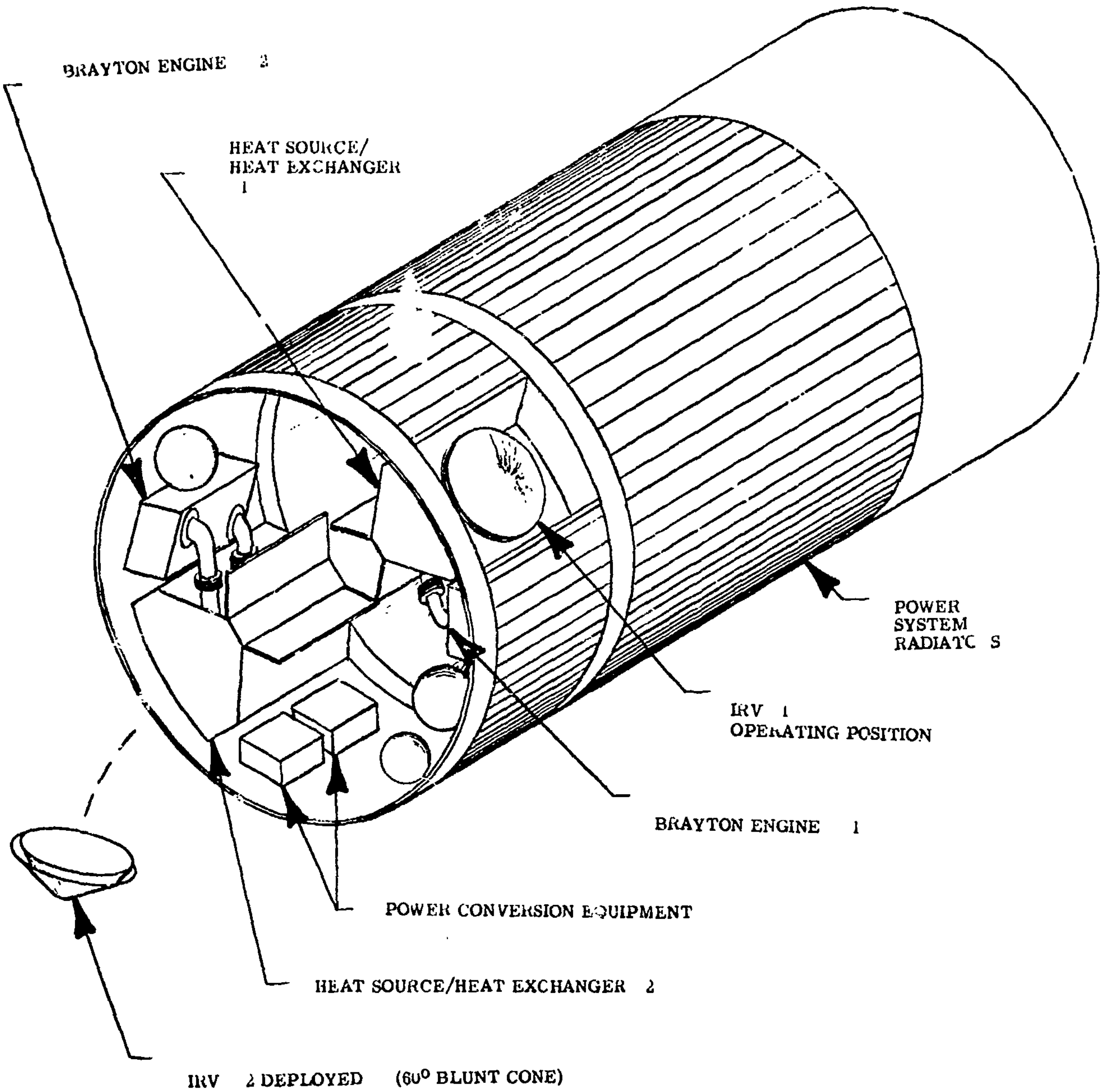


Figure 1.- Isotope-Brayton power system.

EXPERIMENT/EVENT DATA SHEET V A

T181

TITLE: ISOTOPE-BRAYTON POWER SYSTEM

ITEM No.	PHASE: 1 INITIAL START-UP AND EVALUATION	PHASE: 2 EARLY OPERATIONAL EVALUATION	PHASE: 3 NORMAL OPERATIONAL EVALUATION	PHASE:
1	V A-1 (605001)	V A-2 (605011)	V A-3 (605021)	
2	1	6	MISSION BALANCE	
3	1	6	MISSION BALANCE	
4	1	1	1	
5	0	0	0	
6	1			
7				
8	2	2	1	
9	6	6	3	
10	4	3	2	
11	4	4		
12	4	3		
13				
14				
15				
16				
17				
18	0	0	0	
19	0	0	0	
20	0	0	0	
21	0	0	0	
22	0	0	0	
23	0	0	0	
24				
25				
26	0	0	0	
27		605001	605011	
28				
29				
30	0	0	0	
31	1	0.5	0.25	
32	0	0	0	
33				
34				
35				
36				
37	1	1	1	
38				
39				
40		2		

FUNCTIONAL PROGRAM ELEMENT VI

1. Discipline: Advanced Technology

2. Program Element: Advanced Orbital EVA Systems

3. Requirement:

   (a) Provide data for assessing the ability and efficiency of man in using assistive maneuvering systems in performing extravehicular activities (EVA).

   (b) Provide data for determining the feasibility of using unmanned, remotely controlled, maneuvering and manipulator units for performing EVA.

4. Justification:

Future space missions will utilize experiment modules located remotely from an orbiting station. These modules will require support to assure operational status over extended periods of time. For small modules, techniques must be developed which can be used for retrieving the modules for onboard repair, component replacement,and general maintenance. The module must then be redeployed to the proper location. For modules too large to be taken aboard the space station, repair and maintenance operations will have to be performed while the module is at its deployed position. To perform these previously-described functions, orbital EVA systems, both manned and unmanned, must be developed.

In addition to the EVA required to assure the proper functioning of the scientific modules, extravehicular techniques will have to be developed to assure a rescue capability.

(a) Only a limited amount of data are available on man's capability to perform EVA and on the effectiveness of various maneuvering systems. Therefore, considerable extravehicular experience is required to provide data for assessing man's ability and efficiency in performing various space activities with and without assistive devices. The devices considered are Controlled Tether/Remote Maneuvering Unit (RMU) systems and a Manned Space Shuttle.

(b) Although master/slave manipulators have been used on earth to perform various functions, space applications of manipulators have been limited to the simple Surveyor Moon-Digger. Space operational data are required in order to determine the feasibility of using remotely-controlled unmanned maneuvering units with manipulators for performing the anticipated extrevehicular activities.

5. Component Experiments:

(a) Controlled Tether/RMU System

(b) Remote Maneuvering/Manipulator System

(c) Space Shuttle

6. Description:

The areas of interest that need investigation to provide for future EVA missions include (1) the region near the station ($\leq$ 200 ft) where retrieval of an astronaut or equipment is required, (2) remote regions (< 5 miles) where unmanned retrieval or manipulation of modules is desired, (3) remote regions (< 5 miles) which require the transfer of astronauts for repair, monitoring, etc., of the module.

The following experiments are proposed to develop the EVA systems required to cover these areas of interest.

(a) Controlled tether/RMU system.- The controlled tether/RMU experimental system consists of a tether reel-in system, a full six-degree-of-freedom RMU with closed-circuit TV, a tether and RMU control console, and the supporting equipment such as sensors, refueling station, etc. The system can be included in the initial space station launch or in a resupply module. The experiment will consist of investigating various aspects of controlled-tether retrieval and to develop retrieval techniques utilizing a controllable tether for both manned and unmanned situations. The area of particular interest includes distances up to 200 feet from the space station. The tests will first utilize the RMU as the retrieved object until the techniques and systems are fully tested. Then an astronaut will be used to determine how he effects the retrieval techniques developed. Various preliminary aspects of controlled-tether retrieval and RMU's have already been studied.

(b) Remote maneuveuring/manipulator system.- The system proposed is similar to the concept studied by the General Electric Company. It consists of an electrical bilateral master/slave manipulator. The slave manipulator is integrated with a remotely-controlled maneuvering unit. The remotely-controlled slave will have three docking arms and two working arms. It can be launched with the space station but it is anticipated that it will be launched on one of the logistic missions. The slave manipulator will be used to perform a number of extravehicular tasks such as module deployment, component replacement, and the maneuvering and joining of several orbiting modules or packages to simulate orbital structure assembly. Times to perform various tasks, power consumptions, and astronaut evaluation of the system will be recorded to provide data for development of an optimum EVA system.

(c) Manned space shuttle.- The shuttle system proposed for the experiment consists of a simple tubular framework with thrusters for translation and attitude control, two propellant tanks, a three-axis attitude controller, an onboard life support system,and cargo carrier. The translation jets for the shuttle are in the front section and this section is hinged with respect to the back (pilot and cargo) section. This arrangement provides a tractor-type operation for forward translation and a source of control over misalinement during thrusting. The shuttle can be launched with the space station or separately. Initial assembly will occur in the hangar. The experiment program will consist of checkout of systems and developing of maneuvering techniques in varying degrees of freedom up to the final full systems test to a remote object approximately a mile away while carrying cargo. The system,once developed,can be utilized to support remote modules with monitoring, resupply, repair, and maintenance to provide astronaut rescue and satellite retrieval capability.

7. Special Considerations:

Provisions should be incorporated in station design for storage and handling of toxic fuels, such as hydrazine.

BIBLIOGRAPHY

1. Straly, Warren H.; and Adlhock, Robert W.: Study of the Retrieval of an Astronaut from an Extravehicular Assignment. NASA CR-185, 1965.

2. Straly, Warren H.; and Adlhock, Robert W.: An Investigation of Controlled Tethering in Space. NASA CR-69392, 1965.

3. Beasley, Gary P.; and Thomas, David F., Jr.: Extravehicular Maneuvering In Space Maintenance and Extravehicular Activities. NASA and USAF, Orlando, Florida, 1966.

4. Anon: Proceedings of Second National Conference on Space Maintenance and Extravehicular Activities. NASA-Wright Patterson AFB, Las Vegas, Nevada, August 6-8, 1968.

5. Iribe, P.; and Lieske, J. A.: Study of Extravehicular Protection and Operations. Report No. TG-841, Applied Physics Laboratory, Johns Hopkins University, July 1966.

6. Anon: Definition of Experiment Program in Space Operations, Techniques and Subsystems for an Independent Manned Manipulator. Vol. II, Report No. 00.859 (contract NAS8-20316), Ling-Temco-Vought, Inc., November 1966.

7. Long, Edward R.; Pennington, Jack E.; and Deal, Perry L.: Remote Pilot-Controlled Docking With Television. NASA TN D-3044, October 1965.

8. Adlhock, Robert W.; Bell, Michael, J.: Articulated Two-Body Astronaut Propulsion System. Report No. S-474, Marquardt Corporation, August 1965.

9. Anon: Personal Locomotion Attitude Control Equipment for Extravehicular Space Activities. Report No. HSER-2719, Hamilton Standard Div., of United Aircraft Corp., May 2, 1963.

10. Garnett, Robert J.; and Walker, Roger C.: Prephase I Study for the MOL P-6 Extravehicular Activity Experiment. Vol. I of Air Force Technical Report No. AFAPL-TR-64-145 by Ling-Temco Vought Corp., December 1964.

EXPERIMENT DATA SHEET VIA

Controlled Tether/RMU System

1. Specific Objective:

The objective of this experiment is to investigate various aspects of controlled-tether retrieval and to develop retrieval techniques utilizing a controllable tether for manned and unmanned situations. The techniques developed can be used on future space missions for both rescue and normal operations.

2. General Description:

The experiment as proposed would consist of two main phases. The first phase is to investigate and develop tether retrieval techniques over a range of initial velocities, distances, tensions, etc., for various control laws (constant velocity, tension, etc.). This phase will be accomplished with and without thrust or angular momentum dumping assists to remove tangential velocity. The first phase would use a remote maneuvering unit (RMU) for the retrieved object. The second phase would use an astronaut as the retrieved object to verify the techniques and control laws and to determine if man's presence enhances the retrieval techniques.

The equipment required to support this experiment consists of the following major components.

(a) Tether System Control Console (fig. 1)

(1) Television monitor and camera control unit

(2) Tether and RMU system status boards

(3) RMU attitude and thrust controllers

(4) Tether state instrumentation (velocity, tension, etc.)

(5) Tether reel-in controller

(6) Trajectory computer

(b) Tether Reel-In Mechanism and Tether (fig. 2)

(c) Tether Attachment Devices, Boom, and State Sensors (angle, reel-in, speed, etc.)

(d) Momentum Module Assembly and Tether

(e) Remote Maneuvering Unit (RMU) (fig. 3)

(f) RMU Refueling System (fig. 4)

A schematic showing relative location of each component is given in figure 5.

3. Operational Constraints:

During retrieval experiments the space station will be in a zero-"g" mode and will not be allowed to experience any large perturbations. The experiment will be conducted in daylight.

4. Mode of Operation:

The experiment will be conducted with the tether reel-in apparatus connected to the space station and will be controlled from the tether system control console during retrieval. The experiments will be conducted on an intermittent basis.

5. Crew Support:

During the initial studies, using an RMU as the retrieved object, two astronauts will be required for 2 hours during RMU setup, launch, and retrieval for each RMU run. In addition, one astronaut will be required to monitor and control the experiment for 2 hours per run. The RMU phase will require 48 manhours to complete the eight unmanned runs. Verification of the initial studies will use an astronaut as the retrieved object and will use two astronauts during the entire phase. This includes 1 hour for EVA suitup, equipment setup and egress, 2 hours for each test run and 2 hours for final ingress, desuiting and debriefing. Phase II will require 40 manhours to finish four manned runs.

No special crew skills are required. However, prelaunch training on RMU and tether systems, and EVA are necessary.

6. Spacecraft Support:

The performance of this experiment requires the following spacecraft support.

Total system weight: 625 lb

Size: 20 cu ft

Peak power: 600 watts

7. Development Schedule:

(a) System Design and Development Phase - To be completed 16 months after go ahead.

(b) Flight Simulation Test Phase - To be completed 18 months after go ahead.

(c) Reliability and Qualification Test Phase - To be completed 24 months after go ahead.

(d) Flight Hardware Available - To be completed 36 months after go ahead.

8. Cost:

Total Experiment $1.6M

System design and development phase	$0.3M
Flight simulation test phase	0.3M
Reliability and qualification test phase	0.15M
Flight hardware available	0.85M

9. Spacecraft Interface:

(a) The tether system control console would be installed inside the shirt-sleeve environment portion of the space station. Power and communication will be provided by the space station.

(b) The RMU and the RMU refueling system would be located in an area near an EVA air lock. This area does not necessarily require a shirt-sleeve environment. Power will be required from the space station.

(c) Tether sensors and the tether reel-in mechanism can be located on the space station skin or mounted under the skin. These systems should be located adjacent to the EVA airlock. Any power required would be supplied from the space station.

(d) The momentum module and tether attachment devices, booms, and RMU launch aids would be stowed in the station.

10. Test Program:

The test program will consist of investigating various aspects of controlled tether retrievals and to develop retrieval techniques utilizing a controllable tether for both manned and unmanned situations. The area of particular interest includes distances up to 200 feet from the space station. The tests will first utilize the RMU as the retrieved object until the techniques and systems are fully tested. Then an astronaut will be used as the retrieved object to determine how he effects the retrieval techniques developed. The controlled tethering system, once developed, can be used on future missions for both astronaut rescue and operational maneuvering.

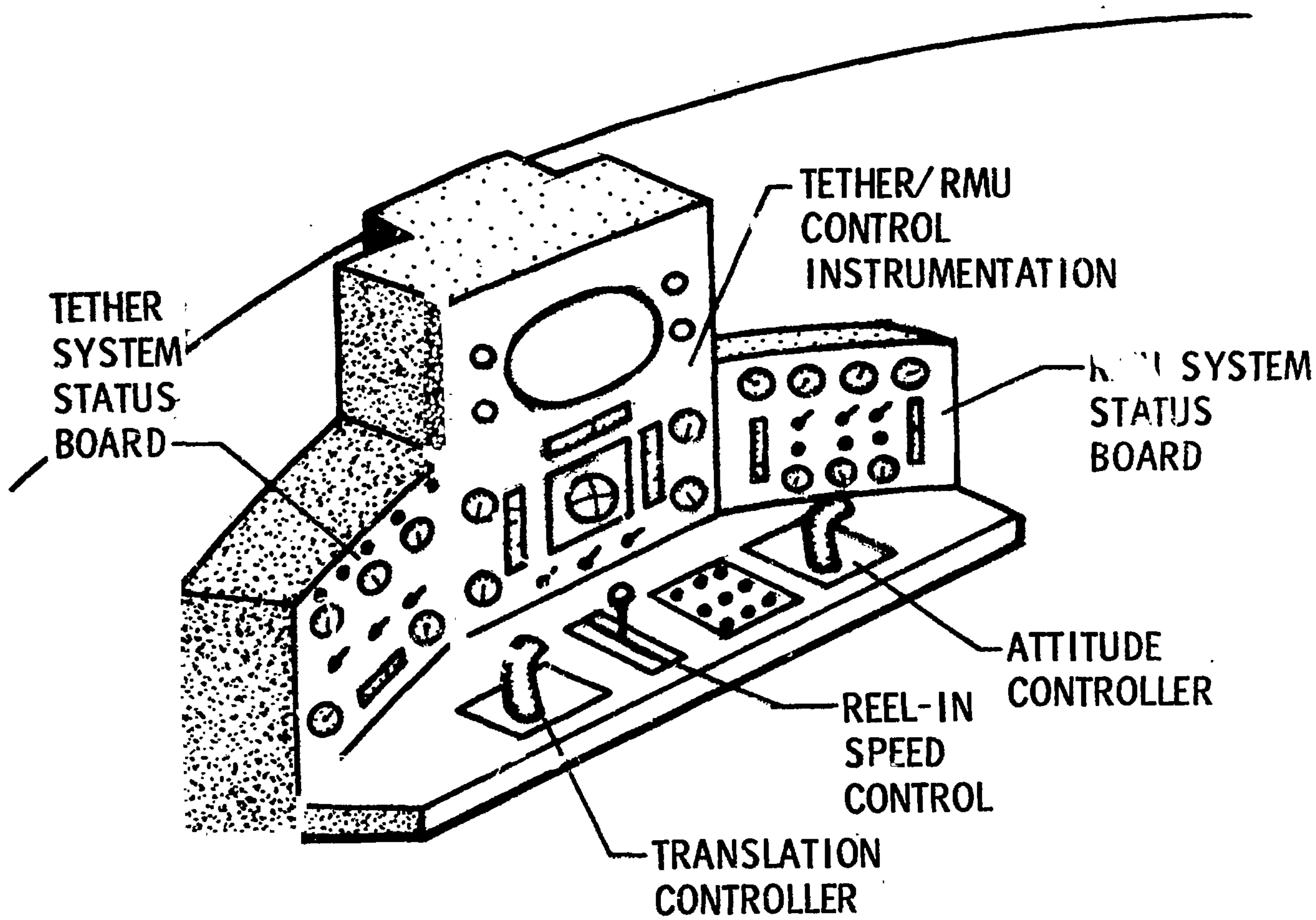


Figure 1.- Tether system control console.

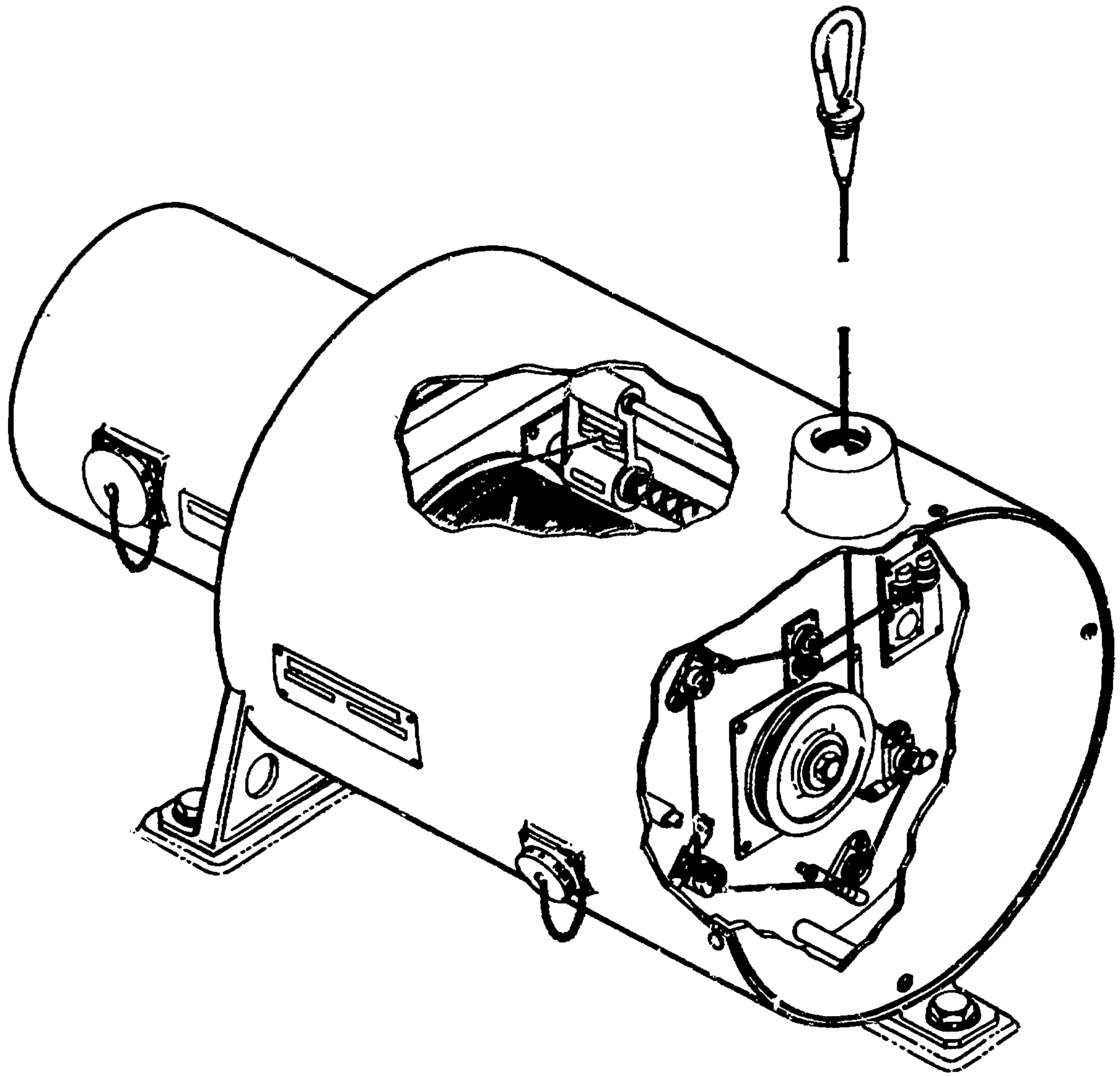


Figure 2.- Tether reel-in mechanism.

T192

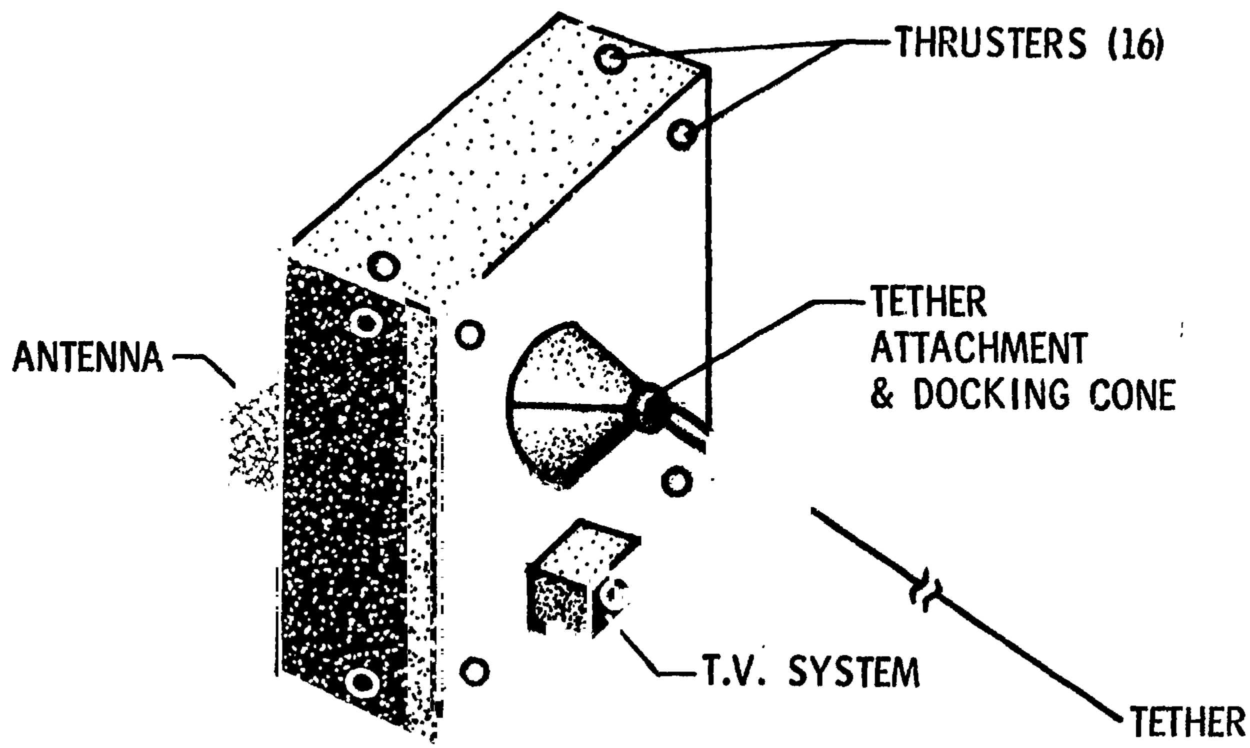


Figure 3.- Remote maneuvering unit.

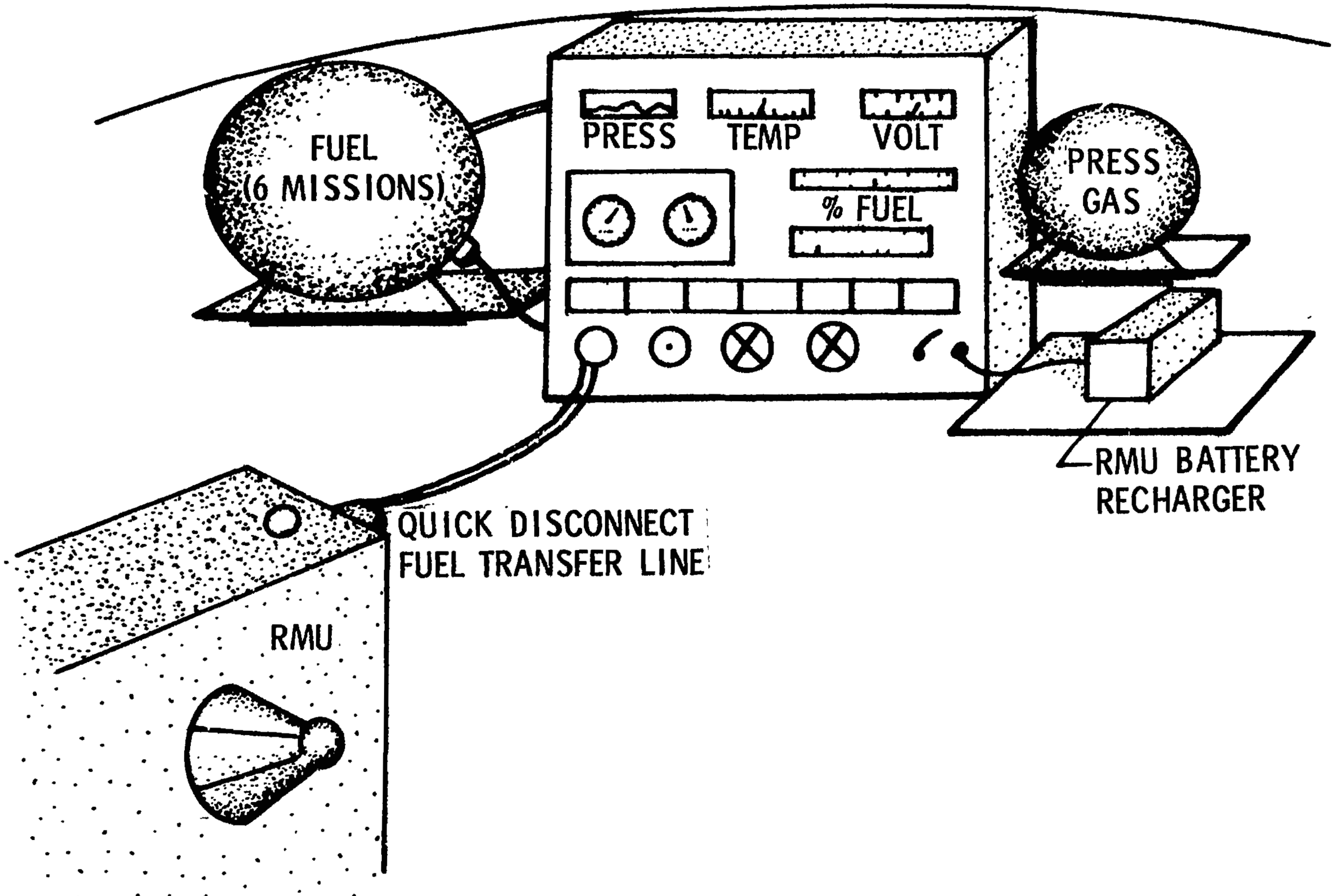


Figure 4.- RMU refueling system.

T194

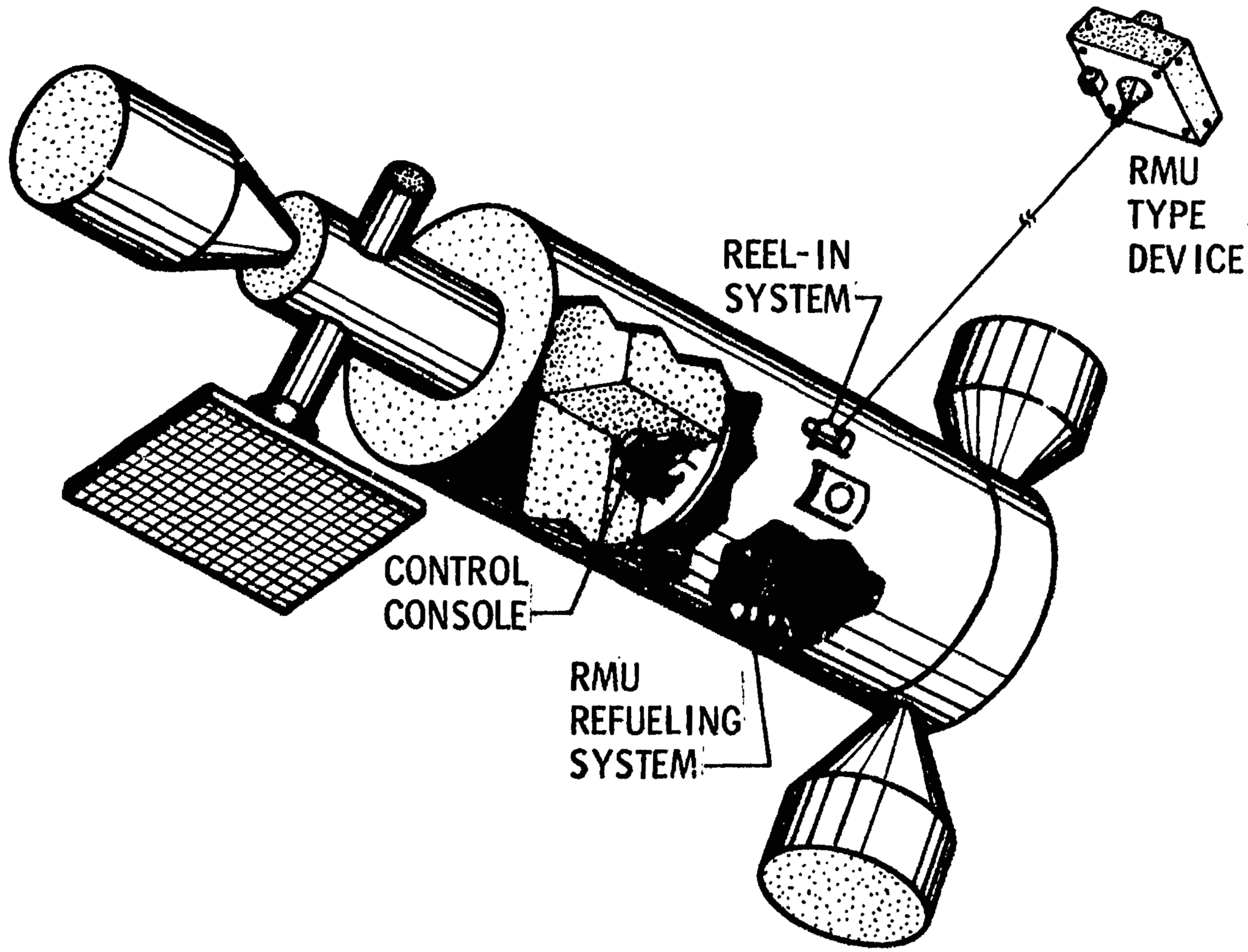


Figure 5.- Controlled tether experiment.

T196

EXPERIMENT/EVENT DATA SHEET VI A

TITLE: CONTROLLED TETHER/RMU EXPERIMENT

ITEM No.	PHASE: 1 RMU/TETHER EXPERIMENTS	PHASE: 2 ASTRONAUT/TETHER EXPERIMENTS	PHASE:	PHASE:
1	VI A-1 (606001)	VI A-2 (606011)		
2	8	4		
3	8	4		
4	1	1		
5	0	0		
6	1	1		
7				
8	2	2		
9	16	16		
10	4	5		
11	16	16		
12	2	5		
13				
14				
15				
16				
17				
18	200	200		
19	0	0		
20	3	4		
21	3	4		
22	300	300		
23	0	0		
24	625			
25	20			
26				
27		606001		
28				
29				
30				
31	2	3		
32	3	3		
33	0	0		
34				
35				
36				
37	-1	-1		
38				
39				
40	0	2		

EXPERIMENT DATA SHEET VIB

Remote Maneuvering/Manipulator System

1. Specific Objective:

The objective of this investigation is to evaluate the effectiveness of unmanned remotely-controlled, manipulator-equipped, maneuvering units for performing orbital extravehicular activities (EVA).

2. General Description:

The slave manipulator unit controlled by radio from the space station will be used to deploy and orient modules of various sizes at different locations relative to the station. The range of the unit will be about 6,000-7,000 ft. The ability to redock to the modules and remove and replace components will be evaluated. The slave manipulator will also be used to join two or more of the packages to simulate assembly of structures in space.

An electrical bilateral master/slave manipulator system will be used in the experiment. Figure 1 illustrates the basic concepts of the system. The slave manipulator will have three docking arms and two working arms. The slave manipulator will be provided with a system for illuminating the work site, a head-directed TV camera, and force and position feedback systems, all controlled by the master manipulator located on the space station. In addition, the slave manipulator will have a maneuvering-and attitude-control system with an inertial platform, plus an RF communications link, electrical power, and thermal control systems. A schematic of the slave manipulator is shown in figure 2.

3. Operational Constraints:

The space station motions will have to be kept at a minimum during redocking of the slave manipulator.

4. Mode of Operation:

The slave manipulator will be launched from the space station, then maneuvered and docked at various work sites by an astronaut located at a master control console on the space station. The astronaut will use master manipulators to control the slave manipulators in performing the work required. Unmanned EVA as long as 4 hours is anticipated, however, this need not be continuous since the slave manipulator may be positioned in space or docked at a work site in a dormant/standby mode if necessary.

5. Crew Support:

The crew will be required to prepare the slave manipulator for launch. This will include fueling and checkout of the various systems. An astronaut will be required to perform the launch, control the activities,and recover the slave manipulator. Experience in fuel handling,manipulator operation, and knowledge of electronics will be required. Approximately 112 manhours will be required to complete this experiment.

6. Spacecraft Support:

A master control station will be needed on the spacecraft to control the slave manipulator operations. The guidance and attitude control system and power supply for the master control station may be integrated with the system used for controlling modules launched on unmanned logistics missions.

In addition, master manipulators will be required at the control station. The minimum effective working volume for two arms is about 4 cu ft, however, the ideal work volume for a standing operator is about 20 cu ft.

The master manipulator weight, excluding the data link and heat rejection system, is approximately 100 lb. Average power required is about 40 watts.

The space station will have to provide a storage and maintenance area for these slave manipulators. The slave manipulators will occupy a volume of 40 cu ft and will weigh approximately 600 lb. Slave manipulator propellant and dc power resupply capability must be provided by the space station.

7. Development Schedule:

A space qualified master/slave manipulator system will have to be developed and integrated with a remote-control maneuvering system. From 5 to 7 years from go ahead will be required to provide an operational integrated system.

8. Cost:

Total Experiment $8.0M

Years from go ahead	Advanced studies	Prototype fabrication	Fabrication and qualification of final system	Cost by year
1	1.0 M			1.0 M
2	1.0 M	0.5 M		1.5 M
3		1.5 M		1.5 M
4		2.0 M	0.3 M	2.3 M
5			1.7 M	1.7 M

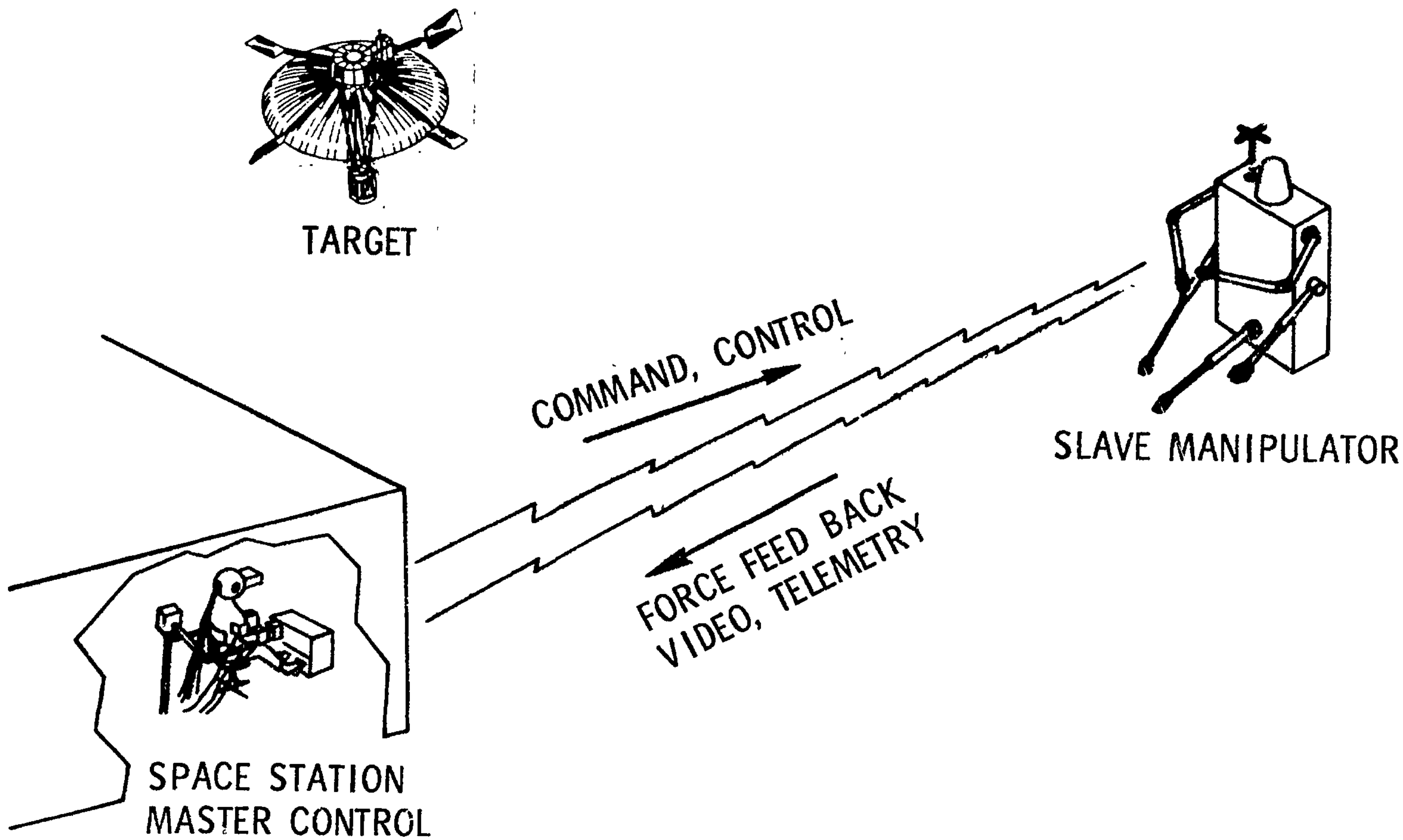
9. Spacecraft Interface:

Spacecraft electrical power supply will be required to provide electrical power to the master control station.

It is possible that the guidance and control system used for the rendezvous and docking control of unmanned logistic modules may be used to perform the guidance and control of the maneuvering manipulator unit.

10. Test Program:

The slave manipulator will be used to perform a number of extravehicular tasks such as module deployment, component replacement, and the maneuvering and joining of several orbiting modules or packages to simulate orbital structure assembly. The time to perform various tasks, power consumption, and astronaut evaluation of the system will be recorded to provide data for the development of an optimum EVA system.



T201

Figure 1.- Remote maneuvering/manipulator system concept.

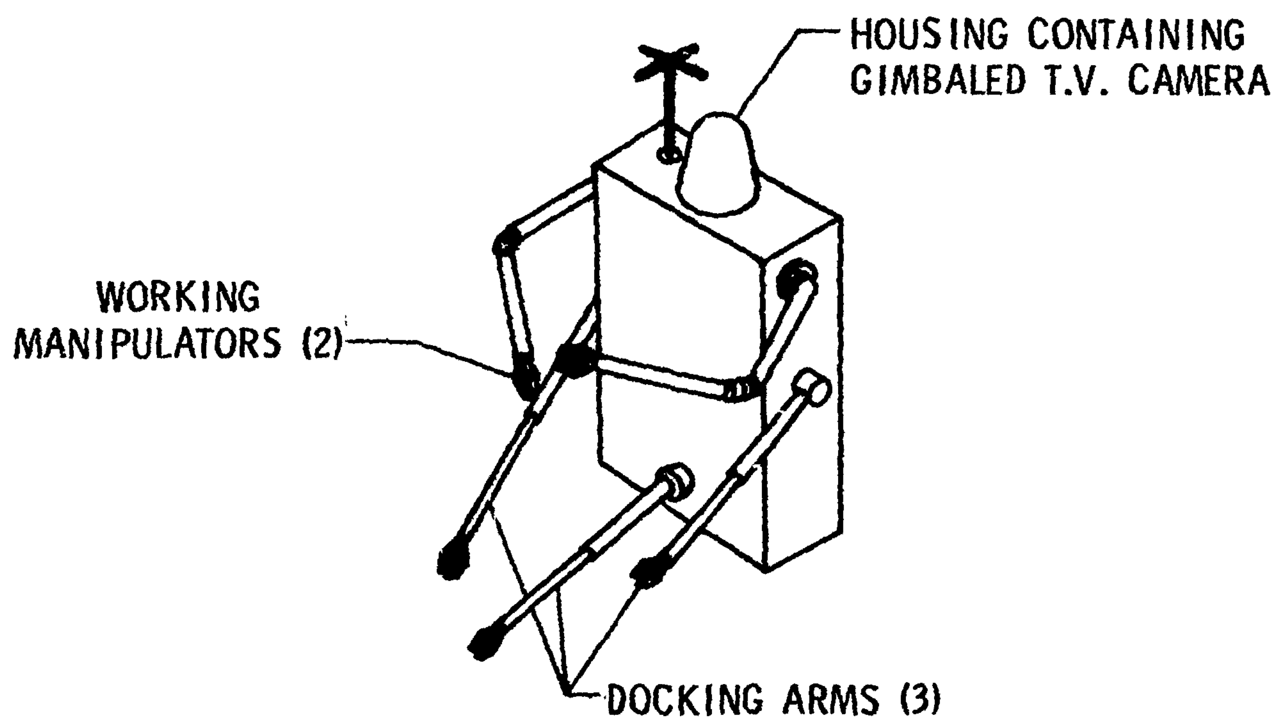


Figure 2.- Schematic of a maneuvering remotely-controlled slave manipulator.

E-202

EXPERIMENT/EVENT DATA SHEET VI B

T203

TITLE: REMOTE MANEUVERING/MANIPULATOR SYSTEM EXPERIMENTS

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	VI B-1 (606002)			
2	14			
3	14			
4	1			
5	0			
6	1			
7				
8	2			
9	16			
10	4			
11	16			
12	4			
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	10			
22	800			
23	40			
24	700			
25	40			
26	0			
27				
28				
29				
30	0			
31	4			
32	4			
33	0			
34				
35				
36				
37	-1			
38				
39				
40	0			

EXPERIMENT DATA SHEET VIC

Space Shuttle

1. Specific Objective:

The objective of this experiment is to investigate a simple shuttle-type space vehicle (fig. 1), to determine its characteristics and to define its usefulness for rescue, intraorbital cargo transfer, crew transfer, satellite retrieval, etc., in support of a long-term orbital facility or planetary mission.

2. General Description:

The general approach to the study of a space shuttle as proposed consists initially of assembly and checkout of the shuttle system. Next, maneuvering and visual rendezvous techniques will be developed. Finally, the systems and techniques will be tested in varying degrees of freedom up to the final full systems test involving travel to a remote object while carrying cargo. The shuttle system, once developed, can be utilized to support remote modules with monitoring, resupply, repair, and maintenance, and to provide astronaut rescue and satellite retrieval capability.

The equipment required to support this experiment consists of the space shuttle (fig. 2) with its cargo carrier, attitude controller, life-support system, thrusters, etc., and the space shuttle refueling system with sufficient fuel for the experimental program. An alternate mode is shown in figure 3. The experimental shuttle would provide both modes shown.

3. Operational Constraints:

During the tests in or near the station large perturbations should be prohibited, and the tests outside the space station should be conducted in daylight to allow for closed-circuit TV (CCTV) monitoring of the astronaut and shuttle. Communication between the shuttle and space station must be maintained during all test phases. Bio-medical measurements of the subject may be desirable during all phases. Specific orbital altitude and inclination are not critical.

4. Mode of Operation:

The equipment will be assembled in orbit. Tests will be on an intermittent basis for a total of 16 test periods. Most of the operations will require EVA.

5. Crew Support:

Two crewmen will be required to support the experiment in all phases. Both will be used as subjects. They require no special skills other than preflight training on the shuttle and experience in fuel transfer techniques and EVA. The crew time required is estimated as follows:

Phase I	- 4 setup and re-stow periods	- 8 manhours
	4 test periods of 2 hours(each man)	- 16 manhours
Phase II	- 4 setup, retrieval, and re-stow periods	- 16 manhours
	4 test periods of 2 hours(each man)	- 16 manhours
Phase III	- 4 setup, retrieval, and re-stow periods	- 16 manhours
	4 test periods of 2 hours(each man)	- 16 manhours
Phase IV	- 4 setup, retrieval, and re-stow periods	- 16 manhours
	4 test periods of 2 hours(each man)	- 16 manhours
		120 manhours

6. Spacecraft Support:

Space shuttle: Weight = 250 lb

Volume = 48 cu ft

Expendables - 16 test periods: Weight = 725 lb
(H_2N_4, N_2, and O_2)

Volume = 12 cu ft

7. Development Schedule:

Flight hardware could be available 4 years after go ahead.

8. Cost:

It is estimated that 4 million dollars over a 4-year period will be required to support this experiment.

9. Spacecraft Interface:

The space shuttle and expendables would be stowed in the hangar area where the assembly and checkout would be performed in a shirt-sleeve environment. All communications (voice and bio-medical) between the shuttle and the space station will utilize existing space station systems.

10. Test Program:

The test program will consist of four phases to provide for sufficient in-space training and experimental time in various situations and to assure astronaut safety. Two astronaut subjects will be used. The experiment phases are as follows:

(a) Assemble and checkout of systems in hangar area. This provides for a complete checkout of all shuttle systems in both shirt-sleeve and pressure-suit environments, and some simple maneuvering depending on hangar size. This phase will continue until confidence in the system and knowledge of maneuvering techniques are assured.

(b) Tethered maneuvering near station. This will place the shuttle outside the station to maneuver near the space station (< 200 ft) while tethered and under CCTV observation from the space station. Maneuvering techniques and system checks would be completed during this phase. The effect of various cargo sizes would be evaluated in this phase.

(c) Untethered maneuvering near station. The shuttle will be untethered and flown in the near vicinity of the station (< 200 ft). Free-flight maneuvering and visual techniques will be tested and complete confidence in the system would be demonstrated.

(d) Remote maneuvering. The final test phase would consist of flying to some remote object to fully checkout the shuttle system and to verify the transfer techniques (visual aids, rendezvous philosophies, etc.) developed earlier. Cargo transfer to a remote object would also be fully demonstrated.

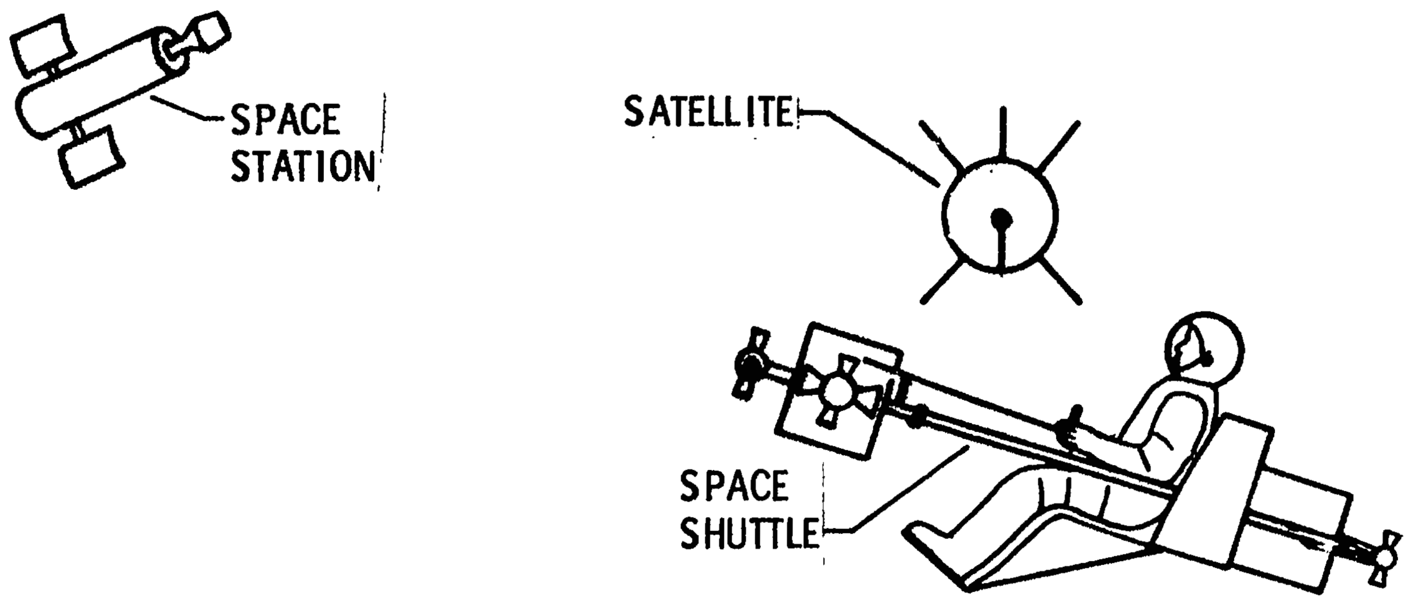


Figure 1.- Space-shuttle experiment.

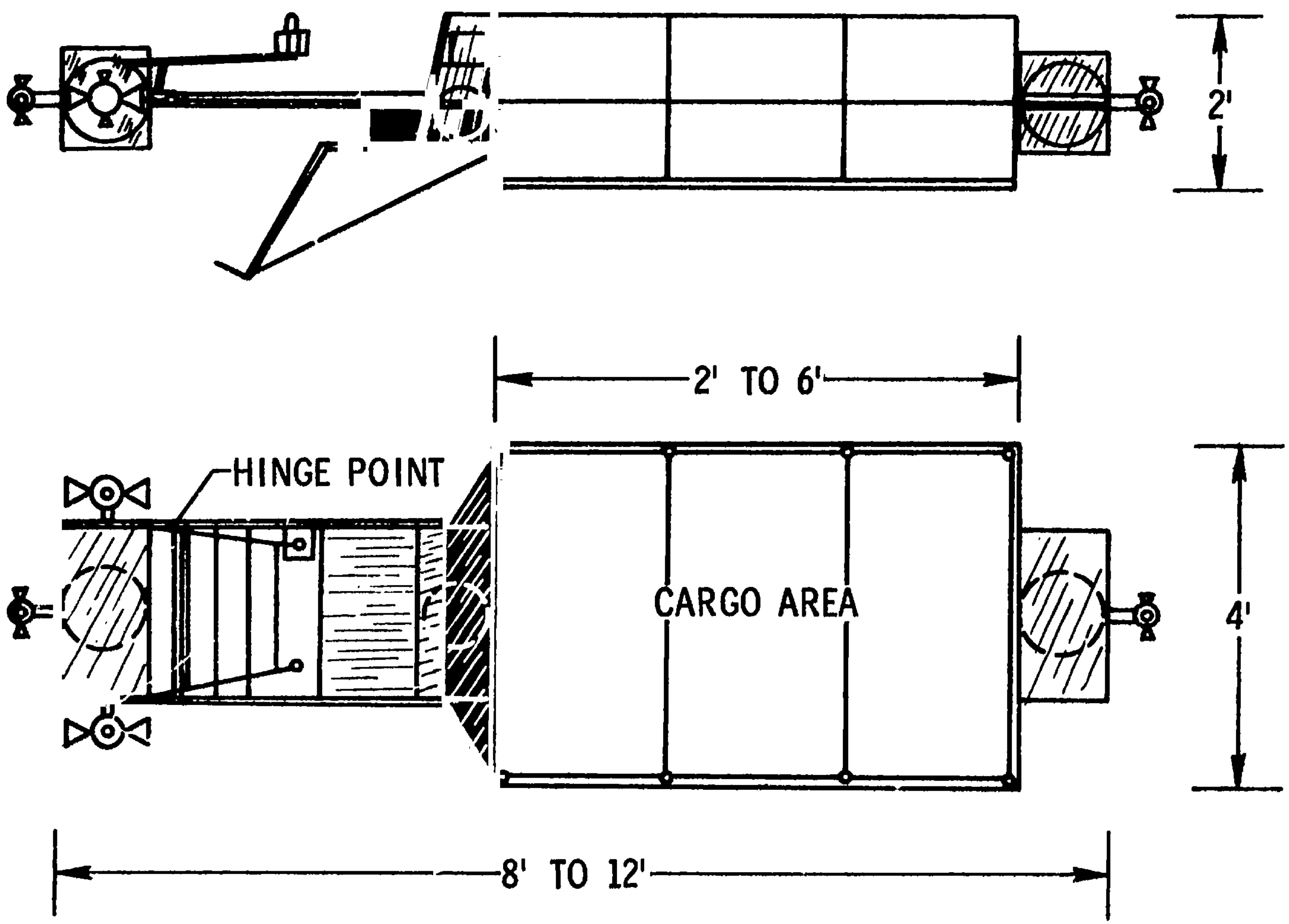


Figure 2.- Space-shuttle experiment (cargo-transfer and rescue mode).

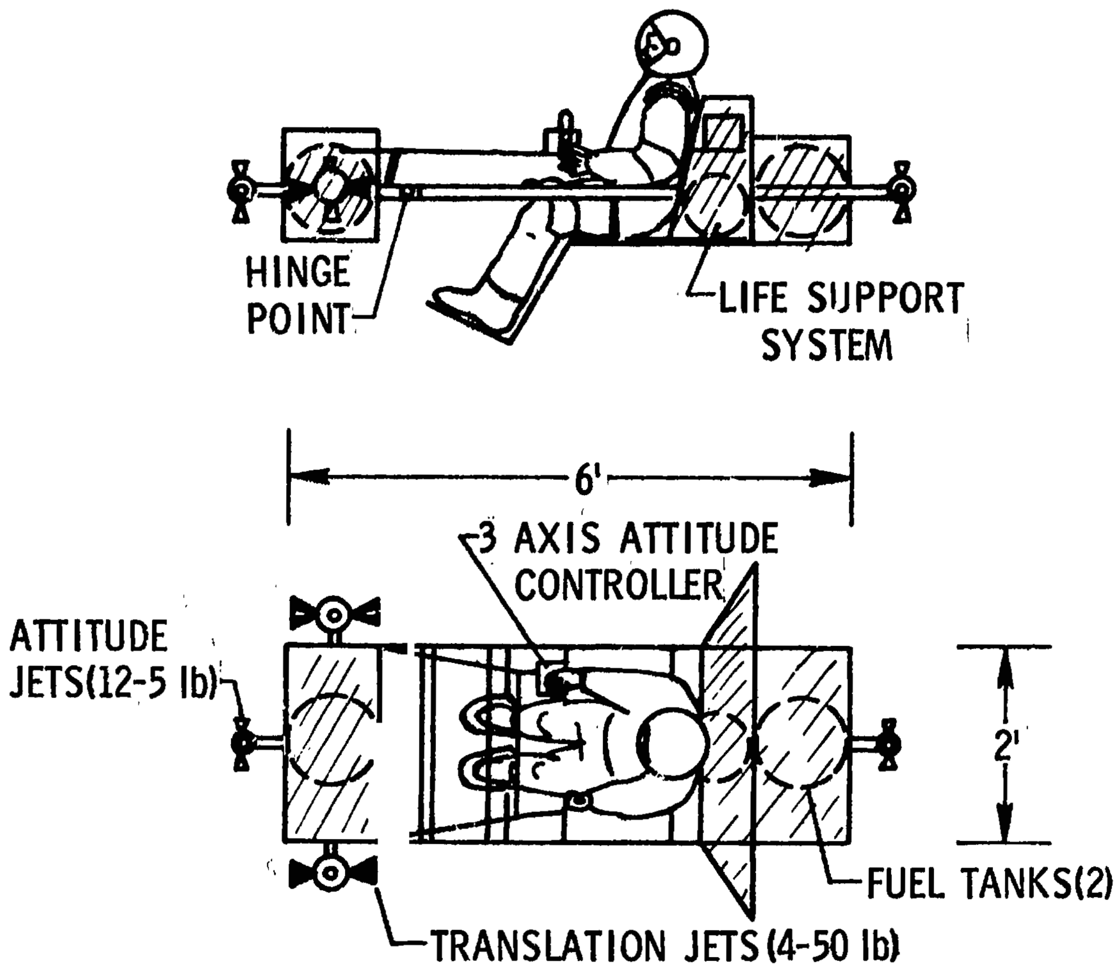


Figure 3.- Space-shuttle experiment (one man transfer mode).

T210

EXPERIMENT/EVENT DATA SHEET VI C

T211

TITLE: SPACE SHUTTLE EXPERIMENT

ITEM No.	PHASE: 1 ASSEMBLY, CHECKOUT OF SHUTTLE	PHASE: 2 TETHERED SHUTTLE CHECKOUT	PHASE: 3 SHUTTLE FREE-FLIGHT TEST NEAR STATION	PHASE: 4 LONG-RANGE SHUTTLE FREE-FLIGHTS
1	VI C-1 (606003)	VI C-2 (606013)	VI C-3 (606023)	VI C-4 (606033)
2	4	4	4	4
3	4	4	4	4
4	1	1	1	1
5	0	0	0	0
6	1	1	1	1
7				
8	2	2	2	2
9	16	16	16	16
10	3	4	4	4
11	16	16	16	16
12	3	4	4	4
13				
14				
15				
16				
17				
18	0	0	0	0
19	0	0	0	0
20	0	0	0	0
21	0	0	0	0
22	0	0	0	0
23	0	0	0	0
24	250			
25	48			
26	0	0	0	0
27		606003	606013	606023
28				
29				
30	0			0
31	3	3	3	3
32	2	2	2	2
33	0	0	0	0
34				
35				
36				
37	-1	-1	-1	-1
38				
39				
40	0	2	2	2

FUNCTIONAL PROGRAM ELEMENT VII

1. Discipline: Advanced Technology

2. Program Element: Fluid Systems Laboratory

3. Requirement:

A requirement exists for a Fluid Systems Laboratory in which basic fluid phenomena may be studied in a long-term zero-or low-gravity environment. Typical phenomena requiring further definition to permit more efficient system design include storage, transfer, and mixing of various fluids, heat transfer in boiling and condensing fluids, separation of aerosols and liquid/gas mixtures, and basic fluid behavior.

Since accidental release and dispersion of the fluids must be considered possible under laboratory testing and since the fluids are potentially hazardous on the basis of toxicity or other characteristics, any laboratory design must be enclosed. Because of the hazards, a separate module for the laboratory should be considered.

4. Justification:

A continuing need exists for long term, zero-gravity-dependent data on fluids behavior upon which to base future component and systems designs. Principal systems involved are life support, liquid propulsion, and basic experiments in science and manufacturing in which fluids are involved.

A further need exists for a facility capable of providing "proof of concept" for components before committing them to system design. Present facilities capable of zero-gravity testing are too limited in test time to meet the requirements. A Fluid Systems Laboratory in a space station would provide a flexible, multi-use facility capable of establishing the necessary technology base to design and test systems whose operation is affected by fluid behavior in zero gravity.

5. Component Experiments:

To identify the types of equipment required, space station support, and laboratory capability; the following experiments have been defined for the Fluid Systems Labo. .tory.

VII.- A. A Device for Liquid/Liquid Mixing and Prevention of Thermal Stratification.

VII.- B. Determination of Gravity Effects on Liquid Release, Aerosol Size, and Parallel-Passage Plugging.

VII.- C. Rotating Liquid Globules.

VII.- D. Self-Pressurization and Venting of Liquid Hydrogen Tankage.

VII.- E. Fluid Experiments in the Critical Region Under Reduced and Zero Gravity.

VII.- F. Long-Term Zero-Gravity Effects on Nucleate Boiling.

VII.- G. Fluid Dynamics Experiments Under Reduced Gravitational Conditions.

VII.- H. Liquid Hydrogen Storage and Transfer.

In addition to the above experiments, the following have been identified as candidate areas for useful experiments in zero-gravity fluid systems technology:

Heat Pipe System for Telescope Mount
Evaporative and Boiling Heat Transfer
Bladderless Tank Designs
Condensing Heat Transfer
Liquid Interface Stability Tests
Super Insulation Tank Systems
Deaeration of Liquid in Tankage
Liquid Retention in Wicks
Separation (Aerosol, Liquid/Gas etc.)
Reliquifaction for Long-Term Storage of Cryogens
Two-Phase Flow Through Porous Beds
Plume Impingement and Heat Transfer at Very Low Pressures

6. Description:

The Fluid Systems Laboratory, as proposed, could be either an enclosed volume within the space station or built as a separate module. The laboratory would be provided with life support, power, chilled water, and cryogenics from the space station. Also the space station would provide for data storage and transmission of the experimental results. One possible configuration of the laboratory is shown in figure 1.

7. Special Considerations:

The number and types of experiments located in the Fluid Systems Laboratory will vary between logistics resupply missions but it is assumed that not more than two experiments will be run simultaneously. Based on two experiments of average size being run simultaneously the requirements for the laboratory are estimated to be as follows:

Power - 400 watts peak, 4 hrs/day, 30 watts quiescent (AC and DC)

Data output - 10^6 bits/day

Chilled Water (by-passed from life support system) -0.5 gal/min. maximum for 2 hrs/day

Cryogenic supply (between resupply missions) { N_2 - 300 lb; H_2 - 700 lb }

Special Equipment

Zero-"g" vent (from laboratory to space)

Micro - "g" Table - soft-mounted table approximately 3' x 3' affixed to the laboratory low modulus springs (for special experiments requiring isolation from small disturbances such as equipment-excited vibrations)

Crew Aids - foot and body restraints to provide the astronaut with mobility for operating experiments.

BIBLIOGRAPHY

1. Cohan, H.; Rogers, M.: Fluid Mechanics and Heat Transfer Under Low Gravity. Proceedings of Symposium, Palo Alto, Calif., sponsored by USAF/OSR and Space Company, June 24-25, 1965.

2. Anon: Gravity Sensitivity Prediction Criteria For Future Life Support Systems, Rept. No. GDC PIN 68-151.

3. Clark, J. A.: A Review of Pressurization, Stratification, and Interfacial Phenomena. International Advances in Cryogenic Engineering. Vol. 10, Sect. M. U., K. D. Timmerhous, Plenum Press, 1965.

4. Vick, Allen R.; Cubbage, James M.; and Andrews, Earl H., Jr.: Rocket Exhaust Plume Problems and Some Recent Related Research. Presented at a Specialist's Meeting on "The Fluid Dynamic Aspects of Space Flight" (Marseille, France) AGARD, April 20-24, 1964.

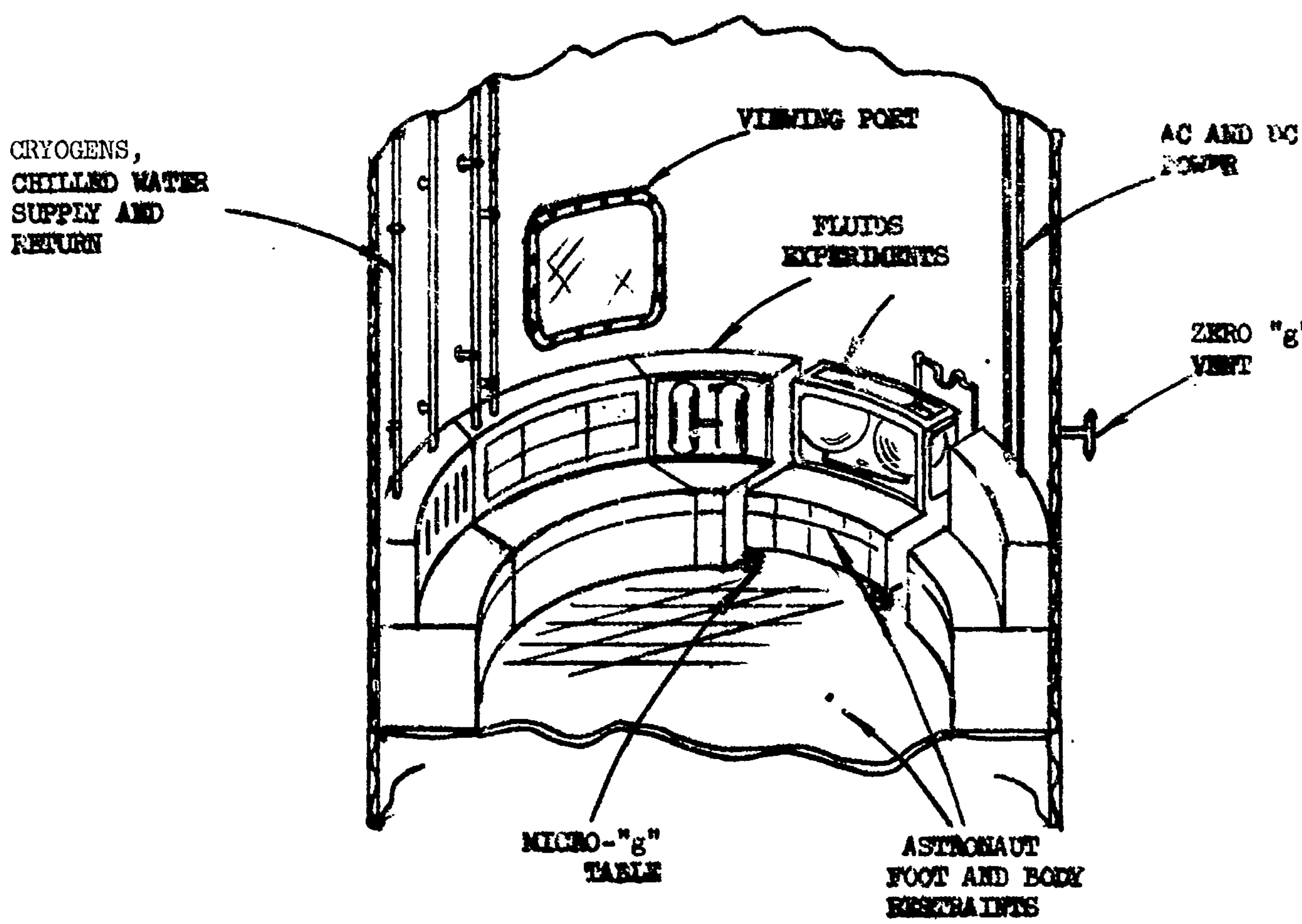


Figure 1.- Fluid systems [illegible]tory.

EXPERIMENT DATA SHEET VII A

A Device for Liquid/Liquid Mixing and Prevention of Thermal Stratification

1. Specific Objective:

The objective of this experiment is to study the phenomena of diffusion and thermal stratification in fluids. A further objective is to test the effectiveness of a device in very low and zero gravity for the mixing of dissimilar fluids and the prevention of thermal stratification.

2. General Description:

The test setup involves the hardware shown in figure 1. This includes a transparent tank containing a heating element. Thermocouples are located inside the tank to measure the temperature distribution. The tank has two appendages; one containing the mixing nozzle, pressure check valve, and mixing diaphragm; the other containing a diaphragm to compensate for the fluid displacement during the mi action. The test setup includes a camera, camera lights, a recorder for temperature measurements, and a low pressure gas supply for actuation of the mixer.

For the mixing test the tank is filled with two dissimilar liquids. Pressurized gas is used to lift the mixing diaphragm. This displaces a volume of liquid through a nozzle, creating a liquid stream with sufficient velocity to cause mechanical mixing. The cycle is completed by venting the pressure to the mixing diaphragm. The mixing action is recorded by a movie or sequential camera.

For the thermal stratification tests, temperature gradients are created in the fluid by a heating element. The mixing action as described above is used to reduce stratification. The thermocouple readout is used to determine the temperature distribution before and after mixing.

3. Operational Constraints:

This experiment requires no special constraints other than a zero-or near-zero gravity environment.

4. Mode of Operation:

Both phases of this experiment require the astronaut to set up and monitor the equipment for each run. Each run is continuous, but various runs can be made on a time-available basis. Some astronaut tasks could be automated at the expense of increased volume, weight, and cost.

5. Crew Support:

Crew support is required for maintenance and changeover of the experiment. The mixing test requires approximately 10 min/run for set up and monitoring, and approximately 1 hr for changeover. The thermal stratification test will require approximately 15 min/run for monitoring.

6. Spacecraft Support:

The spacecraft will be required to provide filming and recording capabilities with logistics support and/or telemetry relay of the data to ground. The power requirement for the experiment is approximately 200 watts. A small amount of compressed gas is needed. Storage is required for approximately 50 lb of nonrecoverable test fluids.

7. Development Schedule:

A laboratory model of the mixer has been demonstrated. Approximately 2 years will be required to develop flight hardware.

8. Cost: Development costs will be approximately $200,000.

9. Spacecraft Interface:

No special space station interface has been established. A volume of approximately 1.5 cu ft should be alloted for the equipment in the Fluid Systems Laboratory.

10. Test Program:

For the liquid/liquid mixing phase of the experiment, the tank is filled with two dissimilar fluids. The mixing action is initiated and the results observed. The parameters that can be varied are: displacement volume, actuation pressure, frequency of mixing action, and liquid characteristics.

For the thermal stratification test, the tank is filled with one fluid. The heater is turned on and the thermal stratification is monitored. The mixing action is initiated and the results observed. The parameters that can be varied are heater temperature, displacement volume, actuation pressure, and frequency of mixing action.

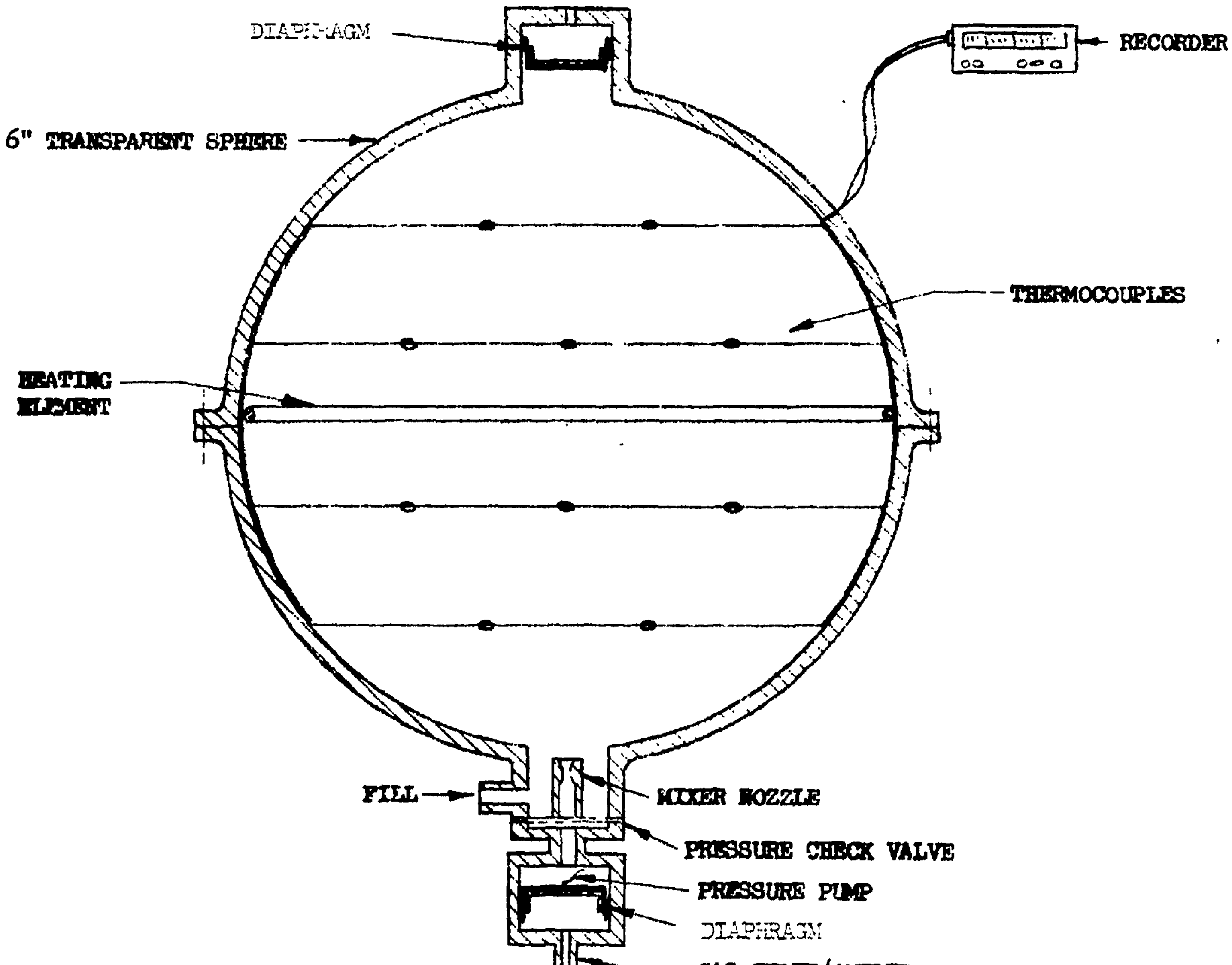


Figure 1.- Liquid/liquid mixing and thermal stratification.

T220

EXPERIMENT/EVENT DATA SHEET VII A

T221

TITLE: A DEVICE FOR LIQUID/LIQUID MIXING AND PREVENTION OF THERMAL STRATIFICATION

ITEM No.	PHASE: 1 LIQUID/LIQUID MIXING	PHASE: 2 THERMAL STRATIFICATION	PHASE:	PHASE:
1	VII A-1 (607001)	VII A-2 (607011)		
2	7	3		
3	1	1		
4	7	3		
5	0	0		
6	1	1		
7				
8	1	1		
9	16	16		
10	1.5	0.75		
11				
12				
13				
14				
15				
16				
17				
18	0	0		
19	0	0		
20	0	0		
21	0.1	0.75		
22	200	50		
23	0	50		
24	20	2		
25	1.5	0.1		
26	0	0		
27		607001		
28				
29				
30	0	0		
31	0.1	0.1		
32	0.1	0.1		
33	1	1		
34				
35				
36				
37	0	0		
38				
39				
40	0	1		

EXPERIMENT DATA SHEET VII B

Determination of Gravity Effects on
Liquid Release, Aerosol Size, and
Parallel-Passage Plugging

1. Specific Objective:

The objective of this experiment is to investigate the mechanism of liquid release from a fin and tube heat exchanger, to determine aerosol sizing, and to study the conditions and effects of parallel-passage plugging in a zero-or reduced-gravity environment.

A further objective is to obtain data at zero-and fractional-gravity levels which may be correlated with data established from ground tests.

2. General Description:

The test equipment for the experiment is shown in figure 1. It consists of a fan which forces cabin air into a duct, baffled for air flow control. The flow is measured by a probe. A cold water fin-and-tube heat exchanger is located under a transparent section of duct downstream from the baffle. Thermocouples are located at the cold water inlet and outlet of the heat exchanger. An aerosol evaluator, located downstream of the heat exchanger, requires a vacuum pump for operation.

In operation the fan provides a controlled amount of airflow over the heat exchanger. Air intake is from the cabin at standard operating conditions. The airflow rate and the inlet and outlet temperatures of the cold water passing through the heat exchanger are monitored and recorded.

As condensate forms on the fins, its action is observed and photographed through the transparent section of the duct. Of interest is the action of the condensate on the plates; whether or not the passages become plugged, and the related effects; and the size of the aerosols created when the condensate leaves the plates. Aerosol sizes and quanities are monitored by the aerosol evaluator.

3. Operational Constraints:

The characteristics of the space station air should remain reasonably constant during test runs A zero-or near-zero-gravity environment is required.

4. Mode of Operation:

This experiment will require an astronaut for test setup and monitoring. Each run will require a normalizing period of 0.5 to 1.0 hr during which no attention is necessary. The runs are continuous, but various runs can be made on a time available basis.

5. Crew Support:

Crew support for setup and monitoring will require approximately 15 min/run.

6. Spacecraft Support:

The spacecraft will be required to provide filming and 10 channels of recording capability with logistics support and/or telemetry relay of the data to ground. The total power requirement is approximately 210 watts.

7. Development Schedule:

A laboratory model of the aerosol evaluator is currently under development. Approximately 2 years will be required to develop flight hardware for the experiment.

8. Cost: Development cost will be approximately $150,000.

9. Spacecraft Interface:

The space requirement for this experiment will be approximately 3.0 cu ft. Approximately 0.5 gal/min of cold water will be used from the spacecraft cooling system for the experiment.

10. Test Program:

The test setup will involve positioning of the equipment and the initiation of air and water flow. After the experiment has normalized, the action of the condensate is observed and photographed and the flow, temperature, and aerosol evaluator readings are recorded. The parameters which can be varied are: airflow rate, cold water flow rate, and fin spacing. The fin spacing, and possibly shape, will be varied by the use of interchangeable units.

10. Test Program:

The test setup will involve positioning of the equipment and the initiation of air and water flow. After the experiment has normalized, the action of the condensate is observed and photographed and the flow, temperature, and aerosol evaluator readings are recorded. The parameters which can be varied are: airflow rate, cold water flow rate, and fin spacing. The fin spacing, and possibly shape, will be varied by the use of interchangeable units.

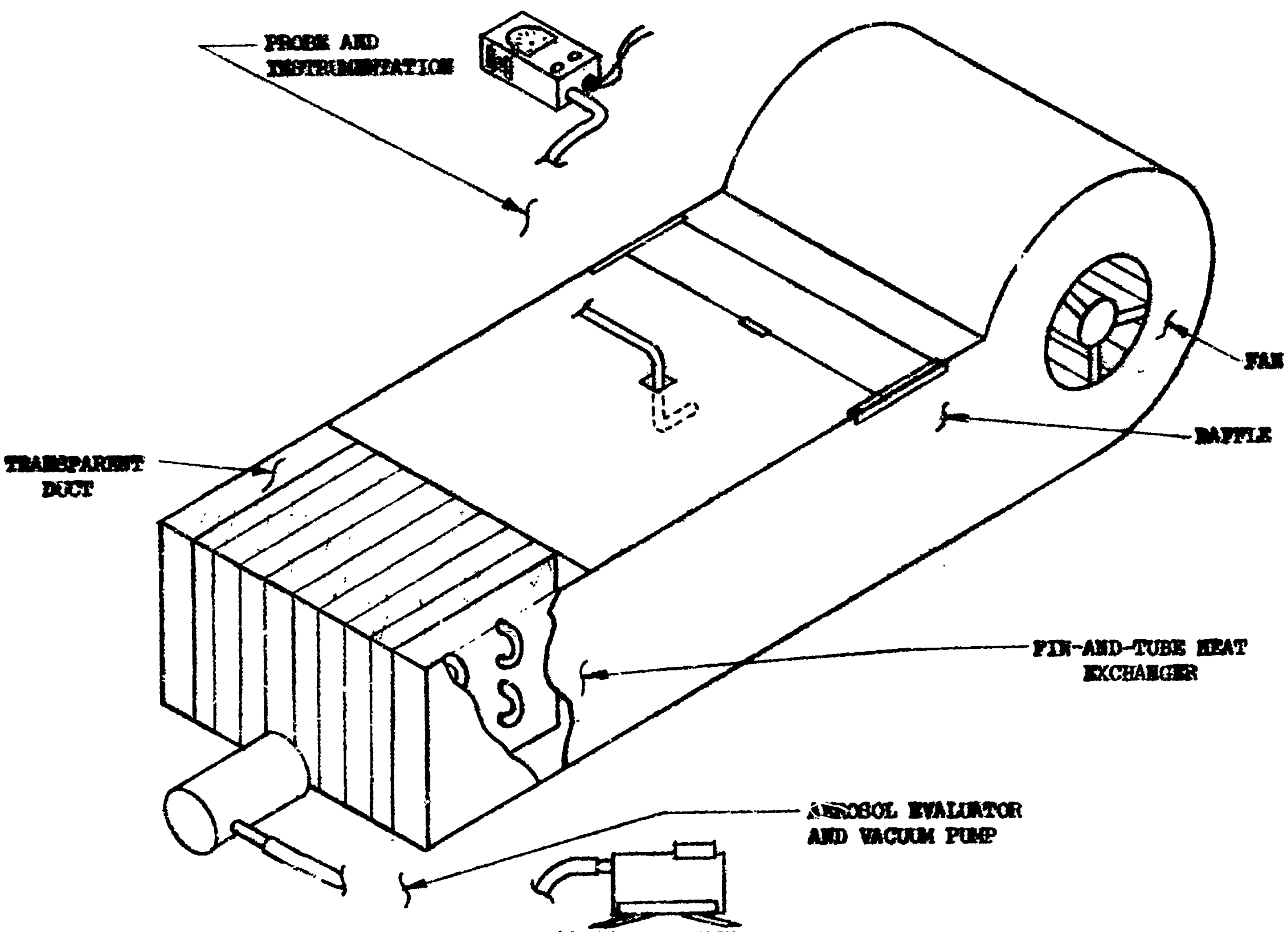


Figure 1.- Gravity effects on liquid release, aerosol size, and parallel passage plugging.

T226

EXPERIMENT/EVENT DATA SHEET VII B

T227

TITLE: DETERMINATION OF GRAVITY EFFECTS ON LIQUID RELEASE, AEROSOL SIZE, AND PARALLEL PASSAGE PLUGGING

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	VII B-1 (607002)			
2	2-5			
3	1			
4	5			
5	0			
6	1			
7				
8	1			
9	16			
10	0.75			
11				
12				
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	0.1			
22	210			
23	100			
24	75			
25	3			
26	0			
27				
28				
29				
30	0			
31	0.1			
32	0.1			
33	1			
34				
35				
36				
37	0			
38				
39				
40	0			

EXPERIMENT DATA SHEET VII C

Rotating Liquid Globules

1. Specific Objective:

The objective of this experiment is to study the behavior of liquid globules rotating at various speeds in a zero-gravity environment.

A further objective is to advance the state of knowledge in the basic behavior of fluids under zero-gravity conditions in support of future fluid system design and developments.

2. General Description:

This experiment will require a transparent spherical tank approximately 12 in diameter; a 1/50 hp motor equipped with a variable speed drive; and a positive expulsion system for the introduction of fluids into the sphere. A high-resolution short-focal-length movie camera and camera lights will be required.

In operation, a specified amount of the fluid to be tested is supplied through the top of a rotating pressure joint and through the center of an impeller (figure 1). The fluid effluxes through orifices at the geometric center of the sphere and forms a globule. A movie camera is utilized to study the shape and general behavior of the liquid globule formed at various rotational speeds.

The estimated weight of the experiment including transparent sphere, supports, fractional-hp motor, test media, and containers is 60 lb. Volume occupied by the experiment is approximately 1.5 cu ft. Some fluids to be tested in the sphere (such as mercury) are potentially hazardous. Provisions must be made for the storage of small amounts of such fluids and for containment in the event of accidental release.

3. Operational Constraints:

Space station disturbances (or fluid system module disturbances) should be kept to a minimum during the tests. There are no other special constraints.

4. Mode of Operation:

The experiment is conducted within the Fluid Systems Laboratory and requires the continuous attention of the astronaut during test.

5. Crew Support:

One astronaut will be required to run the test. Test duration is estimated to be approximately 15 minutes. Approximately 20 tests will be required which could be carried out on a time-available basis over an extended period. No special technical skills are required other than training in the use of the camera and the experimental equipment.

6. Spacecraft Support:

The spacecraft will be required to provide storage space for the film between resupply missions. Logistics support for the resupply of film with canister and return of exposed film to earth is estimated to be 20 lb in both cases.

7. Development Schedule:

Minimal development is required since all components for the experiment are readily available. Time to develop flight hardware is estimated to be two years.

8. Cost: $200,000.

9. Spacecraft Interface:

No special spacecraft interface is established since the experiment will be located within the Fluid Systems Laboratory space.

10. Test Program:

The test program could be carried out over an extended period. New fluids and components could be brought to the laboratory on resupply missions or on an as-needed basis.

In the operation of the experiment, high-speed photography will be used to obtain globule shape and motions as a function of rotational speeds of the impeller. Speed of the impeller will be increased until rupture occurs. Each experiment is expected to be of short duration and no warm-up period is required. Initial tests will probably lead to requirements for new fluids and possible changes to the impeller shape. These tests could be carried out during subsequent 90-day intervals between resupply missions.

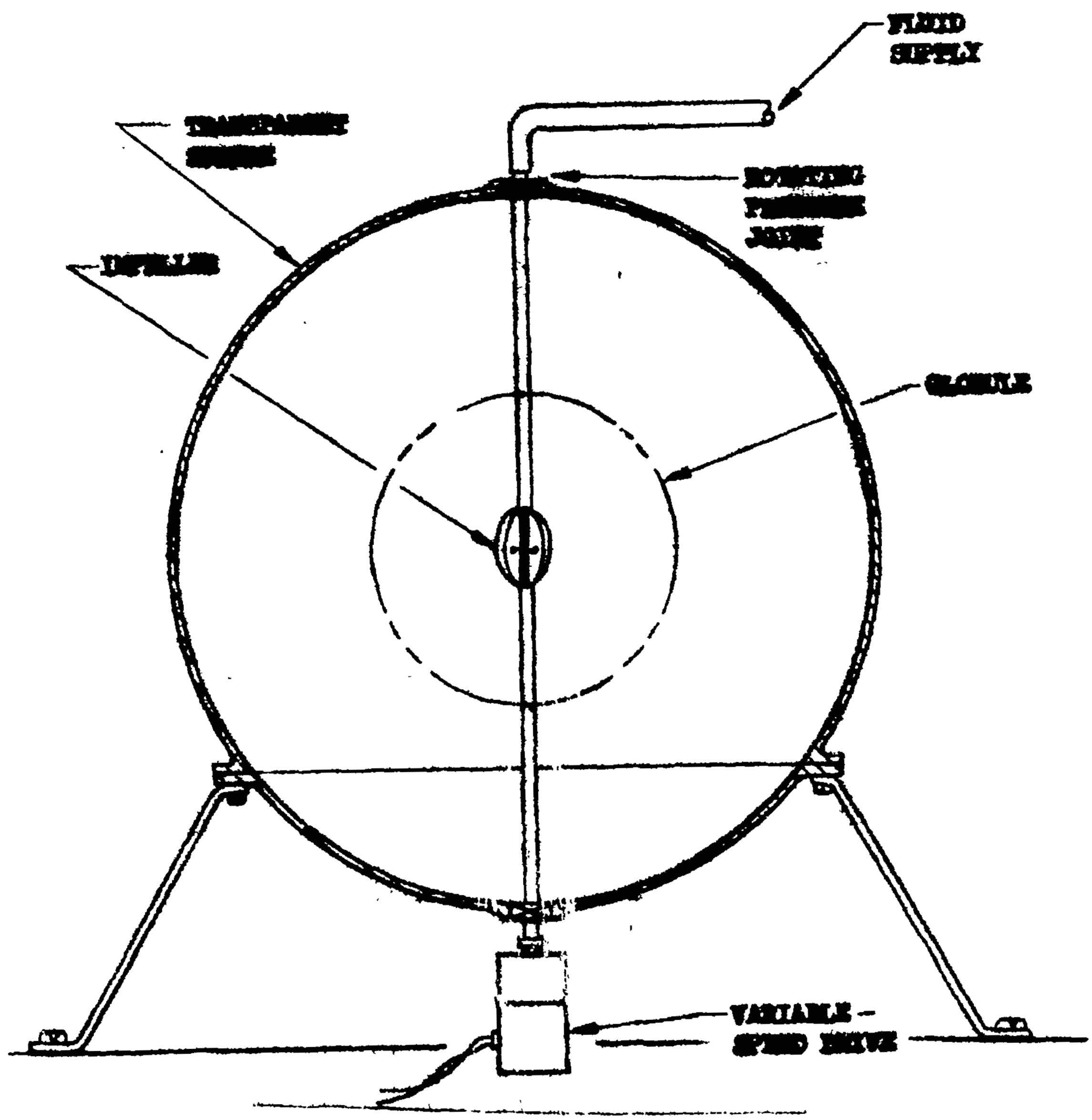


Figure 1.- Experiment on rotating liquid globules.

EXPERIMENT/EVENT DATA SHEET VII C

T232

TITLE: ROTATING LIQUID GLOBULES

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	VII C-1 (607003)			
2	20			
3	1			
4	20			
5	0			
6	1			
7				
8	1			
9	16			
10	1			
11				
12				
13				
14				
15				
16				
17				
18	120			
19	20			
20	0.01			
21	0			
22	0			
23	0			
24	20			
25	0.3			
26	0			
27	607001			
28				
29				
30	0			
31	0.01			
32	0.01			
33	0			
34				
35				
36				
37	1			
38				
39				
40	1			

EXPERIMENT DATA SHEET VII D

Self-Pressurization and Venting of Liquid Hydrogen Tankage

1. Specific Objective:

The objective of this experiment is to determine the effects of the following on stored cryogens: acceleration, tank geometry, heat transfer rate and distribution, venting rate and frequency, and percent filling.

A further objective is to study inflow dynamics and liquid reorientation under zero or low-gravity conditions.

2. General Description:

The experimental apparatus will consist of a spherical pressure vessel approximately two feet in diameter which contains the test fluid (figure 1). Exterior to the pressure vessel are two concentric shells; one containing nitrogen cooling coils and segmented resistance heaters; and a second (or outer shell) which serves as a vacuum jacket. Approximately 30 thermocouples are located at strategic points within the tank. The thermocouples are used both to measure temperature distribution within the fluid and vapor, and to determine fluid orientation. The tank has fill and vent lines attached to one end and a small outflow line at the other. To study the effects of geometry, a very similar test setup to that shown in figure 1 will be utilized except that the tank will be cylindrical (two feet in diameter and four feet long with hemispherical heads).

In operation, the vacuum jacket around the tank being investigated will be exhausted to space. The tank will then be filled to the desired liquid level, the heaters set to the prescribed temperatures, the data recording system activated, and either a self-pressurization or venting test will be run. Following the test, the liquid hydrogen remaining in the tank will be vented to space.

Because the fluids being tested are potentially explosive, location of the experiment in an explosive-safe area is required.

3. Operational Constraints:

Controlled acceleration levels from 0 to 10^{-4} "g" along the centerline of the experiment are required. Disturbances due to crew motion, docking, or equipment operation should be kept to a minimum.

4. Mode of Operation:

The experiment is conducted within the Fluid Systems Laboratory and requires the attention of the astronaut during a test run to the extent prescribed under Crew Support.

5. Crew Support:

The astronaut will be required to monitor the filling of each experiment tank from the liquid hydrogen supply tank. The desired liquid level will be obtained by the astronaut. Continuous monitoring of the tank pressure will be required during self-pressurization tests. Also periodic checks of the liquid quality and flow in the vent line will be required. Approximately 5 hours per test will be required.

6. Spacecraft Support:

Approximately 100 data channels will be required to record pressure, temperature, flow, and quality of the cryogens in vents. During inflow and self-pressurization tests, data from each channel will be recorded every ten seconds. During the venting tests, data will be recorded from each channel every ten minutes. Power required during peak periods (principally for heaters) is estimated to be 250 watts. Quiescent power is estimated at less than 50 watts. Gaseous helium will be required for purging the tanks and transfer lines. Approximately 300 lb of nitrogen and 700 lb of hydrogen will be needed for the test series. A storage must be provided for these cryogens.

7. Development Schedule:

Similar test equipment has been flown on Aerobee sounding rockets and in Atlas scientific passenger pods. It is estimated, however, that it will require two to three years to develop flight hardware.

8. Cost: Estimated cost for design, fabrication, and testing of the two liquid hydrogen tanks is $400,000.

9. Spacecraft Interface:

No spacecraft interface is established. The experiment will interface with the Fluid Systems Laboratory.

10. Test Program:

The tests must commence early in the mission or soon after delivery of the cryogens by the logistics vehicle in order to minimize requirements for makeup due to venting losses. Otherwise the time during which tests are conducted is flexible.

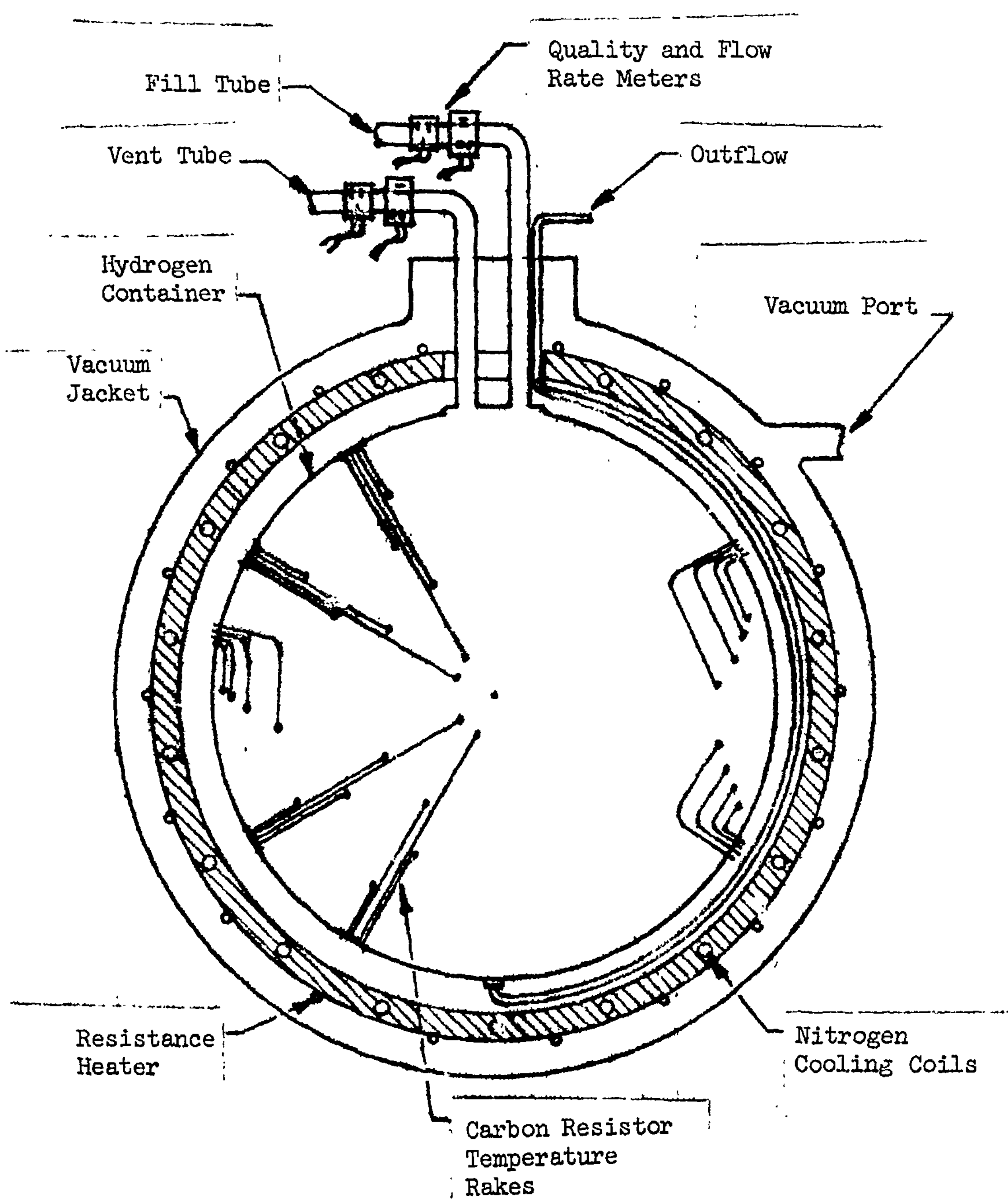


Figure 1.- Self-pressurization and venting of liquid hydrogen tankage.

EXPERIMENT/EVENT DATA SHEET VII D

T237

TITLE: SELF - PRESSURIZATION AND VENTING OF LIQUID HYDROGEN TANKAGE

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	VII D-1 (607004)			
2	5-10			
3	1			
4	10			
5	0			
6	1			
7	7			
8	1			
9	16			
10	5			
11				
12				
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	1			
22	250			
23	30			
24	1200			
25	24			
26	0			
27				
28				
29				
30	0			
31	0.1			
32	0			
33	1			
34				
35				
36				
37	0			
38				
39				
40	0			

EXPERIMENT DATA SHEET VII E

Fluid Experiments in Critical Region Under Reduced and Zero Gravity

1. Specific Objectives:

The objectives of these experiments is to measure thermodynamic and transport properties of fluids in the critical region under "zero-gravity" conditions.

2. General Description:

This experiment will involve the measurement of thermal conductivity in the critical region. Secondarily measurements of density and specific heat could be included in the experimental program.

The experiment involves the placing of a fluid between two surfaces, electrically heating one surface, and measuring the temperature difference between the surfaces. Thermal conductivity can be calculated from the known heat flow (electrical input) and the measured temperature differences. (The two surfaces may be either flat plates or concentric spheres.)

The working fluid will be either CO_2 or xenon, of fixed mass, and will be contained in a cell of about one liter. The temperature and volume of the test cell will be accurately controlled allowing the average temperature and density of the fluid to be varied (Fig. 1).

The procedure used in performing the experiment is to initially set the temperature and density of the test fluid near the critical reg. The thermal conductivity is obtained at this point by the method described above. (Several values of the conductivity should be obtained at various heat flow rates.) With the cell temperature held constant, the conductivity is measured at other densities throughout the critical region. The cell temperature is then increased and the process repeated.

3. Operational Constraints:

Acceleration levels during the tests must be limited to $<10^{-4}$g. There are no other operational constraints.

4. Mode of Operation:

Manned operation and observation and control of experiment will be required; however, data recording could be automated. Photographic coverage of the experiment would be desirable.

5. Crew Support:

In flight, the astronaut will set predetermined temperature and density values for the test cell. Following equilibrium, predetermined heat flow rates between the two surfaces in the cell will be set and transient data recorded. Setup time is estimated to be about 15 minutes; each data point may take 10 minutes. No special skills are required. Estimated number of data points required for each fluid is 72 making the time required for investigation 12 hours; for each fluid 24 hours will be required.

6. Spacecraft Support:

The experiment will occupy a total volume of about 1.5 ft.^{3} and be self-contained with the exception of electrical power and data readout and recording instrumentation. The experiment will weigh approximately 100 pounds. Electrical input power requirements are about 250 watts. Approximately six data channels will be required to record the output of the instrumentation.

7. Development Schedule:

Phase one: Selection of the method for measuring thermal conductivity, specific heat, and density - 2 to 4 months estimated time. Phase two: Design, construction and testing of breadboard apparatus - 10 to 12 months. (The major design problem will be in the temperature control system; however, some progress has already been made in this area.) Phase three: Design, construction and testing flight unit - 6 to 8 months. Final construction should be routine. Temperature calibration may have to be performed with the National Bureau of Standards.

8. Cost:

$325K to 400K (total).

9. Spacecraft Interface:

The experiment will interface with the Fluid Systems Laboratory.

10. Flight Test Program:

The flight test program will consist of a series of measurements of the thermal conductivity in the critical region for one fluid. Thermal conductivity will be measured as a function of density along isotherms in the critical region. A series of six isotherms, with each isotherm generated by approximately twelve points, is desired.

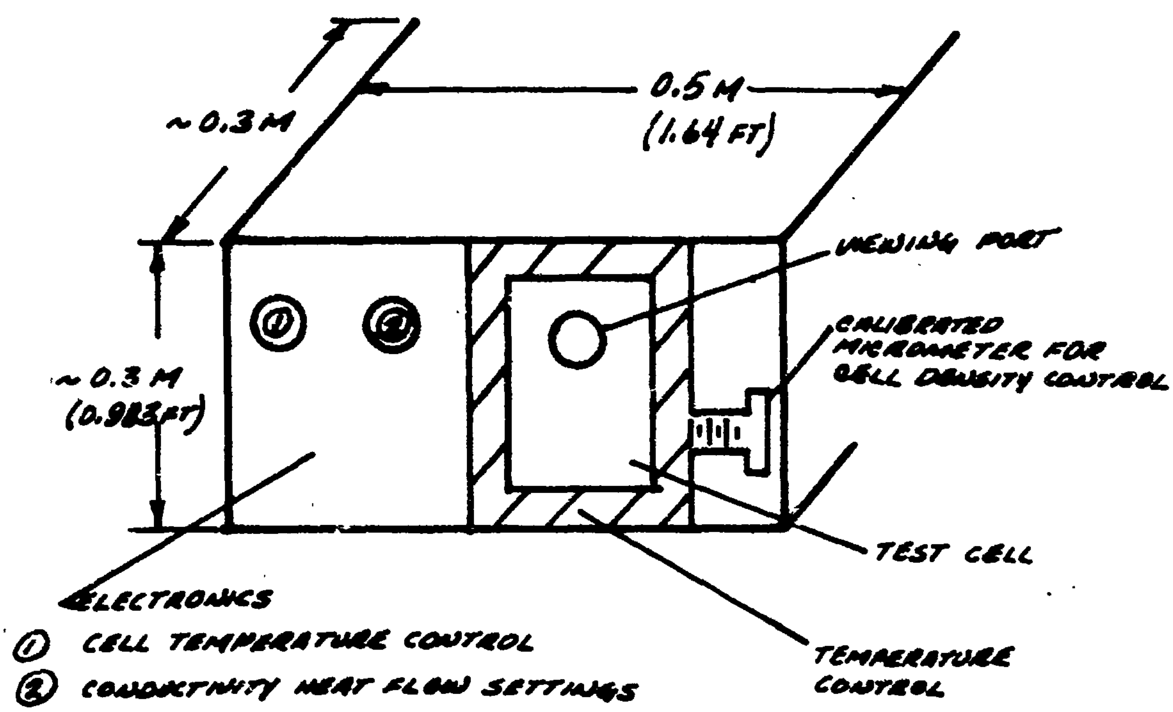


FIGURE 1.- FLUID EXPERIMENTS IN THE CRITICAL REGION UNDER REDUCED AND ZERO GRAVITY

EXPERIMENT/EVENT DATA SHEET VII E

T242

TITLE: FLUID EXPERIMENTS IN THE CRITICAL REGION UNDER REDUCED AND ZERO GRAVITY

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	VII E -1 (607005)			
2	6			
3	6			
4	1			
5	0			
6	1			
7				
8	1			
9	16			
10	2			
11				
12				
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	12			
22	250			
23	125			
24	100			
25	1.5			
26	0			
27				
28				
29				
30				
31	0.2			
32	0			
33	1.0			
34				
35				
36				
37	0			
38				
39				
40	0			

EXPERIMENT DATA SHEET VII F

Long Term Zero Gravity Effects on Nucleate Boiling

1. Specific Objective:

The primary objective of this experiment is to obtain the steady state boiling curve (Q/A versus Δ T) in zero gravity for a saturated liquid. A secondary objective is to investigate the heating of a container of liquid, by boiling, from quiescent conditions to saturation conditions or to the peak heat flux, whichever occurs first.

2. General Description:

The test apparatus consists of a container in which two heaters are mounted (Fig. 1). One is used to heat the bulk of the liquid to the saturation temperature and to maintain it at that temperature. The second heater is the test surface on which the various boiling phenomena are observed. The container is constructed so that the boiling is observable externally both by eye and with a camera. A reflux condenser may be employed in order to both conserve the test liquid and to maintain a constant pressure within the system. Separate power sources for the two heaters are required. Measurements consist of bulk temperature, heater surface temperature, heater power dissipation, and system pressure.

For the first phase the bulk heater is used to bring the liquid bulk to its saturation temperature and to maintain it there. The test surface heater is activated and power to it is slowly increased until boiling is initiated. The power to this heater is then increased in small increments allowing the boiling phenomena to come to steady state prior to each increase. This procedure is followed until the peak heat flux is reached, which concludes the test.

For the second phase only the test surface heater is used to heat the liquid bulk from quiescent condition. Power to the heater is increased to initiate boiling at a high subcooling. The boiling is then observed until saturation conditions or the peak heat flux is reached, whichever occurs first. The liquid is then permitted to return to spacecraft quiescent conditions, the heater is again activated and boiling is initiated at a lower subcooling than in the first run and again observed to steady state conditions. The third run is the same as the previous two but with a still lower initial subcooling at which boiling is initiated.

3. Operational Constraints:

"G" levels during testing must be maintained at 10^{-4} "g's" or less.

4. Mode of Operation:

The experiment is conducted within the Fluid Systems Laboratory. The operation of the experiment will be primarily manual with some automated data collection. Once started, the experiment will run continuously until completion.

5. Crew Support:

An astronaut will be required to maintain and operate the experimental equipment, to take measurements periodically and to make critical observations. One man for four hours will be needed for each test. It will be necessary for the experimenter to be basically familiar with the phenomena in order to intelligently conduct the experiment. This will necessitate some pre-flight preparation.

6. Spacecraft Support:

The hardware will occupy a volume of approximately 2x3x3 feet and will weigh about 350-400 pounds. Power from the spacecraft amounting to 200 watts will be required. Approximately six data channels will be needed to record the output of the instrumentation.

7. Development Schedule:

The total time necessary to develop the apparatus to the flight experiment stage is estimated to be $1\frac{1}{2}$ to 2 years.

8. Cost:

$200,000 hardware and services.

9. Spacecraft Interface:

The experimental package could be mechanically attached inside the Fluid Systems Laboratory as space and convenience dictated.

10. Flight Test Program:

The flight test program consists of two phases to accomplish the primary and secondary objectives as outlined in Paragraph 1.

The first phase consists of a single test in which the power dissipated by a heater submerged in a saturated liquid is varied and the difference between the heater surface temperature and saturation temperature is measured.

The second phase consists of three tests. In each test boiling is initiated while the liquid bulk is subcooled and the characteristics of the phenomena are observed from the inception point to saturation of the bulk or to the peak heat flux of the heater. The primary variable in these tests is the subcooled temperature at which boiling is initiated.

Ground based testing required is minimal and is limited to equipment qualification and personnel familiarization.

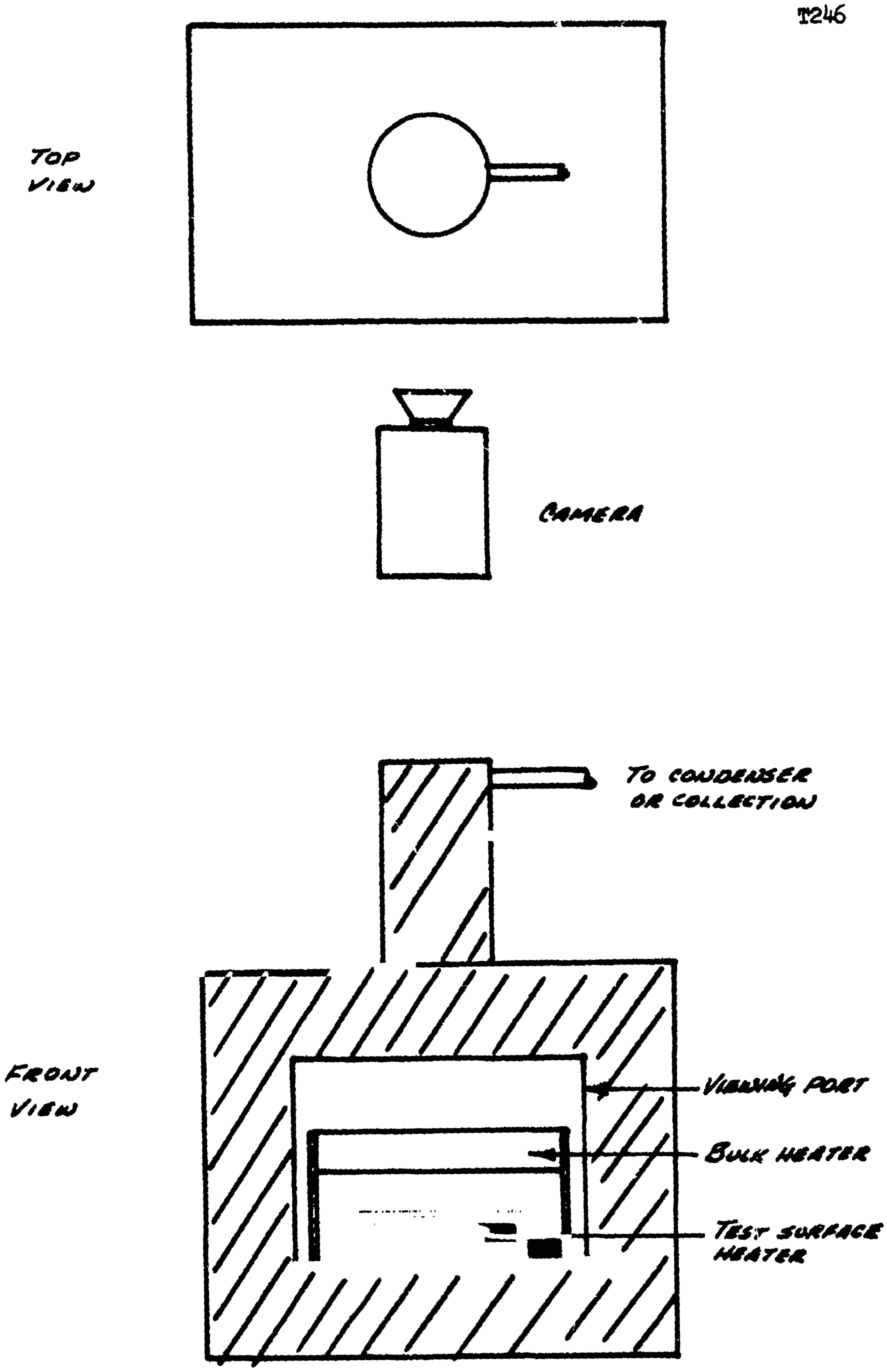


FIG. 1.- LONG-TERM ZERO-GRAVITY EFFECTS ON NUCLEATE BOILING.

T247

EXPERIMENT/EVENT DATA SHEET VII F

TITLE: LONG-TERM ZERO-GRAVITY EFFECTS ON NUCLEATE BOILING

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	VII F-1 (607006)			
2	10			
3	5			
4	1			
5	5			
6	1			
7				
8	1			
9	16			
10	4			
11				
12				
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	2			
22	200			
23	100			
24	350			
25	18			
26	0			
27				
28				
29				
30	0			
31	0.2			
32	0			
33	1			
34				
35				
36				
37	0			
38				
39				
40	0			

EXPERIMENT DATA SHEET VII G

Fluid Dynamics Under Reduced Gravitational Conditions

1. Specific Objective:

The objective of this experiment is to observe the behavior of a liquid-vapor interface in a reduced gravity environment over long periods of time.

2. General Description:

The fluid dynamics tests in this experiment correspond to those encountered in spacecraft operation and involve the study of fluid transfer, large amplitude sloshing, liquid reorientation, and the formation and coalescence of vapor bubble clusters. The effects of baffles on the fluid dynamics would be included in the study.

The experiment consists of three transparent tanks, suitably interconnected to conduct the series of experiments planned; it will utilize a noncombustible, storable liquid (Fig. 1). The first tank will be an oblate spheroid with an outlet located on the centerline at the tank bottom and two outlets 180 degrees apart located on the major diameter. The second tank will be cylindrical with an outlet also located on the centerline at the tank bottom. The third tank will be spherical with an outlet located on the centerline at the tank bottom. All three tanks will have gas pressurant inlets on centerline at the tank top. Plumbing and valving shall be so designed as to permit liquid transfer from any one tank to any other tank. The cylindrical and spherical tanks will be designed so as to permit in-orbit installation of internal baffles for liquid-vapor interface inflow-outflow control. The tanks will be moveable to the extent required to induce slosh of the liquid-vapor interface. One conceptual layout of the experiment described herein is shown in Figure 1. The three-tank experiment program, however, is flexible with regard to layout and packaging of concepts.

3. Operational Constraints:

A range of accelerations will be required from zero up to approximately 10^{-3} gravities.

4. Mode of Operation:

Preparation of the tests requires the installation or removal of tank baffles, the switching of selector functions, and the repositioning of cameras. Two to ten data points can be obtained in one test series.

5. Crew Support:

The experiment will require photography during the tests, and critical observation and comments from the astronaut. Each test series is anticipated to require one astronaut for a period of 4 hours. This includes hardware changes, test setup, test operation, and system shutdown time. Each test run should be on the order of 10 minutes or less, during which time up to 10 data points will be obtained.

6. Spacecraft Support:

One proposed envelope indicating placement along the longitudinal section of the vehicle is shown in the attached sketch. The envelope is estimated to weigh 1500 pounds. The power requirement for the system is 500 watts. Data communications required in support of the tests include a photographic record, two differential pressures, one temperature, one flow rate, the appropriate test function, and the acceleration level for each test. Flow rate, temperature, pressure, and acceleration level data should be recorded continuously during each test. Flow rate, temperature, pressure, and acceleration level data should be recorded continuously during each test run. Approximately 30 pounds of film and canisters occupying 1 ft.^{3} of volume will be required on the logistics vehicle supply and return missions.

7. Development Schedule:

The time required to design, fabricate, test and qualify, and deliver the experiment is estimated to be approximately two years.

8. Cost:

It is estimated that the experiment and module required to perform the above experiment will cost approximately $600,000.

9. Spacecraft Interface:

The experiment interfaces with the Fluid Systems Laboratory.

10. Flight Test Program:

The flight test program consists of four study phases; namely the study of fluid transfer, large amplitude sloshing, liquid reorientation, and the formation and coalescence of vapor bubble clusters. Each of these phenomena will be studied systematically in a series of tests which require some hardware changes, refilling, pressure regulation, etc. Test setups, when completed, will allow a series of tests to follow by manipulating console settings. The fluid transfer program, for example, will be conducted in two phases, one investigating the outflow process and the second studying the inflow phenomenon. For the outflow fluid transfer phase, a series of 44 tests will be performed in which the outflow rate from each of the test tanks will be successively varied, with and without baffles installed. A similar schedule is planned for the inflow phase, which includes 40 tests without baffles and an additional series of 60 tests with baffles. The large emplitude slosh programs will require 16 test runs, the reorientation phase: 50 test runs; and the bubble cluster phase: 10 test runs.

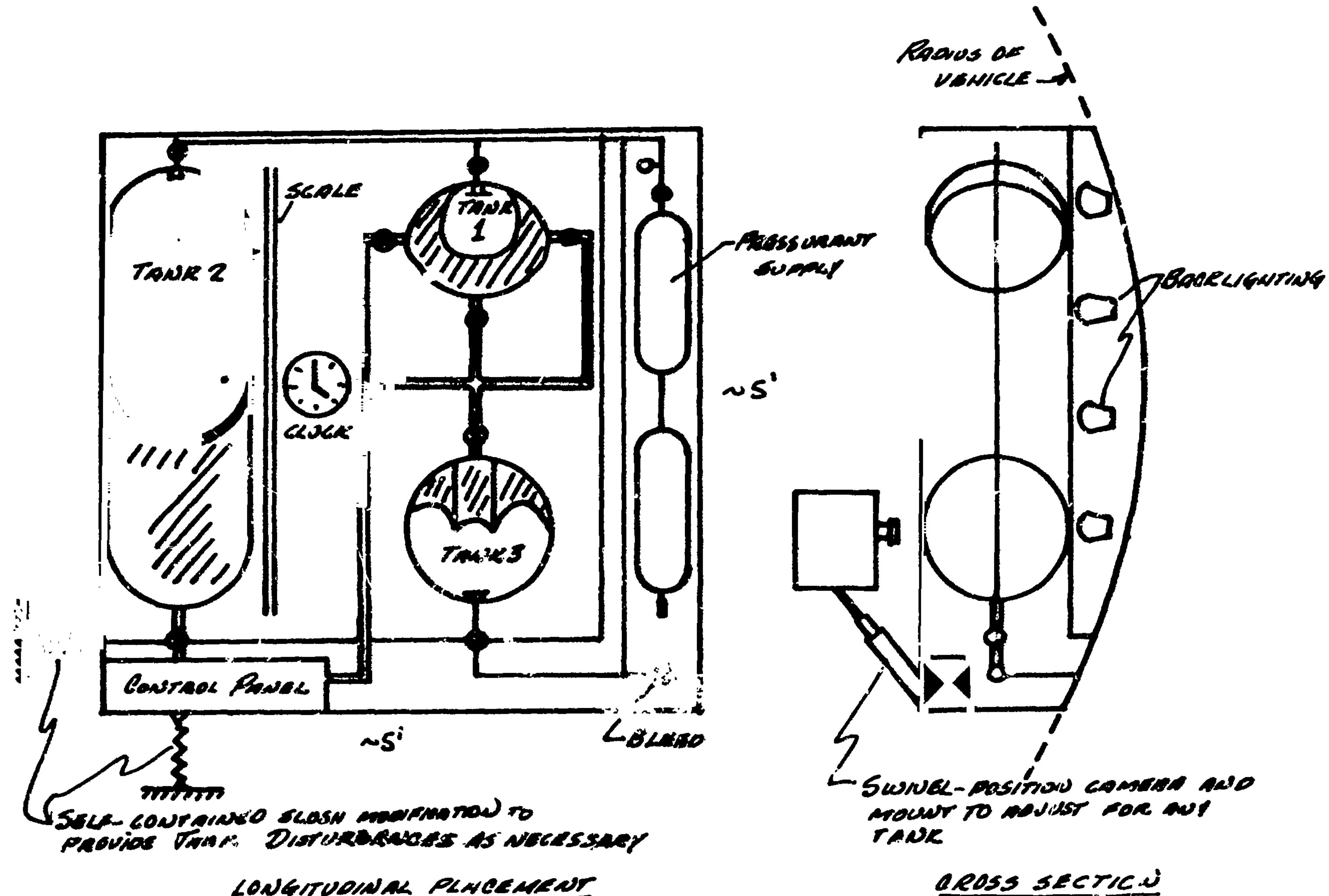


FIG. 1.- FLUID DYNAMICS EXPERIMENTS UNDER REDUCED GRAVITY CONDITIONS

T251

EXPERIMENT/EVENT DATA SHEET VII G

TITLE: FLUID DYNAMICS EXPERIMENTS UNDER REDUCED GRAVITY CONDITIONS

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	VII G-1 (60700T)			
2	220			
3	1			
4	220			
5	0			
6	1			
7				
8	1			
9	16			
10	4			
11				
12				
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	4			
22	250			
23	0			
24	500			
25	6			
26	0			
27				
28				
29				
30	0			
31	0.2			
32	0			
33	1			
34				
35				
36				
37	0			
38				
39				
40	0			

EXPERIMENT DATA SHEET VII H

Liquid Hydrogen Storage and Transfer

1. Specific Objective:

The objective of this experiment is to evaluate various techniques for storage and transfer of liquid hydrogen.

2. General Description:

The experiment involves the evaluation of various insulation and shadow shields as a means of reducing the energy input to a cryogenic storage tank; also, to be evaluated are a thermal conditioning system and a passive venting system to maintain tank pressure at an acceptable level for long term storage. Tests will also be conducted in the transfer of liquids.

The experiment will consist of an eight-foot diameter tank, sixteen feet long, with hemispherical ends (Fig. 1). The experiment will have fill, vent, and pressurization lines attached to one end; and an outflow line at the other end. The tank will be covered with superinsulation and have shadow shields installed at the fill and vent end of the tank. A thermal conditioning system will be installed inside the experiment at the outflow end of the tank with suitable connections to the vent line; provisions will be made for power input at the same point. Quality meters and flow rate meters will be installed in the fill, vent, and outflow lines to determine the fluid mass flow rate. Temperature sensors will be mounted on the outside surface of the tank, on the insulation, and on the shadow shields to determine the rate of energy input to the tank. Carbon resistor rakes will be mounted inside the tank to determine liquid and vapor temperatures and the liquid location. Also, pressure transducers will be used to measure the tank pressure.

As outlined in Paragraph 10, this experiment consists of a single test lasting for a year or more. At the start of the experimental program, the astronauts will fill the test tank with liquid hydrogen from the supply vehicle. During this time they will be required to monitor the experiment. The astronauts will orient the tank such that the shadow shields are pointed away from the sun and maintain this orientation over the next several months. During this time they will operate the thermal conditioning system and periodically record all instrumentation outputs. The astronauts will then reorient the tank such that the shadow shields are pointed toward the sun, settle the propellants by temporarily accelerating the spacecraft, and maintain this orientation over the remaining time. Once again periodic recording of all instrumentation outputs will be required. After a few months in this orientation the astronauts will perform the necessary preparations and monitor the filling of other experiments using the liquid hydrogen from the storage tank.

3. Operational Constraints:

Controlled acceleration levels from 0 to 10^{-4} "g" along the centerline of the experiment are necessary. Disturbances due to crew motion or docking should be minimized. The entire experiment shall be exposed to space vacuum and oriented alternately such that the shadow shields are either facing toward or away from the sun.

4. Mode of Operation:

Astronauts may be required to hook up transfer lines and monitor the filling of the experiment from the Saturn Second Stage. Once the experiment is filled, the astronaut will be required to determine the position of the liquid within the tank and to determine the acceleration level necessary to settle or reorient the liquid. During venting, periodic checks of the quality and flow meters in the vent line will be required. The astronaut will be required to hook up transfer lines and monitor the outflow of liquid hydrogen to be used for other research programs within the fluid dynamic laboratory.

5. Crew Support:

Four man-hours will be required to perform the fuel transfer from the Saturn second stage. One man-hour per day will be required to monitor the venting of the tank during storage periods.

6. Spacecraft Support:

The size of the experiment tank itself (8x16 ft.) is such that it will probably be located outside the spacecraft where its size and envelope will not be critical. The weight of the system is estimated at 5,000 to 10,000 pounds.

The thermal conditioning system will require approximately twenty-five watts of power. The power requirement for the instrumentation is estimated to be less than fifty watts.

Approximately one-hundred data channels will be required to record the output of the pressure transducers, temperature transducers, flow meters, and quality meters. During inflow, outflow, and reorientation tests, data from each channel shall be recorded every ten seconds. During the storage periods, data from each channel shall be recorded once an hour.

7. Development Schedule:

Approximately three years will be required for the design, fabrication, and testing of the experiment module.

8. Cost:

It is estimated that the experiment module could be designed, fabricated and tested for $8,000,000 to $10,000,000.

9. Spacecraft Interface:

The possibility of constructed the experiment as a separate module should be considered in order to minimize the danger associated with liquid hydrogen. One half of the module would contain the experiment described herein with the other half forming a fluid systems laboratory. (See Fig. 1).

If the required accelerations are supplied by thrustors mounted on the experiment module, the module should be docked at the center of gravity of the space station in order to minimize any transverse accelerations.

10. Flight Test Program:

The flight test program consists of one continuous test lasting for a year or more. During this time the various aspects of liquid hydrogen storage and transfer will be studied. The test starts during the operation of filling the tank from the supply vehicle. At this time inflow dynamics (and possibly outflow dynamics from the supply vehicle) will be studied. The test tank will then be oriented with the shadow shields opposite the sun and the performance of the insulation and the thermal conditioning system will be studied. After several months, the test tank will be fired to settle the liquid hydrogen. With the tank in this position the performance of the passive venting system, shadow shields, and insulation can be evaluated. During the later stages of the experimental program it will be permissible to withdraw liquid hydrogen for use in other areas of the space station at which time further outflow dynamics studies will be made.

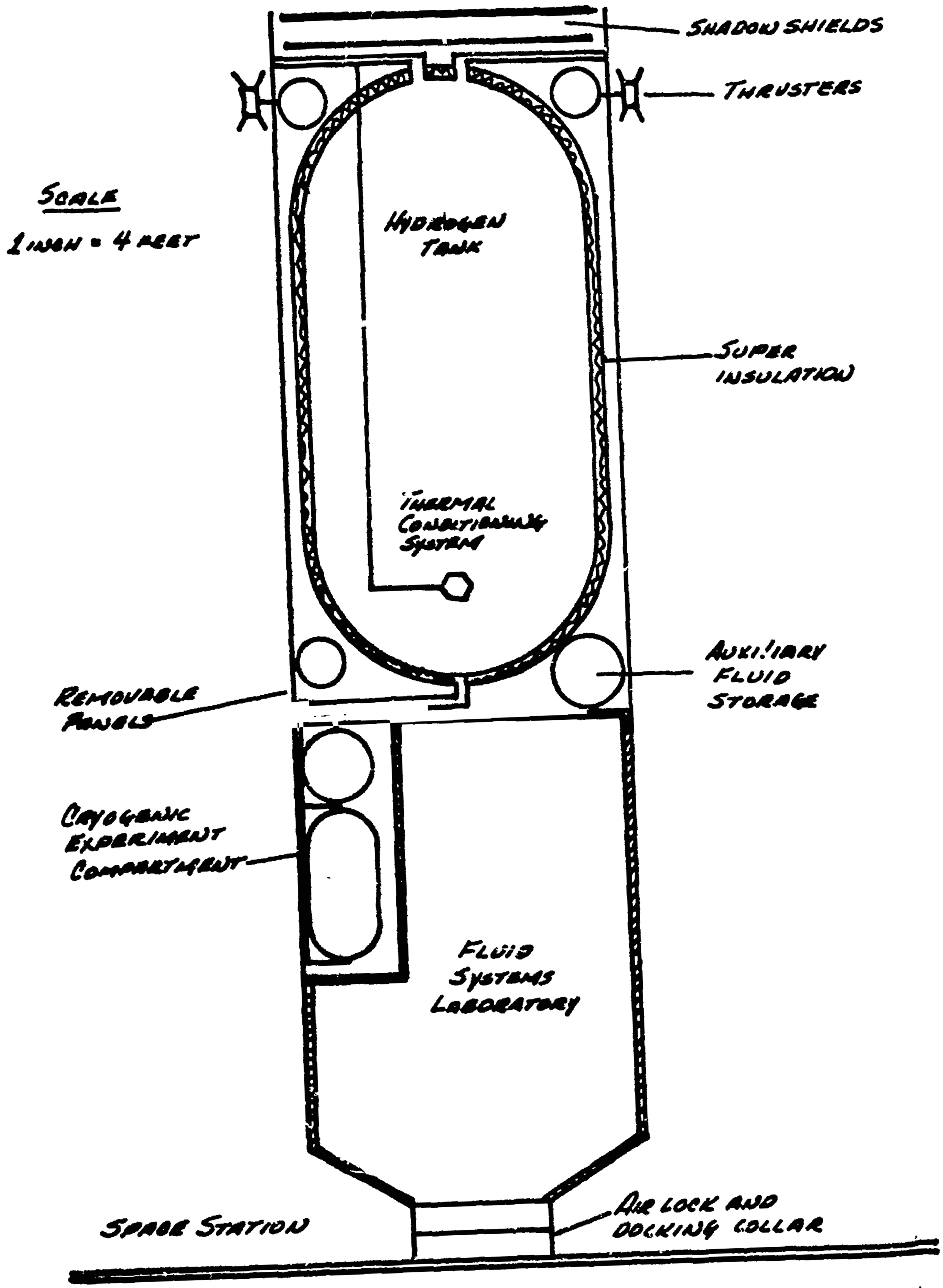


FIG 1.- LIQUID HYDROGEN STORAGE AND TRANSFER.

EXPERIMENT/EVENT DATA SHEET VII H

T258

TITLE: LIQUID HYDROGEN STORAGE AND TRANSFER

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	VII H-1 (607008)			
2	365			
3	365			
4	1			
5	0			
6	1			
7				
8	1			
9	16			
10	1			
11				
12				
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	0.5			
22	75			
23	50			
24	0			
25	0			
26	0			
27				
28				
29				
30	1			
31	0.3			
32	0			
33	1			
34				
35				
36				
37	0			
38				
39				
40	0			

FUNCTIONAL PROGRAM ELEMENT VIII

1. Discipline: Advanced Technology

2. Program Element: Remote Sensor Technology

3. Requirement:

(a) Investigate man's capabilities in the maintenance and calibration of long wavelength infrared (LWIR) and microwave sensors for remote sensing.

(b) Establish the technology for design and development of accurate space calibration facilities for remote sensors.

(c) Examine the accuracy limitations on LWIR sensing due to atmospheric transmittance variability.

4. Justification:

(a) The use of spacecraft for remote sensing of the earth's characteristics is justified by the economic benefits inherent in the quickly-obtained, yet wide-coverage data which is provided. A number of the earth's characteristics desired may be obtained using LWIR and microwave sensors.

(b) The LWIR sensors presently planned depend on the accuracy of prelaunch calibrations performed in a ground-based laboratory, with subsequent inflight calibration checks using devices built into the equipment. The radiometric accuracy required for the remote-sensing applications makes the radiometric stability of the sensors and the accuracy of existing inflight check devices questionable. A manned calibration facility in the space station is therefore needed to examine the calibration stability of such devices as the flight duration increases.

(c) The capability of man to perform adjustments to, and calibration of, precise electro-optical instruments needs to be investigated under the rigors of the space environment. This capability can be best evaluated by the use of such instruments and facilities in a controlled experiment. This experiment is designed to check man's ability to:

(1) Make minor adjustments to sensors.

(2) Setup, checkout, and calibrate sensors to a high degree of accuracy.

(3) Based on apriori knowledge of orbital ephemeris, to plan for and obtain remote measurements of specified earth terrain.

(d) The effects of the earth's atmosphere on remote sensing of earth's surface temperatures from satellite altitudes has not been verified experimentally. The improved accuracy capability provided by the flight calibration laboratory will allow experimental determination of the atmospheric effects through the observation of ground-monitored targets.

5. <u>Component Experiments</u>:

(A) Inflight adjustment and calibration of LWIR and microwave remote sensors.

(B) Evaluation of calibration accuracy and atmospheric variability on remote sensing.

6. <u>Description</u>:

A laboratory will be provided to allow adjustment and precise calibration of radiometric devices operating in the LWIR and microwave regions of the electromagnetic spectrum. An air-lock-mounted, rate-controlled platform will be provided to furnish a stabilized base for a LWIR radiometer which can be pointed at selected earth targets by an astronaut using a boresighted auxiliary guide scope. The LWIR radiometer can be removed from the platform and calibrated several times during the mission. When remounted on the platform, the radiometer will be used to obtain measurements of several ground targets whose characteristics are independently monitored. Several measurements of a single target will be made at difficult nadir angles, each representing a different atmospheric pathlength. These data, when compared to the target information, will allow evaluation of atmospheric effects (variable with pathlength) and calibration accuracy (uncompensated bias in a given measurement set). Observation of the same target at several times in the mission provides variations due to weather or season. Various targets will be selected to obtain variety in surface emissivity characteristics.

7. Special Considerations:

Orbital altitude	$\leq$ 250 n. mi.
Spacecraft pointing	$\pm 2^{\circ}$ - yaw (relative to orbit plane)
	$\pm 3^{\circ}$ - roll or pitch
Spacecraft stabilization	2.0°/sec

An airlock is required for mounting the stabilized platform which can provide radiometer sightlines from nadir to 60° in the direction of orbital motion. The airlock must provide access for removing the radiometer from the platform.

The calibration laboratory will require a space at least 90 in. in one dimension to accommodate the optical bench. Liquid N_2 and regulated dc power must be provided.

EXPERIMENT DATA SHEET VIII A

Inflight Adjustment and Calibration of LWIR
and Microwave Sensors

1. Specific Objective:

The objective of this experiment is to evaluate man's ability to adjust and calibrate infrared and microwave radiometric sensors in space with accuracy comparable to that obtained in ground-based facilities. A further objective is to develop the technology base for precise calibration facilities in the space environment.

2. General Description:

A laboratory will be established on the space station capable of accurate calibration of radiometric devices. The IR calibration facility will consist of a chamber enclosing a component (radiometric sensor) test compartment and containing a cryogenically shrouded calibration device consisting of a blackbody source; a 20-in. diameter, 80-in. focal-length collimator; and a cooled IR detector with its associated readout electronics. Accuracy of the blackbody source is estimated to be of the order of 0.1 percent, which, combined with the shrouded collimator and detector check device, should yield an overall calibration accuracy of approximately 1 percent. The chamber will be vented to the vacuum of space during the calibration of radiometric devices. A radiometer specifically provided for this test is described as a part of experiment VII B. The component test compartment will accept any onboard radiometers requiring calibration by the use of a series of adapters. In the event calibrations of devices in other spectral intervals are desired, additional sources may be provided for use with the existing collimator. The detector contained within the calibration chamber provides a means of checking the stability of the basic calibration apparatus during prelaunch and launch operations, and in orbiting flight. Subsequent to the initial verification of the calibration facility accuracy, the various onboard radiometric IR sensors will be calibrated as required.

The facility for calibration of microwave radiometers consists of a variable-temperature oven with a series of loads which are interchangeable to match various microwave radiometers, and voltage-standing-wave-ratio (VSWR) measuring equipment. It is planned that multichannel microwave radiometers proposed by other experimenters will be tested. If none are available, a single-channel radiometer will be installed as a part of this experiment to evaluate man's calibration capabilities for microwave calibration in space.

3. Operation Constraints:

Pointing the microwave antennas toward space during calibration is required.

4. Mode of Operation:

The crew will determine when use of the space station calibration facility is required. The calibration procedure will be performed manually by the astronaut-scientist.

5. Crew Support:

About 1 hour will be required for an astronaut to calibrate a radiometer. Additional time may be necessary if sensor degradation is evident.

6. Spacecraft Support:

The following requirements are placed on the space station:

Weight: 200 lb

Volume: ≥ 2000 cu ft   Equipment volume ~ 35 cu ft

Size: See figure 1

Power: 200 watts, dc

Cryogen: LN_2 (equivalent to removal of 200 watts)

Data recording: 10 channels, 15-bit word length per channel; 10 measurements per second per channel

The scientific data will be recorded on magnetic tape and transported to the earth with the logistics vehicle.

7. Development Schedule:

Total development - 54 mo.

Engineering model - 24 mo.

Flight hardware - 18 mo.

Payload integration - 12 mo.

8. Cost:

Total Experiment - $2.0 Million

FY 70 - 0.25M

FY 71 - 0.5M

FY 72 - 0.6M

FY 73 - 0.4M

FY 74 - 0.25M

9. Spacecraft Interface:

The main components of the calibration facility will be permanently attached to the spacecraft (see fig. 1). The collimator and component test enclosures, with a total volume of 20 cu ft (0.56 m^3), will be vented to space during each calibration run and refilled with onboard makeup air. The station data-recording facilities are required for the 10 channels of data taken during sensor calibration. A source of liquid N_2 which can be utilized at varying, controllable rates must be available to the facility.

10. Test Program:

To accomplish the objectives of this experiment, the laboratory will be used similarly to a ground facility. The tests performed on a sensor will require determination of the physical operating parameters (primarily temperatures) of the facility and sensor components. Tests must be performed to determine optical focus and field-of-view, in addition to mechanical alinement. Radiometric calibration requires extremely close control and monitoring of the source and shroud temperatures. All pertinent data must be permanently recorded for later detailed analysis.

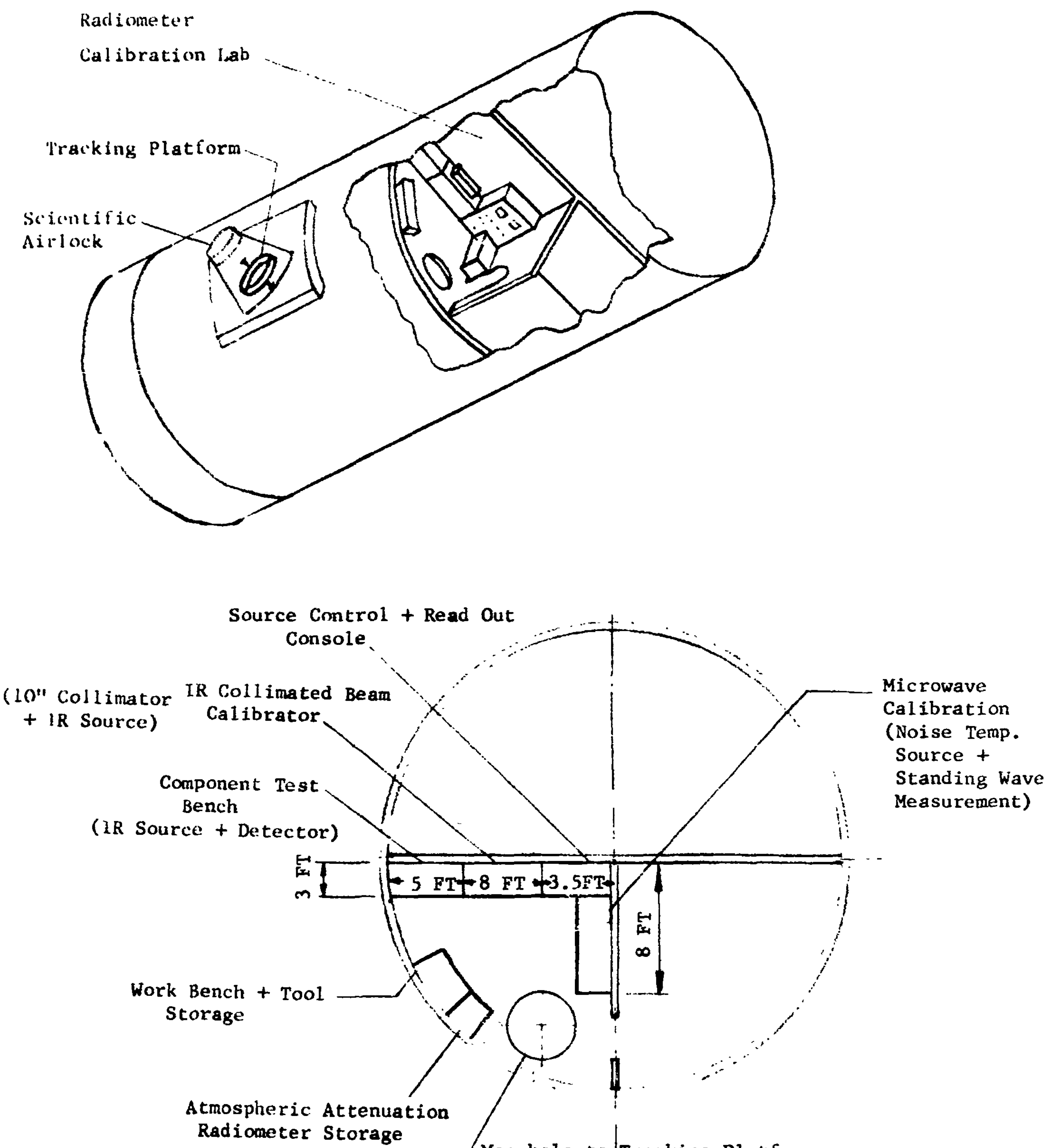


Figure 1.- Orbital radiometer calibration laboratory experiment.

EXPERIMENT/EVENT DATA SHEET VIII A

TITLE: INFLIGHT ADJUSTMENT AND CALIBRATION OF LWIR AND MICROWAVE SENSORS

ITEM No.	PHASE: 1 FUNCTIONAL CHECKOUT	PHASE: 2 ORBITING CALIBRATION LAB. EXPERIMENT	PHASE:	PHASE:
1	VIII A-1 (608001)	VIII A-2 (608002)		
2	1	360		
3	1	1		
4	1	4		
5	0	89		
6	1	1		
7	1			
8	1	2		
9	4	4		
10	1	4		
11		27		
12		0.5		
13				
14				
15				
16				
17				
18	0	0		
19	0	0		
20	0	0		
21	1	4		
22	200	200		
23	0	0		
24	450			
25	45			
26	0	0		
27		608001		
28				
29				
30		0		
31	0	0		
32	0	0		
33	0	0		
34				
35				
36				
37	1	0		
38				
39				
40	0	2		

EXPERIMENT DATA SHEET VIII B

Evaluation of Calibration Accuracy and Atmospheric Variability on Remote Sensing

1. Specific Objective:

The objective of this experiment is to obtain precise long wavelength infrared (LWIR) measurements of ground targets having known characteristics to determine the effects of both radiometer calibration uncertainties and atmospheric attenuation on the accuracy of remote sensing from space.

2. General Description:

A radiometer with a spatial resolution of 200 feet, and designed for the 8-12μ range of the electromagnetic spectrum, is mounted on a rate-controlled platform to observe a preselected ground target. The radiometer can be removed from the platform for calibration in a space station laboratory designed for this purpose (see experiment VIIIA and fig. 1). The stabilized platform is capable of pointing the radiometer to selected targets at nadir angles in the range 0° to 60° in the direction of orbital motion. Measurements at three nadir angles (i.e., 60°, 45°, and 0°) as the spacecraft approaches the target will provide a single target observation set. These data, when compared with ground target characteristics, provide a means of isolating the atmospheric effect (variable with optical path length) and calibration errors (fixed bias for a given set).

The rate-stabilized platform is a two-gimbal system containing two rate gyros. It provides a limited ($\pm 5^{\circ}$) freedom in the yaw plane to allow for uncertainties in the spacecraft pointing relative to the orbital plane, and small lateral orbital position discrepancies relative to the target point.

Each axis of the platform is driven at an angular rate required to maintain the radiometer line-of-sight pointing to a selected target. The gyros also remove short-term angular disturbances caused by space station activity. The platform is manually pointed to a selected target by the astronaut using an auxiliary guidescope, boresighted with the radiometer. The astronaut also sets the orbital characteristics and nominal nadir angle into a small computer, which calculates the rate required for target tracking and drives the appropriate gyro torquer. The radiometer-platform combination must be mounted in a scientific airlock to preclude the use of a window in the station during the observation period, and to provide access to the radiometer for adjustment or removal for calibration from inside the spacecraft. Some of the platform characteristics are shown on figure 2. Figure 1 illustrates the relationship of the platform to the station, however, the platform must be in the belly-down position during data taking. The platform pointing accuracy must be 0.5 arc min and must be rate-driven within 0.002°/sec of the required value, which ranges from 0.3 to 1.2°/sec for the altitude and nadir angle conditions.

The radiometer utilized for this experiment is designed to provide a signal to noise ratio (S/N) = 100 in measuring the radiance increment corresponding to a 1° K temperature change of the earth target. The radiometer characteristics are as follows:

Optical: 25.4 cm clear diameter, f/6

Detector: Ge:Hg (cooled to 20° K utilizing an integral closed-cycle cooler)

Spectral interval: 8-12μ

Ground target spatial resolution: 200 ft × 200 ft

Overall dimensions: 15 in. × 15 in. × 45 in.

Overall weight: 150 lb

The data obtained from the earth observations will be recorded onboard and sent to the ground via ferry for later analysis and comparison with ground-truth data. It is planned that a total of 96 observations will be made, evenly distributed between four targets selected to provide a variety of target characteristics.

3. Operational Constraints:

   (a) Orbital characteristics: Altitude $\leq$ 250 n. mi.

   Inclination $\geq 35^{\circ}$

   (b) Spacecraft attitude: $\pm 2^{\circ}$ yaw relative to orbit plane

   $\pm 3^{\circ}$ roll relative to orbital plane (radiometer must look down in the orbital plane with a clear field-of-view between -30° and -90° (nadir) pitch lines when spacecraft is at 0° pitch)

   (c) Spacecraft stabilization: 2.0°/sec

4. Mode of Operation:

   The experiment activity will be performed on an intermittent basis and scheduled according to target availability. The stabilized radiometer is mounted on the station and manually controlled during the measurement periods.

5. Crew Support:

   The crew will select and program target observations in accordance with orbital ephemeris and target characteristics. Crew will activate and point the observation platform for the measurements. Each observation requires approximately 1 hour for an astronaut trained in operation of the system.

6. Spacecraft Support:

   (a) Power: 20 watts, dc

   (b) Volume: 360 cu ft (spherical airlock)

(c) Weight: 250 lb

(d) Envelope: Airlock-sphere, 53 inch radius

(e) Data recording: 7 channels total

(1) 3 channels, space station attitude - 1 kbps/ch

(2) 2 channels, platform angles - 1 kbps/ch

(3) 2 channels, radiometer output - 1 kbps/ch

7. Development Schedule:

Total development time - 54 mos.

Engineering model - 24 mos.

Flight hardware - 18 mos.

Payload integration - 12 mos.

8. Cost:

Total Experiment $1.8M

FY 71 - 400K

FY 72 - 300K

FY 73 - 400K

FY 74 - 450K

FY 75 - 250K

9. Spacecraft Interface:

The scientific airlock must be located to view the earth when the space station is in a belly-down position. It should be located near the Remote Sensor Calibration Laboratory. The data recording outputs from this experiment must include the orbital attitude of the space station and time.

10. Test Program:

Observation of an earth target will require accurate knowledge of the sensor radiometric output, operating conditions (i.e., the detector temperature), and the spatial quantities which specify the sight-line position and direction. Measurements will include spacecraft parameters, such as position over the earth and precise attitude measurements, as well as the time of the observation(s). The gimbal angles and rates of the pointing platform must also be known.

Limited in-situ measurements of the earth target are also required to meet the experiment objectives. For example, the surface temperature must be measured close to the time of space observation. Visual observations of the surface state (i.e., wave height, if the target is water) and lighting conditions are of value. Use of "standard" meteorological data sources will provide adequate knowledge of atmospheric conditions.

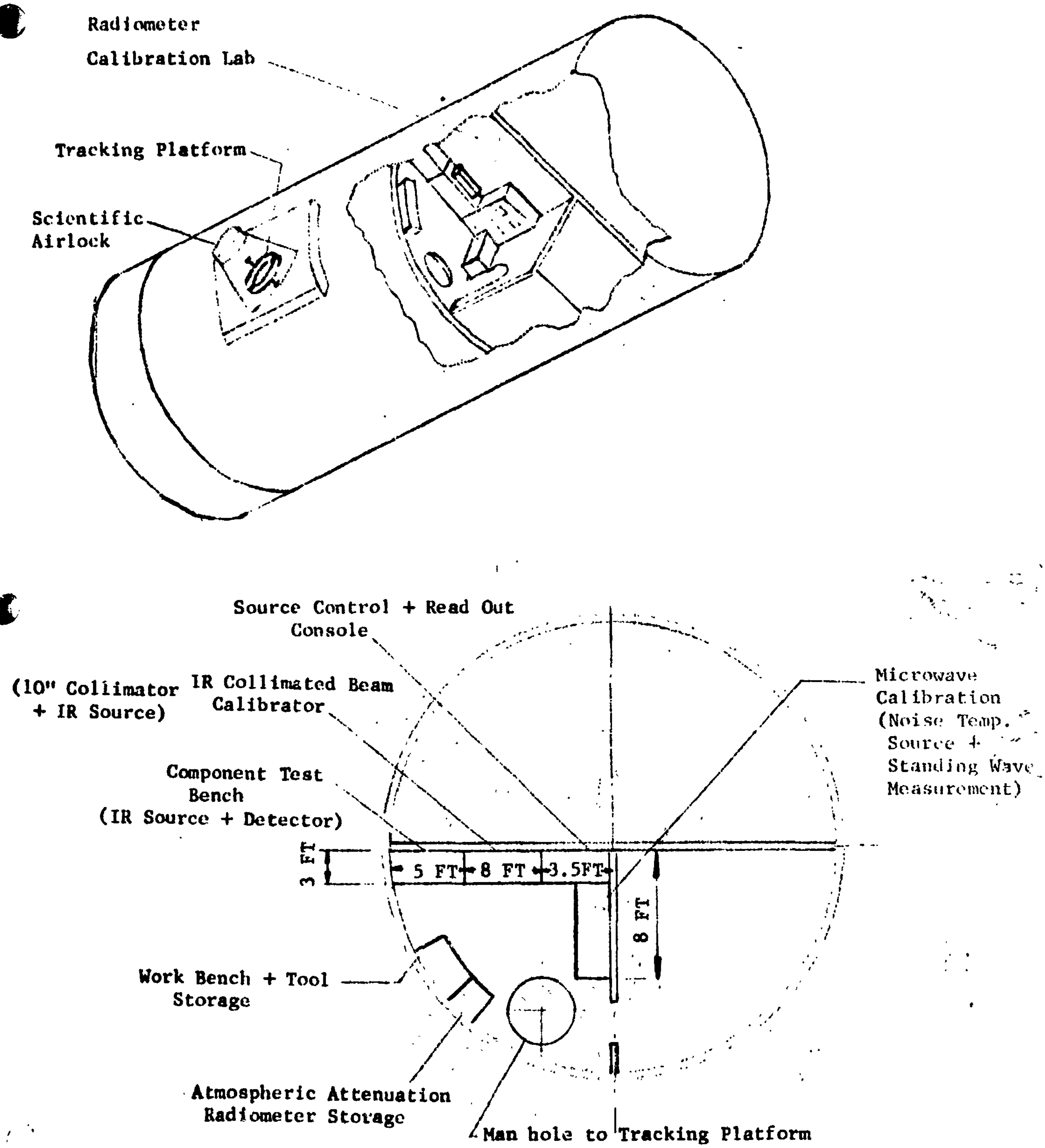


Figure 1.- Orbital Radiometer Calibration Laboratory Experiment

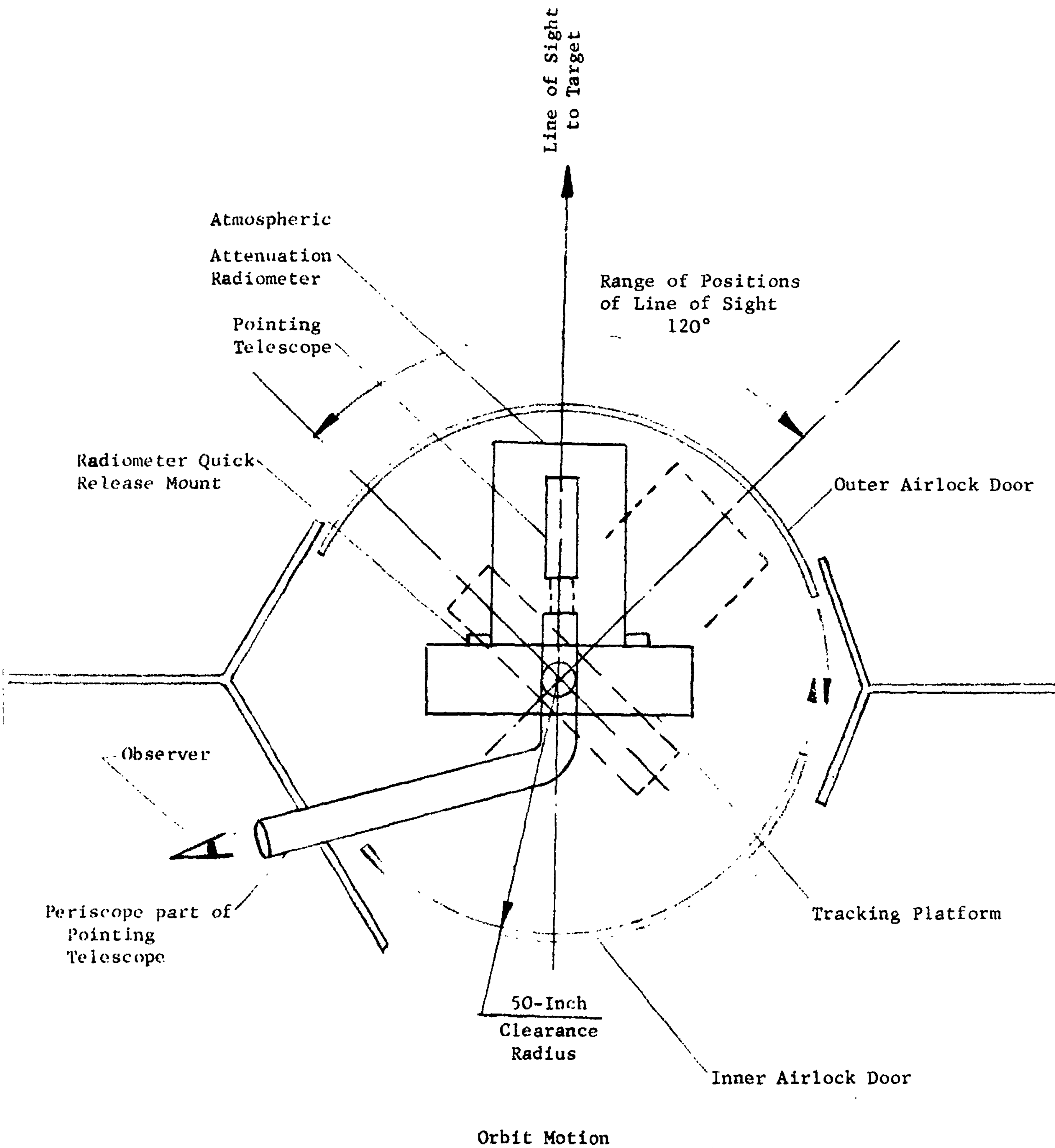


Figure 2.- Scientific airlock with atmospheric attenuation radiometer.

EXPERIMENT/EVENT DATA SHEET VIII B

T275

TITLE: EVALUATION OF CALIBRATION ACCURACY AND ATMOSPHERIC VARIABILITY ON REMOTE SENSING

ITEM No.	PHASE: 1 ATMOSPHERIC ATTENUATION RADIOMETER EXPERIMENT	PHASE: 2-9 SAME AS VIII B-1 (8 ADDITIONAL OBSERVATIONS)	PHASE: 10 SAME AS VIII B-1 EXCEPT SHORTER DURATION	PHASE:
1	VIII B -1 (608010)	VIII B-2-9 (608020-608090)	VIII B -10 (608100)	
2	10	10	6	
3	1	1	1	
4	10	10	6	
5	0	0	0	
6	1	1	1	
7				
8	1	1	1	
9	27	27	27	
10	0.9	0.9	0.9	
11				
12				
13				
14				
15				
16				
17				
18	0	0	0	
19	0	0	0	
20	0	0	0	
21	0.9	0.9	0.9	
22	200	200	200	
23	0	0	0	
24	0.2	0.2	0.12	
25	0.1	0.1	0.06	
26	0	0	0	
27	608001	608001	608001	
28				
29				
30	-1	-1	-1	
31	0.5	0.5	0.5	
32	0	0	0	
33	1	1		
34				
35				
36				
37	0	0	0	
38				
39				
40	2	2	2	

FUNCTIONAL PROGRAM ELEMENT IX

1. Discipline: Advanced Technology

2. Program Element: Onboard Centrifuge

3. Requirement:

A requirement exists for a centrifuge in order to provide a facility that can be used to:

(a) Acquire information for the design of advanced space vehicles and for mission planning.

(b) Evaluate new ways to support man in a zero-g environment.

(c) Advance the general scientific knowledge in experimental areas that cannot be duplicated on earth.

4. Justification:

The centrifuge is an onboard facility providing artificial gravity from 0 to 9g and a rotational environment for accomplishing the following:

(a) Evaluate man's walking mobility at various levels of rotational gravity.

(b) Evaluate man's capability of performing work tasks such as repair, maintenance, operations, etc., at various levels of rotational gravity.

(c) Evaluate habitability at various levels of artificial gravity. This includes evaluation of man's ability to perform personal-care functions such as defecation, waste handling, and bathing. It may also include food preparation, eating, drinking, etc.

(d) Establish the effects on man of weightlessness, reduced gravity, and rotation in the absence of earth's gravity and during space flight in terms of orthostatic and acceleration tolerance, vestibular thresholds of response and sensitivity, and interaction of otolith and semicircular canals.

(e) Evaluate and maintain astronaut proficiency through simulation of reentry maneuvers with acceleration.

(f) Determine the value of centrifuge artificial gravity for allaying and reversing the physiological adaptation to weightlessness.

(g) Determine astronaut mass by use of a rotational force field.

(h) Study equipment and tool design for artificial gravity.

(i) Investigate long-term adaptation to rotating environments.

(j) Study influence of weightlessness, reduced gravity, and rotation on plants, lower animal forms, and primates.

(k) Perform physical experiments and component tests that require artificial gravity or involve artificial gravity as an experimental variable.

5. Component Experiments:

Experiment A - Centrifuge Facility Evaluation

Experiment B - Walking Mobility and Balance as a Function of Rotationally Induced Inertial Support

Experiment C - Bench Task Performance as a Function of Rotationally Induced Inertial Support

Experiment D - Personal Care Capability as a Function of Rotationally Induced Inertial Support

Experiment E - Reentry-Acceleration-Profile Simulation

Experiment F - Cardiovascular and Vestibular Effects

Experiment G - Therapeutic Support Evaluation

6. Description:

The facility consists of the basic rotating member mounted in the centrifuge chamber, and the control and monitoring station. The centrifuge chamber is a clear cylindrical area 21 ft in diameter and 77 in high. A 42-in. maximum-diameter clear passageway through the center of the facility can be provided if required. A weight of 2000 lb is estimated for the rotating portion of the centrifuge, and approximately 800 lb will be required for peripheral stationary equipment. The latter weight includes two control-moment gyros, a control and monitoring console, and the centrifuge support structure. Maximum moment of inertia and momentum of the rotating member are estimated at 1440 ft-lb-sec^2 and 9040 ft-lb-sec, respectively.

Main elements of the centrifuge are the hub and support frame, arms for radius change of the test subject and counterbalance system, the pivot and roll ring assembly containing an instrumented couch for physiological experiments, the waste collection and shower facility, and the inertial-support experiment chamber.

7. Special Considerations:

(a) All experiment operations require a centrifuge operator/monitor as well as a test subject.

(b) Safety procedures have been developed as part of the centrifuge experimental program. Adherence to these procedures are of prime consideration for the operation of the centrifuge.

(c) Maximum continuous disturbance inputs to the space station will be 5 lb at a rotational frequency of 0.96 Hz. Spacecraft first-mode bending frequencies should be such as to avoid problems of amplification and dynamic coupling. The centrifuge facility should be considered a major driver for the design of the space station control system.

(d) The centrifuge facility can be installed in an appropriate module docked to the basic station or it can be made an integral part of the basic station. If the centrifuge facility is integral with the space station, it should be located as near as possible to the station center of gravity in order to minimize disturbance inputs to the station.

(e) Due to the size of some of the centrifuge structural subassemblies, considerable open access to the centrifuge chamber should be provided during initial installation. Bulkheads to which the centrifuge is mounted should not be subject to dimensional changes resulting from differential temperature and pressure. Adequate stiffness of such bulkheads must be provided to avoid structural resonance and control-stability problems during operation.

BIBLIOGRAPHY

1. Anon: Feasibility Study of a Centrifuge Experiment for the Apollo Applications Program. General Dynamics/Convair, NASA CR-66649, 66650, 66651, 66652, Vol. 1-4.

2. Brady, James F.: Experiment Development for the T-010 Space Research Centrifuge. General Dynamics/Convair, NASA CR-66730.

3. Unpublished data from Contract NAS1-8751, Feasibility Study of Center Passageway Incorporation Into Centrifuge. General Dynamics/Convair. (Final report will be available August 1969.)

EXPERIMENT DATA SHEET IX A

Centrifuge Facility Evaluation

1. Specific Objective:

The objective of this experiment is to provide, checkout, maintain, and evaluate a centrifuge facility which will be capable of performing the experiments described in subsequent experiment data sheets.

2. General Description:

The major elements of the facility consist of the basic rotating member mounted in the centrifuge chamber, and the control and monitoring station. For the experimental program described, the centrifuge chamber is a clear cylindrical area 21 feet in diameter and 77 inches high. 42-inch maximum diameter clear passageway through the center of the facility can be provided if required. A weight of 2,000 pounds is estimated for the rotating portion of the centrifuge and approximately 800 pounds will be required for peripheral stationary equipment. The latter weight includes two control-moment gyros, a control and monitoring console, and the centrifuge support structure. Maximum moment of inertia and momentum of the rotating member are estimated at 1440 ft-lb-sec^2 and 9040 ft-lb-sec, respectively.

The basic centrifuge concept is illustrated by figure 1. Main elements are the hub and support frame, arms for radius change of the test subject and counter balance system, the pivot and roll ring assembly containing an instrumented couch for physiological experiments, the waste collection and shower facility, and the inertial-support experiment chamber. The test-subject instrumentation will make maximum use of equipment developed under the Integrated Medical-Biological Laboratory Measuring System study (IMBLMS) and will be integrated into a couch such as that illustrated by figure 2.

The major centrifuge facility subsystems are listed as follows:

(a) Electrical power.

(b) Data collection and sensing.

(c) Drive and positioning controls and control logic.

(d) Experiment and biomonitoring instrumentation.

(e) Video and audio communications. (telemetry)

(f) Imbalance sensing and control.

(g) Counter-momentum system; dual, counter-torqued, single axis control-moment gyros (300 lbs/gyro, 2450 lb-ft-sec/gyro, 56 watts/gyro).

(h) Lighting.

(i) Environmental control for centrifuge chamber.

3. Operational Constraints:

Operational constraints are generally applicable only to the individual subsequent experiments. No operational constraints are foreseen during facility initial preparation. However, during checkout, maintenance, and evaluation of the rotating member the space station control system should be in the hold-mode. No finely controlled experiments should be scheduled at this time.

4. Mode of Operation:

Initial facility qualification consists of physical and visual inspection and one automatic centrifuge dynamic checkout over the normal operating range. Facility maintenance and evaluation will involve periodic physical inspection, subsystem checkout, and replenishing of expendables. It will furthermore involve automatic recharging of batteries and checkout of the centrifuge combined dynamic systems.

5. Crew Support:

Initial preparation and checkout will require one astronaut for one hour. Subsequent facility maintenance and evaluation will involve two astronauts, at least once every 10 days.

6. Spacecraft Support:

The space station must provide electrical power for instrumentation, communications centrifuge drive, and counter-momentum system during initial facility preparation and subsequent evaluation. Peak power of 5.3 kW of 28 vdc for one minute will be required once every 10 days for dynamic systems evaluation. Average power requirement for the duration of the experiment is approximately 500 watts.

7. Development Schedule:

The development schedule for the centrifuge facility and experiment program as estimated by a contractor study is shown by Table I. The schedule features the development of a ground-based, engineering prototype of the centrifuge prior to design and fabrication of the flight article. The conceptual study which preceeds all other activities is currently in progress.

8. Cost:

The total cost is estimated to be $22,028,000. Table II shows a cost breakdown for the centrifuge experiment program in two phases. The first phase, the Ground Test Unit program, is currently estimated to cost about $3.83 million, and the follow-on flight-unit program about $18.2 million. The incremental cost of a flight unit is estimated at about $7.2 million. Costs for biomedical sensors, biomedical test program, and NASA in-house effort are excluded.

The ground-test unit consists of a centrifuge unit, an air-bearing support structure, and a facility to house the unit. The ground-test unit is assumed similar to the flight unit in function, design, operation, configuration, and materials. The differences principally lie in the test program for flight qualification and the quality control/reliability program.

9. Spacecraft Interface:

The centrifuge facility may be flown as an integral part of the space station. In this configuration, the centrifuge would have a passageway through the hub to integrate it with a space station center-core passageway. Integral with the space station, the centrifuge facility becomes a major driver for the design of the space station control system. In order to minimize disturbance ir[illegible] the station, the centrifuge should be located as near to the st[illegible] [illegible]ter of gravity as possible. The centrifuge may also be within a separate module launched with a logistics vehicle and then docked to the space station.

10. Test Program:

Flight test of a centrifuge facility would consist of the following:

(a) Initial facility preparation and checkout.

1. Activate support equipment,ie., batteries, lighting, environmental control system, communications.

2. Make physical inspection of chamber, verify equipment status, and adjust centrifuge geometry.

3. Checkout monitor's console.

4. Conduct centrifuge combined-systems dynamic checkout procedure.

5. Verify centrifuge systems readiness.

(b) Facility Maintenance and Evaluation.

1. Routine check list.

2. Replenish expendibles.

3. Recharge batteries.

4. Conduct centrifuge combined-systems dynamic checkout procedure.

5. Evaluate checkout data and verify centrifuge facility status.

Table I. Centrifuge Facility Development Schedule

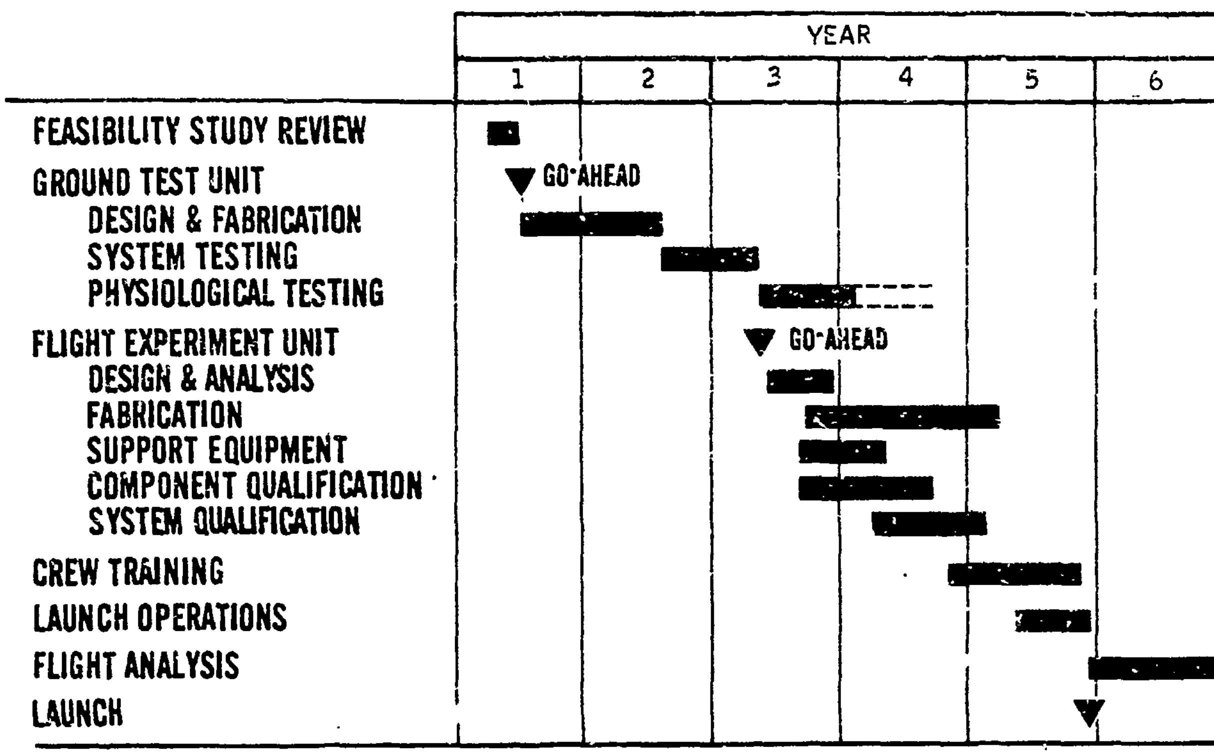


Table II. Centrifuge Facility Cost Analysis (Thousands of Dollars)

GROUND UNIT PROGRAM		3,830
PROGRAM MANAGEMENT	156	
ENGINEERING DESIGN AND DEVELOPMENT	1,200	
HARDWARE	1,750	
TOOLING	117	
TEST AND EVALUATION	525	
SPECIAL TEST EQUIPMENT	69	
FACILITIES	13	
FLIGHT UNIT PROGRAM		18,198
PROGRAM MANAGEMENT	994	
ENGINEERING DESIGN AND DEVELOPMENT	4,076	
HARDWARE	9,618	
TOOLING	470	
TEST AND EVALUATION	1,200	
GSE	320	
MISSION SUPPORT	1,[illegible]0	
TOTAL	22,028	

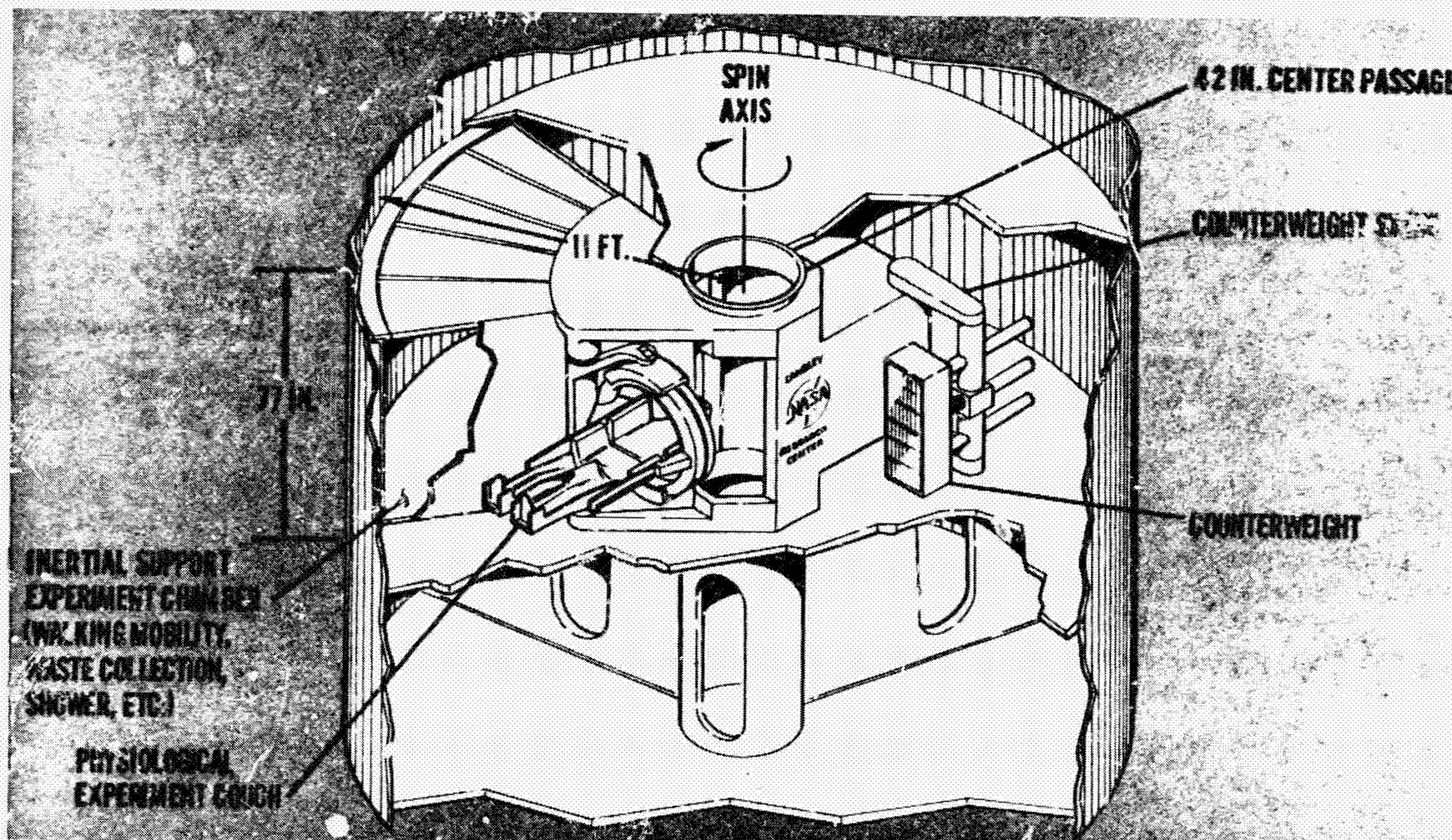


Figure 1.- Research centrifuge facility concept.

(a) Overall schematic drawing.

T287

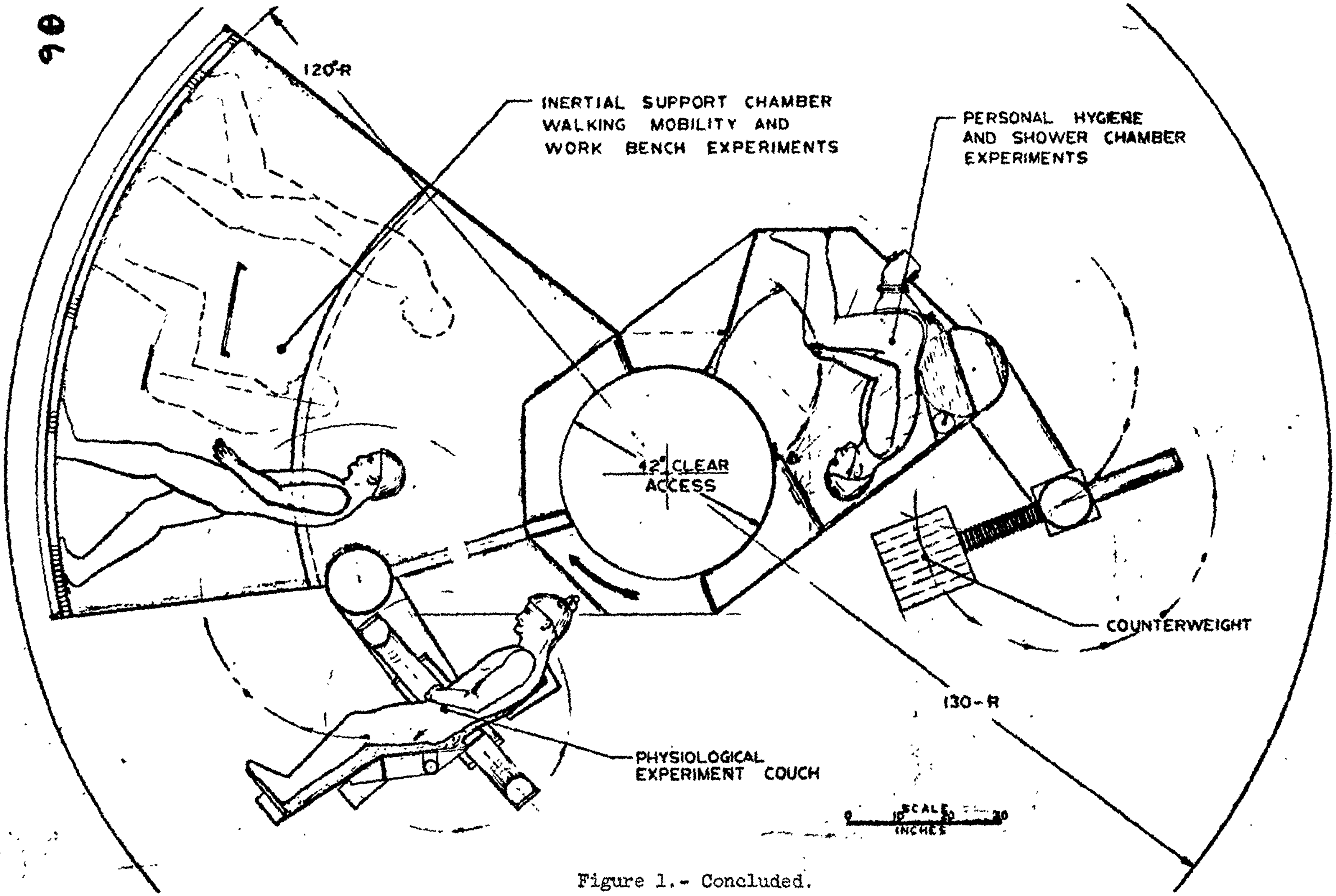


Figure 1.- Concluded.

(b) Detailed plan view.

T288

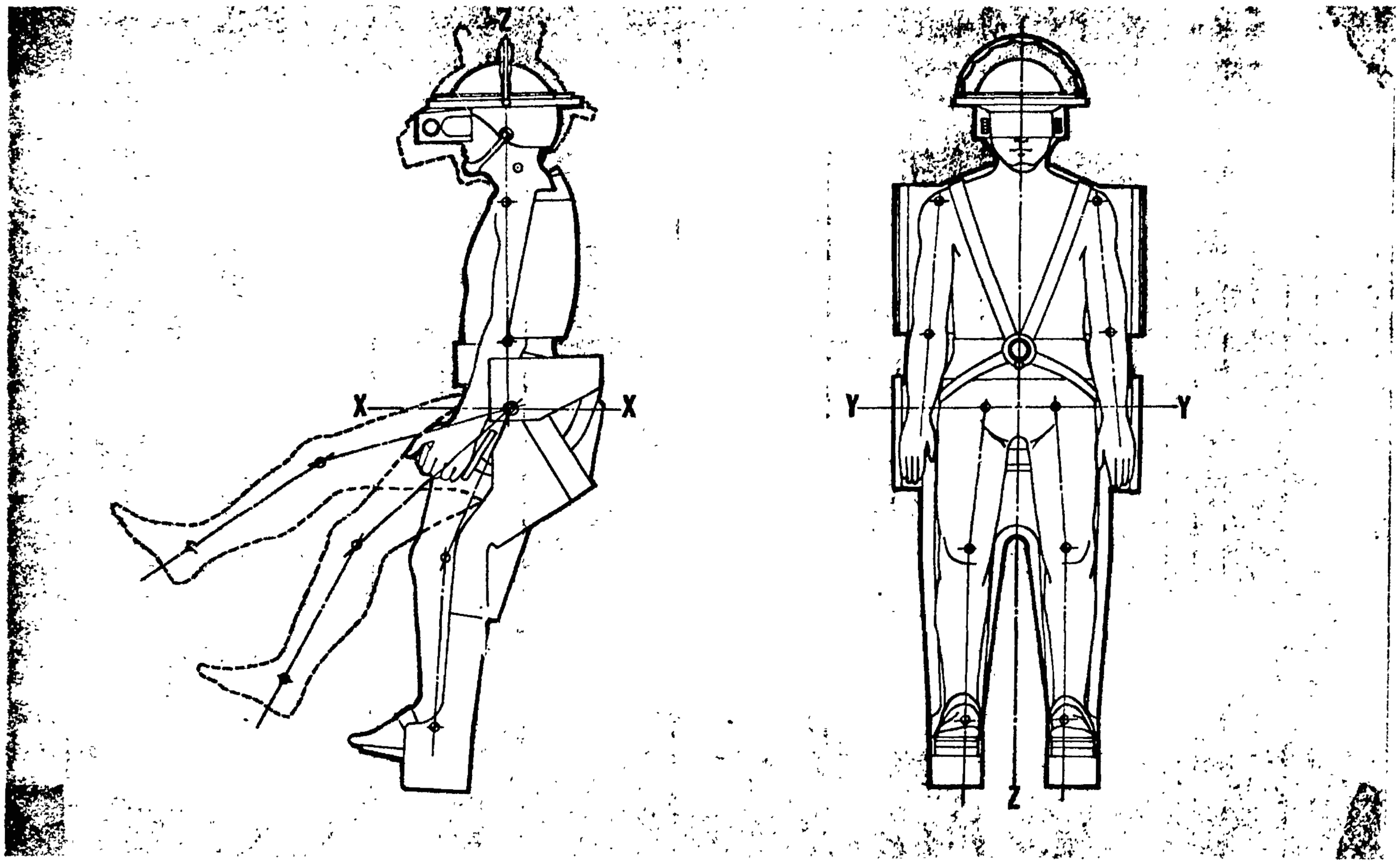


Figure 2.- Test subject couch concept.

EXPERIMENT/EVENT DATA SHEET IX A

T290

TITLE: CENTRIFUGE FACILITY EVALUATION

ITEM No.	PHASE: 1 INITIAL PREPARATION AND CHECK-OUT	PHASE: 2 MAINTENANCE AND EVALUATION	PHASE:	PHASE:
1	IX A-1 (609001)	IX A-2 (609011)		
2	1	3.0		
3	1	1		
4	1	36		
5	0	9		
6	1	1		
7	7	0		
8	1	1		
9	27	27		
10	1	1.25		
11				
12				
13				
14				
15				
16				
17				
18	0	0		
19	0	0		
20	0	0		
21	1	1		
22	500	500		
23	0	0		
24				
25				
26				
27		609001		
28				
29				
30				
31	0	0		
32				
33	1	1		
34				
35				
36				
37				
38				
39				
40	0	2		

EXPERIMENT DATA SHEET IX B

Walking Mobility and Balance as a Function of Rotationally Induced Inertial Support

1. Specific Objective:

The objective of this experiment is to establish the capability of man to effectively walk and maintain postural equilibrium at various levels of centrifugation.

2. General Description:

Subjects will be tested in a two-part standing/mobility test, with the complete test being performed at each of four g levels*(0.1, 0.2, 0.3, and 0.4g). Test design will permit quantitative rating of performance as a function of the g level. Testing will involve both tangential and axial excursion components, with radial components limited to marginal limb movements parallel to the subject's long-body axis.

The test floor (see fig. 1) will consist of 55 square feet of cushioned surface (comparable to Ensolite) marked off in a grid of 6 by 6-inch squares, each of whose coordinates is boldly designated alpha-numerically to facilitate performance rating. The floor is curved along the centrifuge circumference to place it at equal radius at all points. Compartment bulkheads are padded and the subject is unrestrained but wears a protective headgear. The subject's clothing shall be marked with fluorescent lines or spots, to facilitate cinematographic evaluation of walking.

The subject's balancing ability will be rated on the basis of standing time. Walking along designated floor paths will be evaluated on the

*Measured at floor level.

basis of number of in-and-out-of-balance steps, timing, subject's anecdotal rating, and cinematographic records.

The experiment will be performed using each of four subjects eight times during an assumed 45-day crew rotation period. Longer crew rotation periods are acceptable to the experiment.

3. Operational Constraints:

In order to minimize test subject discomfort, space station motions should be minimized during this experiment. Stabilization must be maintained such that the cross-product of angular velocities at the subject's head remains below $100^{o}/sec^{2}$.

4. Mode of Operation:

The centrifuge will be rotated using automatic mode.

5. Crew Support:

The experiment will require four subjects eight times for 1.3 hrs, or 11 hrs/subject during the mission. An operator/monitor will be required during each experiment. Subjects may serve as each others monitors.

6. Spacecraft Support:

Peak power requirement for the experiment is 2.5 kW at 28 vdc for one minute. Average power requirement for the duration of the experiment is approximately 800 watts. Two channels at 3×10^{6} bits/channel will be required for storing biomedical data. Logistic support for returning approximately 10 lbs of film will also be required.

7. Development Schedule:

Same as for Centrifuge Facility Evaulation Experiment IX A-7.

8. Cost:

Same as for Centrifuge Facility Evaluation Experiment IX A-8.

9. Spacecraft Interface:

Same as for Centrifuge Facility Evaluation Experiment IX A-9.

10. Test Plan:

The first part of the standing/mobility test involves restricted mobility (RM), the second part unrestricted mobility (UM). The first offers the advantages of greater experiment control, easier scoring quantification, and a substantial normative and experimental data bank from previous ground-based testing. The UM relates more directly to operational mobility requirements.

The RM testing includes standing with eyes closed (SEC) and walking with eyes closed (WEC), both performed with feet tandemly heel-to-toe, arms folded against the chest, and body erect. The scoring rates standing time, and number of in-balance steps and their direction along oblique lines AA' and BB' (fig. 1). UM testing requires normal walking and emergency running rates around path CC', including intra-trial reversals in the mobility direction. UM scoring is based on timing of mobility cycle, numbering of required steps, subject anecdotal ratings, and gait parameters to be subsequently extracted from cinematographic records.

Full testing sequence (RM + UM) will be repeated at all g levels during one testing session. Balancing of cumulative artifacts will be effected by scheduling a complete testing session eight times (each utilizing a different primary g-level permutation) during a mission for each subject, requiring a mission time-commitment of 8 times 1-1/3 hrs, or 11 hrs/subject.

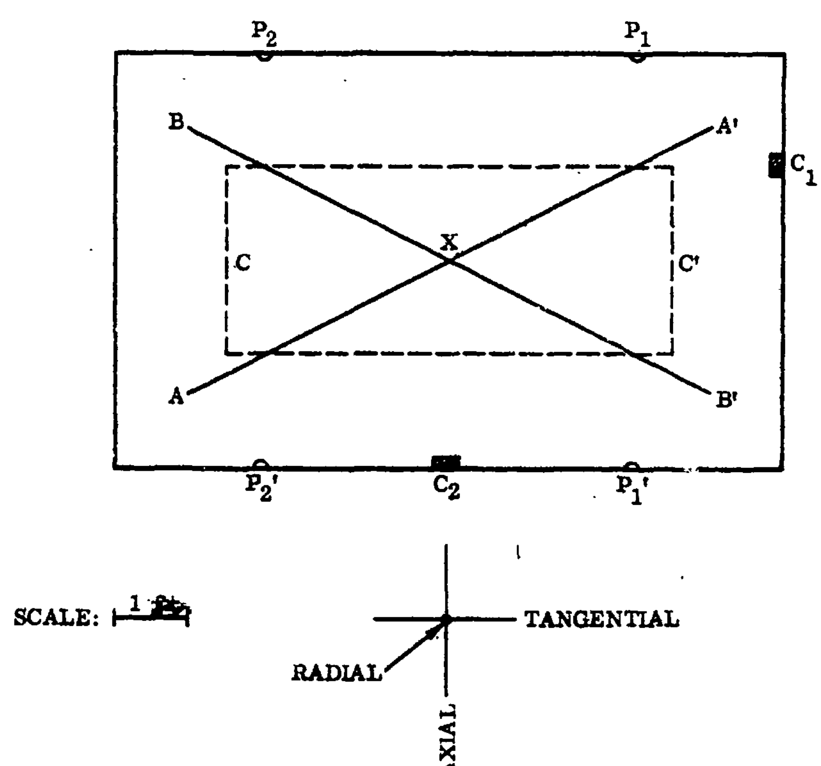


Figure 1.- Radial view of mobility test area.

C_1, C_2 - Cameras

P_1, P_2, P_1', P_2' - Photoelectric camera controls

EXPERIMENT/EVENT DATA SHEET IX B

TITLE: WALKING MOBILITY AND BALANCE AS A FUNCTION OF ROTATIONALLY-INDUCED INERTIAL SUPPORT

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	IX B-1 (609002)			
2	40			
3	4			
4	8			
5	1			
6	1			
7	0			
8	2			
9	27			
10	1.5			
11	27			
12	1.5			
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	1.5			
22	800			
23	0			
24	1			
25	0.1			
26	0			
27	609001			
28				
29				
30	0			
31	0			
32				
33	1			
34				
35				
36				
37	1			
38				
39				
40	2			

EXPERIMENT DATA SHEET IX C

Work Task Performance as a Function of Rotationally Induced Inertial Support

1. Specific Objective:

The objective of this experiment is to establish the capability of man to perform work tasks at various levels of artificial gravity.

2. General Description:

The subjects will be tested on a battery of perceptual-motor tasks that encompass all of the fundamental hand-eye abilities required to adequately perform all bench tasks. The battery of tests is integrated into two consoles (subject's and examiner's). The range of artificial g will be provided by the onboard centrifuge. Each subject will be tested facing tangential at four floor g levels (0.1, 0.2, 0.3, and 0.4g) during one testing period. Scores will be evaluated by comparing them to normative scores established in ground laboratory baseline testing.

Subjects will also be tested on assembly and disassembly of small spacecraft components.

3. Operational Constraints:

Space station stabilization must be maintained such that the cross product of angular velocities at the subject's head remains below $100^{\circ}/s^2$.

4. Mode of Operation:

Each test is programed and conducted automatically from the examiner's console. The centrifuge will be rotated using automatic mode.

5. Crew Support:

The experiment will require four subjects four times for 3 hours, or 12 hours/subject during the mission. Each experiment requires an examiner and an operator/monitor. Subjects may serve as each other's examiners and operator/monitors. Approximately 40 hours of ground laboratory training and practice will be required to raise each subject to an asymptotic level of proficiency in performing the test.

6. Spacecraft Support:

Peak power requirement for the experiment is 2.5 kW at 28 vdc for 1 min. Average power requirement for the duration of the experiment is approximately 500 w s. Storage volume for the testing equipment will be required when it is not in use. Data storage for 1470 bits/test at a rate of 10 bits/sec will be required.

7. Development Schedule:

Same as for Centrifuge Facility Evaluation Experiment, IX A-7.

8. Cost:

Same as for Centrifuge Facility Evaluation Experiment, IX A-8.

9. Spacecraft Interface:

Same as for Centrifuge Facility Evaluation Experiment, IX A-9.

10. Test Program:

The console battery includes 18 perceptual-motor tests which score on 21 perceptual-motor performance parameters. Typical perceptual-motor tests that may be used are the Arm-Hand Steadiness Test, the Control-Precision Test, and the Multilimb Coordination Test. Subject will be tested facing tangentially but not axially, as it has already been determined that the former is significantly more desirable as it precludes vestibular coriolis stimuli due to pitching head movements. Subject will repeat battery of tests at each of four floor g-levels (0.1, 0.2, 0.3, and 0.4g) at one continuous testing period. Scores will be related to normative data levels established in ground laboratory baseline testing subsequent to training to an asymptotic proficiency. Four degrees of primary ordering freedom (g sequence ascending and descending, tangential facing with and against rotation) recommend four complete testing sessions for each subject. Each session requires approximately 3 hours resulting in a total mission time per subject of 12 hours.

EXPERIMENT/EVENT DATA SHEET IX C

T300

TITLE: WORK TASK PERFORMANCE AS A FUNCTION OF ROTATIONALLY-INDUCED INERTIAL SUPPORT

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	IX C-1 (609003)			
2	8			
3	2			
4	4			
5	0			
6	1			
7	0			
8	3			
9	27			
10	3			
11	27			
12	3			
13	27			
14	3			
15				
16				
17				
18	0			
19	0			
20	0			
21	3			
22	500			
23	0			
24	0			
25	0			
26	0			
27	609001			
28				
29				
30	0			
31	0			
32				
33	1			
34				
35				
36				
37	1			
38				
39				
40	2			

EXPERIMENT DATA SHEET IX D

Personal-Care Capability As A Function of Rotationally Induced Inertial Support

1. Specific Objective:

The objective of this experiment is to establish the capability of man to perform personal-care functions, for example, defecation and bathing, at various levels of artificial gravity.

2. General Description:

Each time a crewman performs one of the personal-care tasks during his normal daily routine, he will do so at a predetermined g level as scheduled by the ordering of the four g-levels (0.1, 0.2, 0.3, and 0.4g) at a radius of 4.5 ft. The crew member will rate each performance immediately following its completion by ranking a list of appropriate parameters on a habitability scale. At the end of the study, each crewman will have performed and rated each personal care function nearly an equal number of times at each of four g levels.

3. Operation Constraints:

In order to minimize astronaut discomfort while performing personal-care functions, spacecraft stabilization must be maintained such that the cross product of angular velocities at the subject's head remains below $100^{\circ}/sec^2$.

4. Mode of Operation:

After the astronaut has entered the personal-hygiene area, the centrifuge will be operated in the automatic mode.

5. Crew Support:

This personal-care facility will be used on a semi-scheduled basis in addition to the space station operational facility. It is recommended that the facility be used a minimum of once per day by one astronaut. It is estimated that personal-care functions will require 30 min per day per astronaut for defecation and 45 min per day per astronaut for showering. The crew should spend at least a week using the personal-care facilities in the ground-based SRC to familiarize themselves with the techniques and facilities and to provide a baseline for rating the same in flight. Special training will be required for operation of the facility by the experiment monitor.

6. Spacecraft Support:

Peak power requirement is 2.5 kW at 28 vdc for 1 min. Average power requirement for the duration of the experiment is 500 watts. The space station life support system must provide water for bathing and must provide a means for recovering and processing the used wash water and urine. It must also provide a facility for processing and stowing feces. Data storage for 240 bits for each personal care function at a rate of 10 bits/sec is required.

7. Development Schedule:

Same as for the Centrifuge Facility Evaluation Experiment, IXA-7.

8. Cost:

Same as for the Centrifuge Facility Evaluation Experiment, IXA-8.

9. Spacecraft Interface:

Same as for the Centrifuge Facility Evaluation Experiment, IXA-9.

10. Test Program:

Below are two representative examples of parametric rating lists, intended for the functions of defecation and bathing. Rating of each factor will be done by listing a 0 (intolerable), 1 (marginal), 2 (tolerable), or 3 (comparable to 1g) after it, with space allotted for clarifying remarks and recommendations, along with the listing and rating of parameters not included on the original list.

(a) Defecation:

(1) Facility availability (demand)
(2) Facility accessibility
(3) Facility sizing
(4) Interface comfort
(5) Postural equilibrium
(6) Defecation
(7) Urination
(8) Feces detachment
(9) Feces transfer
(10) Urine transfer
(11) Perianal cleaning
(12) Odor control
(13) Tissue disposal
(14) Illumination
(15) Dizziness
(16) Stomach awareness
(17) Nausea

(b) Bathing:

(1) Facility availability
(2) Facility accessibility
(3) Facility sizing
(4) Postural equilibrium
(5) Undressing
(6) Water transfer
(7) Water pressure
(1) Water temperature
(9) Water quantity
(10) Drying
(11) Odor control
(12) Postshower air temp.
(13) Postshower humidity
(14) Mirror fogging
(15) Illumination
(16) Dressing
(17) Dizziness
(18) Stomach awareness
(19) Nausea

Whereas some of the above listed parameters, for example, facility sizing, may seem patently independent of g level, variations in subjective rating of such factors may provide significant clues to crew acceptance.

Although more quantitative rating indices could be used, for example, topical microbiologic assays of personnel and facilities, they tend not only to be techniquely prone to unreliability, but more importantly, are easily invalidated by the usual nonuniformity of such personal care procedures. Therefore, a rating on habitability rather than hygienic contingencies is preferable.

EXPERIMENT/EVENT DATA SHEET IX D

T305

TITLE: PERSONAL-CARE CAPABILITY AS A FUNCTION OF ROTATIONALLY-INDUCED INERTIAL SUPPORT

ITEM No.	PHASE: 1 DEFECATION	PHASE: 2 SHOWER	PHASE:	PHASE:
1	IX D-1 (609004)	IX D-2 (609014)		
2	18	18		
3	1	1		
4	18	18		
5	0	0		
6	1	1		
7	0	0		
8	2	2		
9	27	27		
10	0.5	0.75		
11	27	27		
12	0.5	0.75		
13				
14				
15				
16				
17				
18	0	0		
19	0	0		
20	0	0		
21	0.5	0.75		
22	500	500		
23	0	0		
24	0	0		
25	0	0		
26	0	0		
27	609001	609001		
28				
29				
30	0	0		
31	0	0		
32				
33	1	1		
34				
35				
36				
37	1	1		
38				
39				
40	2	2		

EXPERIMENT DATA SHEET IX E

Reentry Acceleration Profile Simulation

1. Specific Objective:

The objective of this experiment is to measure the rate and level of the astronaut's bodily accomodation to zero-g environment and its influence on the ability of the astronaut to fly an entry maneuver and perform necessary control tasks. In addition, observation is to be made of the degree to which successive g simulation may affect reentry tolerance.

2. General Description:

The centrifuge will be operated in a manner to simulate the reentry acceleration profile a minimum of six times. A representative performance schedule based on a 45-day zero-g exposure period would utilize the 7th, 14th, 21st, 28th, 35th, and 40th days. Crew rotation periods up to 90 days are acceptable to the experiment. The minimum subject sample is one crew member, however, participation of up to four astronauts is desirable for statistical validity and to allow observation of changes in g-tolerance as a function of exposure to the reentry acceleration profile.

During the test period, an acceleration profile as illustrated by figure 1 will be imposed on the test subject by automatic programed of centrifuge rate. The test subject will perform a simple perceptual motor test and/or programed reentry maneuver while under acceleration.

3. Operational Constraints:

Due to divergent physiological effects, test subjects involved in this experiment should be different from those utilized in the centrifuge therapeutic effects experiment. To eliminate the possibility of artifactual disorientation and performance loss, stabilization of the spacecraft must be maintained such that the cross product of angular velocities at the subject's head remains below $100^{\circ}/sec^2$.

4. Mode of Operation:

The centrifuge facility will be configured so that the experiment couch is positioned at maximum radius (113.5 in. approx.) and oriented 78° with respect to the radius vector. The centrifuge will operate in an automatic mode during the entry profile.

5. Crew Support:

A minimum of one astronaut and one operator/monitor will be required 1.4 hours/day for 6 days of the mission. Each test is estimated to require a preparation time of 45 minutes, a test time of 11 minutes, and a period of 27 minutes for removal and storage of instrument and other functions. Special training will be required for operation of the facility by the experiment monitor. Crew skills will be required for the application of instrumentation for electrocardiogram and blood pressure records of the test subject and for medical monitoring during the test. The test subject must be trained to baseline proficiency in the perceptual motor test, and/or programmed reentry maneuver.

6. Spacecraft Support:

The space station must provide electrical power for instrumentation, communications, centrifuge drive and counter-momentum systems during the test period. Peak conditions require power of 5.3 kW for approximately 1 minute. Total electrical energy for each profile is estimated at 1020 watt-hours with a distribution as illustrated by figure 2. Five channels at 3×10^6 bits/channel for storage of biomedical and experimental data will also be required.

7. Development Schedule:

Same as for Centrifuge Facility Evaluation Experiment, IXA-7.

8. Cost:

Same as for Centrifuge Facility Evaluation Experiment, IXA-8.

9. Spacecraft Interface:

Same as for Centrifuge Facility Evaluation Experiment, IXA-9.

10. Test Program:

During the test period, an acceleration profile, as illustrated by figure 1, will be imposed on the test subject by automatic programing of centrifuge rate. The test subject will perform a simple perceptual motor test and/or programed reentry maneuver while under acceleration.

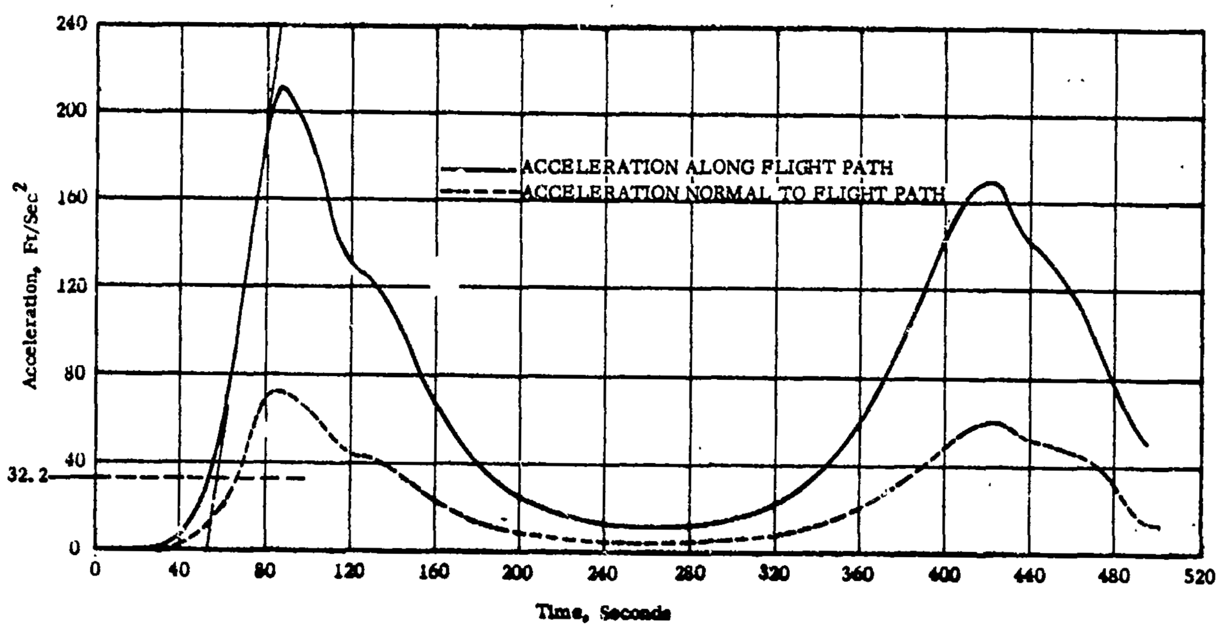


Figure 1. Acceleration load profile for reentry experiment.

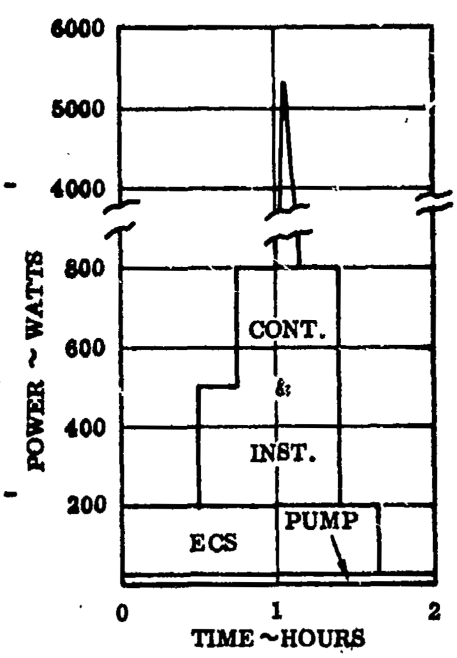


Figure 2.– Reentry experiment power profile.

EXPERIMENT/EVENT DATA SHEET IX E

T310

TITLE: REENTRY SIMULATION

ITEM No.	PHASE: 1	PHASE:	PHASE:	PHASE:
1	IX E-1 (609005)			
2	42			
3	1			
4	6			
5	6			
6	1			
7	0			
8	2			
9	27			
10	1.4			
11	27			
12	1.4			
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	1.4			
22	500			
23	0			
24	0			
25	0			
26	0			
27	609001			
28				
29				
30	0			
31	0.5			
32				
33	1			
34				
35				
36				
37	0			
38				
39				
40	2			

CENTRIFUGE EXPERIMENT DATA SHEET IX F

Cardiovascular and Vestibular Effects

1. Specific Objective:

The objective of this experiment is to establish the effects of weightlessness, reduced gravity, and rotation in the absence of earth's gravity on man during space flights.

2. General Description

This experimental area may be broken down into two categories.

(a) The following experiments fall in the category of orthostatic and acceleration tolerance effects:

(1) Study of grayout thresholds by use of peripheral vision lights.

(2) Tolerance to tilt simulation.

(b) The following experiments fall in the category of threshold levels of sensitivity and response, and interaction of otolith and semicircular canals:

(1) Threshold levels of sensitivity for angular acceleration.

(2) Threshold levels of sensitivity for linear acceleration.

(3) Cross-coupled semicircular canals stimulation.

Gross experimental procedures have been defined for the list of experiments. A representative performance schedule based on a 45-day zero-g exposure period has been developed for each experiment. Crew notation in periods longer than 45 days are acceptable to the experiments. The experiments may be performed as a group in one crew rotation period if the crew work schedule permits, or they may be performed individually throughout the life of the mission.

3. Operational Constraints:

For the orthostatic and angular acceleration tolerance experiments (a and b), in order to eliminate the possibility of artifactual disorientation and performance loss, stabilization of the spacecraft must be maintained such that the cross-product of angular velocities at the subject's head remains below $100^\circ/sec^2$.

Due to the nature of the threshold experiments, the spacecraft must be stabilized such that the motions of the spacecraft are an order of magnitude below the threshold values to be measured. Consequently, stabilization of the spacecraft must be maintained such that for the linear acceleration threshold experiment, spacecraft linear accelerations are ≤ 0.002 g, and for the angular acceleration threshold and semicircular stimulation experiments, spacecraft angular accelerations are ≤ 0.03 deg/sec^2.

4. Mode of Operation:

Generally, for each experiment the radius arm will be manually positioned at the required radius and the couch will be manually positioned into the proper positioned. The centrifuge will operate in the automatic mode during rotation.

Tilt-table operation for the tilt-table simulation experiment is programmed. For the angular acceleration threshold experiment, the centrifuge radius arm will be manually locked in position, the couch roll drive will be manually engaged, and the couch will then be programed for continuous roll motion.

5. Crew Support:

Crew support required during an assumed 45-day crew rotation cycle for the individual experiments is as follows:

(a) The grayout threshold experiment will involve two astronauts each on 6 days for 79 minutes/day total time.

(b) The tilt-table tolerance experiment will involve three astronauts each on 6 days for 77 minutes/day total time.

(c) The threshold levels of sensitivity for angular acceleration experiment will involve two astronauts each on 6 days for 210 minutes/day total time.

(d) The threshold levels of sensitivity to linear acceleration experiment will involve three astronauts each on 3 days for 335 minutes/day total time.

(e) The cross-coupled semicircular-canals stimulation experiment will involve two astronauts each on 6 days for 440 minutes/day total time.

An operator/monitor will be required during each experiment run. Special training will be required for operation of the facility by the experiment monitor. Crew skills will be required for the application of biomonitoring and experimental instrumentation sensors to the test subject and for medical monitoring during the test. Test subjects for the semicircular-canal stimulation experiment must be trained to baseline proficiency in a perceptual motor test.

6. Spacecraft Support:

The space station must provide electrical power for instrumentation, communications, centrifuge drive and counter balance systems during the test period. Peak conditions require power of 5.3 kW for 1 minute for the grayout experiment. Power distribution for each experiment is illustrated in figure 1. Five channels at 3×10^6 bits/channel for storage of biomedical and experimental data will also be required.

7. Development Schedule:

Same as for Centrifuge Facility Evaluation Experiment, IXA-7.

8. Cost:

Same as for Centrifuge Facility Evaluation Experiment, IXA-8.

9. Spacecraft Interface:

Same as for Centrifuge Facility Evaluation Experiment, IXA-9.

10. Test Plan:

(a) Study of Grayout Thresholds by Use of Peripheral Vision Lights - This experiment will involve two astronauts on days 7, 14, 21, 28, 35, and 42 of an assumed 45-day crew rotation period. During the test period, the subject will be subjected to a specific rate of acceleration onset for a time duration sufficient to record the times the peripheral-vision lights are lost to the subject's vision.

(b) Tolerance to Tilt Simulation - This experiment will involve three astronauts on days 5, 12, 19, 26, 33, and 40 of the assumed 45-day crew rotation period. During this test period, the subject is positioned on a saddle-type restraint attached to the centrifuge couch and is positioned along an arc of constant radius. The centrifuge is brought to proper speed. The subject is then tilted outboard from the center of spin.

(c) Threshold Levels of Sensitivity for Angular Acceleration - This experiment will involve two astronauts on days 2, 9, 16, 23, 30, and 37 of an assumed 45-day crew rotation period. During the test period, thresholds for acceleration will be determined about the X, Y, and Z body axis. The astronaut will be positioned in the couch such that the corresponding axis will coincide with the roll axis of the couch. The subject will then be subjected to angular acceleration by rolling the couch while the centrifuge radius arm remains stationary.

(d) Threshold Levels of Sensitivity to Linear Acceleration - This experiment will involve three astronauts, one on days 2, 9, and 30, a second on days 2, 16, and 37, and a third on days 2, 23, and 44. The experiment will be performed in two ways. The subject's response to various combinations of g-level and pitch angles while facing tangentially will be measured. The experiment will be repeated with the subject facing axially, the response to various g-levels and roll angles being measured.

(e) Cross-Coupled Semicircular Canals Stimulation - This experiment will involve one astronaut on days 2, 10, 17, 24, 31, and 38, and a second astronaut on days 4, 11, 18, 25, 32, and 39. The experiment will involve measurement of subject response to various head and hand motions at various rates of centrifuge rotations.

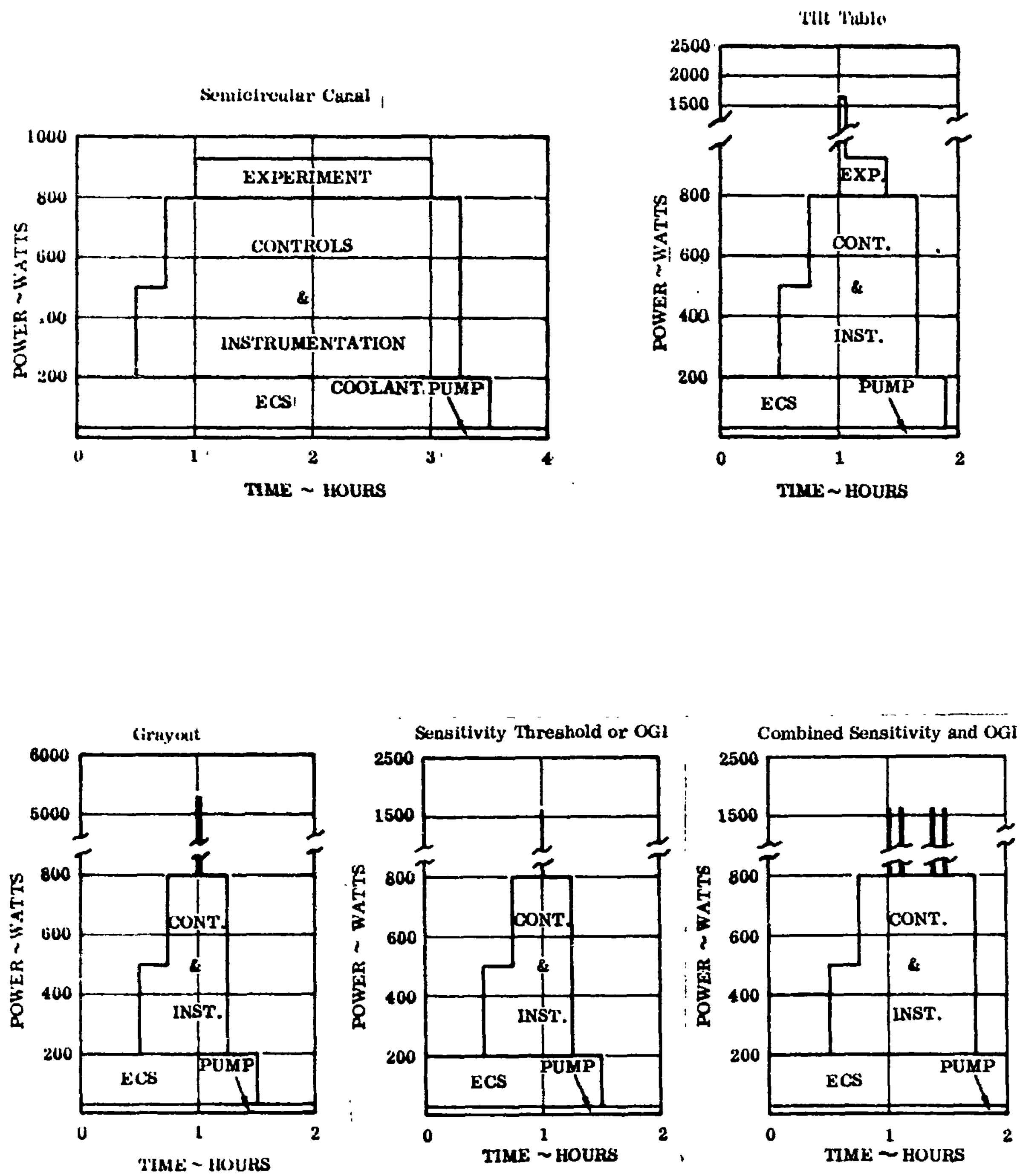


Figure 1.- Experiment power profile curves.

T317

EXPERIMENT/EVENT DATA SHEET IX F

TITLE: CARDIOVASCULAR AND VESTIBULAR EFFECTS

ITEM No.	PHASE: 1 GRAYOUT	PHASE: 2 TILT-TABLE SIMULATION	PHASE: 3 ANGULAR ACCELERATION THRESHOLD	PHASE: 4 LINEAR ACCELERATION THRESHOLD
1	IX F-1 (609006)	IX F-2 (609016)	IX F-3 (609026)	IX F-4 (609036)
2	42	42	42	49
3	1	1	1	1
4	6	6	6	7
5	6	6	6	6
6	0	1	1	1
7	0	0	0	0
8	2	3	2	3
9	27	27	27	27
10	2.6	1.3	7	4
11	27	27	27	27
12	2.6	2.6	7	4
13		27		27
14		3.9		4
15				
16				
17				
18	0	0	0	0
19	0	0	0	0
20	0	0	0	0
21	2.6	2.6	7	4
22	5300	1660	1660	1660
23	0	0	0	0
24	0	0	0	0
25	0	0	0	0
26	0	0	0	0
27	609001	609001	609001	609001
28				
29				
30	0	0	0	0
31	0.7	0.7	0	0
32				
33	1	1	1	1
34				
35				
36				
37	0	0	0	0
38				
39				
40	2	2	2	2

T318

EXPERIMENT/EVENT DATA SHEET IX F-CONCLUDED

TITLE: CARDIOVASCULAR AND VESTIBULAR EFFECTS

ITEM No.	PHASE: 5 SEMICIRCULAR CANAL STIMULATION	PHASE:	PHASE:	PHASE:
1	IX F-5 (609046)			
2	42			
3	2			
4	6			
5	5			
6	0			
7	0			
8	2			
9	27			
10	4			
11	27			
12	4			
13				
14				
15				
16				
17				
18	0			
19	0			
20	0			
21	4			
22	930			
23	0			
24	0			
25	0			
26	0			
27	609001			
28				
29				
30	0			
31	0			
32				
33	1			
34				
35				
36				
37	1			
38				
39				
40	2			

EXPERIMENT DATA SHEET IX G

Therapeutic Support Evaluation

1. Specific Objective:

The objective of this experiment is to establish the extent to which onboard centrifuge acceleration exposure has therapeutic value on the adaptation of man to weightlessness.

2. General Description:

To evaluate the effectiveness of centrifuge acceleration exposure to counteract accommodation to zero-g, astronauts will be centrifuged periodically during the mission. Furthermore, to evaluate the effectiveness of exposure to centrifugation throughout the mission as compared to the effectiveness of exposure just prior to reentry, a minimum of two astronauts will be used for different exposure durations. One astronaut will be centrifuged on days, 5, 10, 15, 20, 25, 30, 35, 40, and 45 of an assumed 45-day crew rotation period. A second astronaut will be centrifuged on each of the last 10 days of the crew rotation period (days 36 through 45). The inflight studies, as well as pre-and postflight examinations, will be used to determine the effectiveness of such exposure.

3. Operational Constraints:

Due to divergent physiological effects, test subjects involved in this experiment should be differ-~t from those utilized in the centrifuge reentry acceleration profile simulation.

To eliminate the possibility of artifactual disorientation and performance loss, stabilization of the spacecraft must be maintained such that the cross-product of angular velocities at the subject's head remains below $100^\circ/sec^2$.

4. Mode of Operation:

The centrifuge facility will be configured so that the experiment couch is positioned at maximum radius and oriented parallel to the radius vector. The centrifuge will operate in automatic mode during rotation.

5. Crew Support:

Two astronauts will be required during the mission, one 9 days and the other 10 days. Each astronaut will ride the centrifuge four times for 20 min each day. Total time required per astronaut per day per exposure is 1.25 hour. An operator/monitor will be required during each run. Special training will be required for operation of the facility by the experiment monitor. Crew skills will be required for the application of biomonitoring instrumentation sensors to the test subject and for medical monitoring during the test.

6. Spacecraft Support:

The space station must provide electrical power for instrumentation, communications, and the centrifuge drive and counterbalance systems during the test period. Peak conditions require power of 4 kW for 1 min. Total electrical energy for each therapeutic experiment is estimated at 1,375 watt-hour with a distribution as illustrated in figure 1. Three channels at 3×10^6 bits/channel for storage of biomedical and experimental data will also be required.

7. Development Schedule:

Same as for Centrifuge Facility Evaluation Experiment, IXA-7.

8. Cost:

Same as for Centrifuge Facility Evaluation Experiment, IXA-8.

9. Spacecraft Interface:

Same as for Centrifuge Facility Evaluation Experiment, IXA-9.

10. Test Program:

One astronaut will be centrifuged on days 5, 10, 15, 20, 25, 30, 35 40, and 45 of an assumed 45-day crew rotation period. A second astronaut will be centrifuged on each of the last 10 days of the crew rotation period (days 36 through 45). More subjects may be used if crew work schedule permits. Each subject will ride the centrifuge four times each day for a period of 20 min each day. The maximum radius will be used with a rate of rotation to give 4g accelerations at the feet. The inflight studies as well as pre-and postflight examinations will be used to determine the effectiveness of such exposure. Subject body orientation on the centrifuge will be radial, facing tangentially, with the head toward the center of rotation.

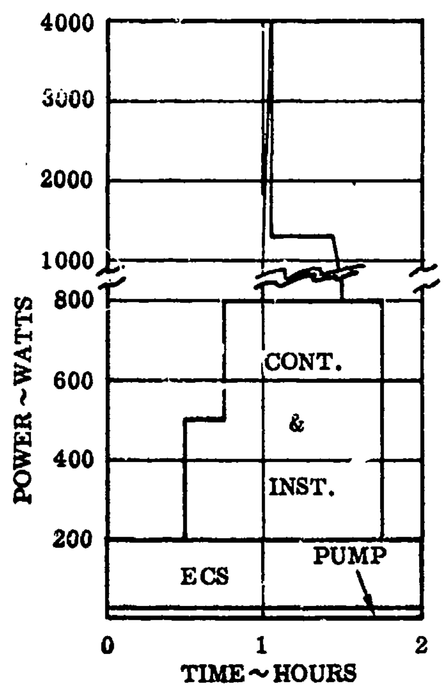


Figure 1.- Experiment power profile curve.

T323

EXPERIMENT/EVENT DATA SHEET IX G

TITLE: THERAPEUTIC SUPPORT

ITEM No.	PHASE: 1 1ST SUBJECT	PHASE: 2 2ND SUBJECT	PHASE:	PHASE:
1	IX G-1 (609007)	IX G-2 (609017)		
2	45	10		
3	1	1		
4	9	10		
5	4	0		
6	0	1		
7	0	0		
8	2	2		
9	27	27		
10	5	5		
11	27	27		
12	5	5		
13				
14				
15				
16				
17				
18	0	0		
19	0	0		
20	0	0		
21	5	5		
22	500	500		
23	0	0		
24	0	0		
25	0	0		
26	0	0		
27	609001	609001		
28				
29				
30	0	0		
31	0.5	0.5		
32				
33	1	1		
34				
35				
36				
37	0	0		
38				
39				
40	2	2		

CONTENTS

SUMMARY

BIOTECHNOLOGY AND HUMAN RESEARCH

OBJECTIVES

To investigate man's physiological, psychological and behavioral responses to prolonged orbital flight.

To establish the criteria for the design, operation, maintenance and reliability of equipment which will best enhance man's ability to perform useful work in orbital flight.

To investigate the environmental requirements for prolonged flight and define the life support and protective systems needed.

PROGRAM

The experiments program consists of three major areas of investigation:

a. Man and selected experimental animals must be studied in the areas known to be affected by weightlessness, confinement, isolation, radiation and the other stresses of the space environment. In addition, screening studies of other areas of human function must be conducted to identify changes not noticed during prior short-duration flights.

b. Required and potential activities of man in orbital flight must be analyzed and flight tested to so refine man's interaction with his equipment that his ability to work in space is optimized. Identification of appropriate tasks, astute design of the tools and equipment to accomplish them, and optimization of procedural options can be confirmed and validated only by extended in-flight test programs. Training methods and performance assessment techniques are necessary adjuvants to this effort.

c. Investigate the features of life support systems which provide a controlled and physiologically acceptable environment during all phases of orbital flight. For intravehicular operations, the perfrection of a shirtsleeve environment with reliable provisions for food, water, personal hygiene, wast removal and thermal equilibrium is required. For extravehicular activity, the pressure suit and assistive devices which enhance maneuverability and dexterity, permit confortable accomplishment of tasks, and protect from radiation; meteoritic particles and thermal overload, are required.

d. Some of these proposed experiments, will be extensions of the medical experiments proposed for AAP and will be affected by the results obtained from that program.

EXPERIMENTS DEFINITION

The three areas of investigation described above each require a group of related studies for their thorough evaluation. These groups are descirbed herein as Functional Program Elements, and, following the same order as the Objectives and the Program, are Biomedical Research, Life Support and Protective Systems, and Man/Systems Integration. Each Functional Program Element (FPE) is described separately, and component experiments of each FPE are further detailed in the associated Experiment Data Sheets.

FUNCTIONAL PROGRAM ELEMENT I

Biomedical (Human and Animal)

REQUIREMENT

The objectives of this biomedical research are:

a. To preserve and extend man's physiological capabilities during prolonged space flight and on the lunar surface by determining:

1. The nature, time-course, and limits of human adaptation to the space flight environment;
2. The specific mechanisms through which these adaptations are mediated;
3. The means of predicting the onset and severity of undesirable effects;
4. The means for preventing or ameliorating the undesirable effects; and
5. An understanding of the effects of the space flight environment on the human body.

b. To utilize the unique qualities of the space environment to obtain scientific information of value to medical science and practice.

JUSTIFICATION

a. Physiological changes which have consistently been observed could reduce the overall capability of man to cope effectively with the stresses of re-entry and landing and with in-flight emergencies.

b. It is impossible on the basis of present day knowledge to predict the rate of onset of deleterious physiological changes or to determine the relative importance of weightlessness as the primary causative factor.

c. Presently available flight biomedical instrumentation is limited to simple vital-sign measurements and as such is inadequate to meet the requirements of mission-rating man for extended flights.

Under the Biomedical Functional Program Element we have the following research categories:

1.1 Neuro physiology

1.2 Cardiovascular Function

1.3 Respiration

1.4 Gastrointestinal

1.5 Metabolism and Nutrition

1.6 Musculoskeletal

1.7 Endocrinology

1.8 Hematology

1.9 Microbiology and Immunology

1.10 Pharmacology

1.11 Radiobiology

1.12 Clinical Medicine

1.13 Bioinstrumentation

RESEARCH CATEGORIES

1.1 Neurophysiology

Statement of the Problem

To date, the neurological evaluation of space flight crews has been limited to pre- and post-flight clinical medical examinations, the recording of two leads of EEG of one astronaut for the first two days of his flight and a vestibular experiment which assessed the otolith function of four flight crew members during the 8- and 14-day Gemini missions. Although no significant changes were detected, these neurophysiological observations were meager. For extended manned space flight, a thorough investigation of neurological function becomes increasingly important since this information will have a direct bearing on the determination of what man can do in space and on the development of means to protect his functional integrity during extended flight.

Scientific Objectives

The aim of the neurophysiology research program is to investigate and evaluate the effects of the space flight environment and the relative roles of component environmental factors on flight crew neurophysiological function. Embodied in this effort are the assessment of the occurrence of adverse effects, the establishment of trend cureves, the determination of specific causative factors and mechanisms by which undesired effects become manifest. In addition, the means of prediction and prevention or correction of ill effects must be discovered.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Neurophysiology are listed. They are followed by detailed sheets on each of the Component Experiments.

1.1 Neurophysiology

1.1.1 Vestibular Function

1.1.1.1 Head Movement Effects

1.1.1.2 Otolith and Semicircular Canal Sensitivity

1.1.1.3 Altered Day - Night Cycle Effects

1.1.1.4 Vestibular Electrical Activity

1.1.2 Sleep - no experiments yet proposed

1.1.3 Alertness - no experiments yet proposed

1.1.4 Biorhythms - no experiments yet proposed

EXPERIMENT REQUIREMENTS SUMMARY

1.1.1.1

EXPERIMENT TITLE

TEXT REF. NO. 1.1.1.1

Effect of Head Movement during Rotation

EXPERIMENT CATEGORY

Neurological Function--Vestibular Function in Space

OBJECTIVE AND SIGNIFICANCE

To determine the thresholds and tolerance to visual illusions produced by head movements in a rotating environment during weightlessness. Results are needed for correlation with ground-based experiments and to establish permissible vehicle rotation rates for defining design requirements of future spacecraft.

MEASUREMENTS AND OBSERVATIONS

Oculogyric illusion
Nystagmus
Task performance (visual)
Egocentric visual localization of the horizontal
Electroencephalography (EEG)

EXPERIMENT DURATION

60 min. every other day for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

4 crew members
Phoropter
Tilting motion chair
Vision test target with horizon reference line
Cine camera and fiber optics
Electroencephalograph
Nystagmographic goggles

SPECIAL REQUIREMENTS/REMARKS

Performance measuring equipment is required to assess specific tasks requiring head motion and hand dexterity. EEG monitoring is recommended for the assessment of behavior and performance parameters. Short-radius centrifuge is desirable to extend observations beyond those initially suggested in references and to make results more comparable to ground-test data.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. National Aeronautics and Space Administration (NASA), Washington, D. C., 15 March 1965.

S. P. Vinograd, Medical Aspects of an Orbiting Research Laboratory. Space Medicine Advisory Group Study, NASA Report No. SP-86, 1966.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE TEXT REF. NO. 1.1.1.2

Sensitivity of Otolith and Semicircular Canal Mechanisms

EXPERIMENT CATEGORY

Neurological Function--Vestibular Function in Space

OBJECTIVE AND SIGNIFICANCE

To measure the sensitivity and interaction of semicircular canal and otolith functions and their changes during prolonged weightlessness. Results will be used in developing countermeasures to prevent the vestibular function from lowering astronaut efficiency in flight and post-flight.

MEASUREMENTS AND OBSERVATIONS

Ocular counter-rolling
Oculogyric illusion
Oculogravic illusion
Task performance
Egocentric visual localization of the horizontal
Eye-muscle balance
Electroencephalography (EEG)

EXPERIMENT DURATION

60 min. every 3 days for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

4 crew members (2 as a minimum)
Nystagmographic Goggles
Phoropter
Tilting motion chair
Vision test target with horizon reference line
Cine camera and fiber optics
Behavioral test equipment
Electroencephalograph

SPECIAL REQUIREMENTS/REMARKS

All parameters should be monitored against EEG signals to access vestibular function as a concomitant of behavioral performance. Short-radius centrifuge is desirable to make results more comparable with ground-test data.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D.C. 15 March 1965.

Feasibility Study of a Centrifuge Experiment for the Apollo Application Program, NASA RFP L-7631.

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.1.1.3

Effect of Altered Day-Night Cycles on Mating Behavior and Litter Size of Rats, and on EEG of Cats

EXPERIMENT CATEGORY

Neurological Function--Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the effect of various combinations of day-night cycles on mating behavior and litter size of rats, and on EEG of cats. In many mammals, light influences pituitary-gonadal functioning.

MEASUREMENTS AND OBSERVATIONS

Task performance
Electroencephalography (EEG)
Temperature

EXPERIMENT DURATION

5 min. daily for first week; then, 30 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

6 rats (3 male, 3 female) and 2 cats
Electroencephalograph
Temperature recorder
Cine camera

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

1 technician

REFERENCES

Originated by MDAC.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE TEXT REF. NO. 1-3

Effect of Altered Day-Night Cycles on Mating Benavior and Litter Size of Rats, and on EEG of Cats

EXPERIMENT CATEGORY

Neurological Function--Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the effect of various combinations of day-night cycles on mating behavior and litter size of rats, and on EEG of cats. In many mammals, light influences pituitary-gonadal functioning.

MEASUREMENTS AND OBSERVATIONS

Task performance
Electroencephalography (EEG)
Temperature

EXPERIMENT DURATION

5 min. daily for first week; then, 30 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

6 rats (3 male, 3 female) and 2 cats
Electroencephalograph
Temperature recorder
Cine camera

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

1 technician

REFERENCES

Originated by MDAC.

1.2 CARDIOVASCULAR FUNCTION

Statem the Problem

Space flight has been demonstrated to perturb the homeostasis of the cardiovascular system of man. Decremental changes have been documented in compartmental fluid volumes (plasma volume, red cell mass, blood volume), hydrostatic pressure (orthoastatic hypotension), and related parameters. The extent to which these changes may be exaggerated by prolonged space flights and the extent to which they may adversely affect the performance of man remain to be determined.

Scientific Objectives

The objectives of the cardiovascular research program are to refine our understanding of the effects of space environmental factors on the cardiovascular system and determine the effectiveness of preventive and/or remedial techniques.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Cardiovascular Function are listed. They are followed by detiiled sheets on each of the component experiments.

1.2 Cardiovascular Function

- 1.2.1 Cardiovascular Deconditioning
  - 1.2.1.1 Circulatory Response to Exercise
  - 1.2.1.2 Volume Effects on Arterial Pressure Control System
  - 1.2.1.3 Peripheral Venous Compliance

1.2.1.4 Cardiac Dynamics

1.2.1.5 Intraocular Arterial Blood Pressure

1.2.1.6 Cardiac Output

1.2.2 Deconditioning Countermeasures

1.2.2.1 Lower Body Negative Pressure Device

1.2.2.2 On-board Centrifuge

1.2.2.3 Occlusive Cuffs

1.2.2.4 Response to Shock Therapy

1.2.3 Homeostatic Mechanisms

1.2.3.1 Carotid Sinus Sensitivity

1.2.3.2 Peripheral Arteriolar Reactivity

1.2.3.3 Blood Volume and Distribution

1.2.3.4 Carotid Baroreceptor Electrical Activity

1.2.4 Total Systems

1.2.4.1 Long Duration Weightlessness - Primate Experiment

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.2.1.1

Changes in Circulatory Response to Exercise

EXPERIMENT CATEGORY

Cardiovascular Function--Cardiovascular Deconditioning

OBJECTIVE AND SIGNIFICANCE

To determine circulatory integrity, with emphasis on the heart's ability to respond to stressful situations under prolonged weightlessness.

MEASUREMENTS AND OBSERVATIONS

Arterial blood pressure
Heart rate
Cardiac output
Circulation time
Electrocardiography (ECG)
Phonocardiography

EXPERIMENT DURATION

35 min. daily for first week; then, 35 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

4 crew members
Ergometer
Cardiac output measurement equipment
Occlusive limb cuffs
Electrocardiograph
Phonocardiograph
Arterial pressure recorder
Cardiotachometer

SPECIAL REQUIREMENTS/REMARKS

Can be integrated with Experiment 1-21.

PERSONNEL REQUIRED

2 technicians

REFERENCES

S. P. Vinograd, Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE TEXT REF. NO. 1.2.1.2

Effect of Blood Distribution on Arterial Pressure Control Systems

EXPERIMENT CATEGORY

Cardiovascular Function--Cardiovascular Deconditioning

OBJECTIVE AND SIGNIFICANCE

To determine the influence of prolonged weightlessness on the integrity of neutral reflex and humoral control mechanisms.

MEASUREMENTS AND OBSERVATIONS

Arterial blood pressure
Heart rate
Electrocardiography (ECG)
Urinary catecholamines
Blood catecholamines

EXPERIMENT DURATION

50 min. daily for first week; then, 50 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

4 crew members
Arterial pressure recorder
Cardiotachometer
Urine collection and storage equipment
Blood collection equipment
Biochemistry analysis equipment
(catecholamines)
Electrocardiograph
Occlusive cuffs
Expiratory resistance device

SPECIAL REQUIREMENTS/REMARKS

Blood volume shifts can be achieved by Valsalva procedure, occlusive cuffs, and/or artificial gravity (short-radius centrifuge, LBNP). Techniques for catecholamine analysis unavailable at present.

PERSONNEL REQUIRED

1 physician and 1 technician

REFERENCES

S. P. Vinograd, Medical Aspects of an Orbiting Research Laboratory. Space Medical A visory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.2.1.3

Alterations in Venous Compliance and Pressure Resulting from Absence of Hydrostatic Pressure

EXPERIMENT CATEGORY

Cardiovascular Function--Cardiovascular Deconditioning

OBJECTIVE AND SIGNIFICANCE

To determine if the reduced stress on the circulatory system, due to absence of hydrostatic pressure, results in alterations in venous compliance and/or venous pressure.

MEASUREMENTS AND OBSERVATIONS

Heart rate
Plethysmography (lower body limb)

EXPERIMENT [illegible] ION

30 min. [illegible] first 10 days; then, 30 min. every 5 days for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Cardiotachometer
Limb plethysmograph

SPECIAL REQUIREMENTS/REMARKS

Methods are equivocal. Additional R&D is required to increase confidence in them.

PERSONNEL REQUIRED

2 technicians

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D. C., 15 March 1965.
S. P. Vinograd, Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.2.1.4

Cardiac Dynamics

EXPERIMENT CATEGORY

Cardiovascular Function--Cardiovascular Deconditioning

OBJECTIVE AND SIGNIFICANCE

To determine if ballistocardiography can accurately measure cardiac dynamics and cardiac output in the weightless state.

MEASUREMENTS AND OBSERVATIONS

Phonocardiography
Ballistocardiography
Electrocardiography (ECG)
Cardiac output
Arterial blood pressure

EXPERIMENT DURATION

Assessment to be made during the times in which cardiac output for other experiments are determined; additional setup time per measurement is negligible.

SUBJECTS, MATERIALS, AND EQUIPMENT

3 crew members
Ballistocardiograph
Electrocardiograph
Cardiac output measurement equipment (various types)
Phonocardiograph
Arterial pressure recorder

SPECIAL REQUIREMENTS/REMARKS

Can be done in conjunction with other cardiovascular experiments which measure cardiac output.

PERSONNEL REQUIRED

2 technicians

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D. C., 15 March 1965.
S. P. Vinogra[illegible] Medical Aspects of an Orbiting Research Laboratory. Space Medicine [illegible] Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.2.1.5

Intraocular Arterial Blood Pressure

EXPERIMENT CATEGORY

Cardiovascular Function--Extent of Cardiovascular Deconditioning during Weightlessness

OBJECTIVE AND SIGNIFICANCE

To determine the effect of weightlessness on intraocular systolic and diastolic blood pressure associated with possible loss in reactivity of the cardiovascular system. Adverse variations in intraocular blood pressure may threaten the limits of visual tolerance.

MEASUREMENTS AND OBSERVATIONS

Intraocular arterial systolic and diastolic blood pressure (measured by loss of retinal sensitivity)
Arterial blood pressure

EXPERIMENT DURATION

10 min., 4 times on first day; 10 min. daily on days 2, 4, 8, and 12; then, once weekly after 3, 6, and 12 weeks.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Plethysmographic goggles
Vision test target
Arterial pressure recorder

SPECIAL REQUIREMENTS/REMARKS

Development of flight goggles with built-in pressure-recording system is required.

PERSONNEL REQUIRED

Subjects serve as their own observers

REFERENCES

S. P. Vinograd, Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE | TEXT REF. NO. 1.2.1.6

Cardiac Output -- Direct Versus Indirect Methods

EXPERIMENT CATEGORY

Cardiovascular Function--Animal Research

OBJECTIVE AND SIGNIFICANCE

To evaluate the usefulness of indirect measurements for determining cardiac output as opposed to the direct Fick method.

MEASUREMENTS AND OBSERVATIONS

Arterial blood pressure
Right atrial pressure and pO_2
Electrocardiography (ECG)
Cardiac output by impedance, ballistocardiographic, and dye dilution methods
Expiratory pO_2 and pCO_2
Circulation time
Temperature
Body mass
Spirometry
Blood volume
Hematocrit

EXPERIMENT DURATION

2 hours every 2 weeks for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 miniature swine
Arterial pressure recorder
Electrocardiograph
Ballistocardiograph
Temperature recorder
Mass measurement devices (large and small)
Expiratory gas analyzer
Recording manometer
Spirometer
Cardiac output measurement device
Cardiotachometer
Clinical centrifuge
Oscilloscope and recorder
Spectrophotometer

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

2 technicians

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.2.2.1

Use of a Lower-Body Negative Pressure Device to Prevent Cardiovascular Deconditioning

EXPERIMENT CATEGORY

Cardiovascular Function--Deconditioning Countermeasures

OBJECTIVE AND SIGNIFICANCE

To determine cardiovascular reponses to a lower-body negative pressure device in weightlessness and to evaluate the effectiveness of this device as a deconditioning countermeasure.

MEASUREMENTS AND OBSERVATIONS

Spirometry
Arterial blood pressure
Heart rate
Electrocardiography (ECG)
Electroencephalography (EEG)
Plethysmography (forearm)
Cardiac output

EXPERIMENT DURATION

30 min. for first 24 hours; then, 30 min. every 2 days for first 2 weeks; then, 30 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Spirometer
Cardiotachometer
Electroencephalograph
Capacitance plethysmogra
Cardiac output measuren pment
Electrocardiograph
Arterial pressure recorder

SPECIAL REQUIREMENTS/REMARKS

Design of lower body negative pressure device should be optimized. Additional evaluation of capacitance plethysmography is required.

PERSONNEL REQUIRED

1 physician and 1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D. C. 15 March 1965.

S. P. Vinograd, Medical Aspects of an Orbiting Research Laboratory. Space Medicine Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.2.2.2

Use of an On-Board Centrifuge to Prevent Cardiovascular Deconditioning

EXPERIMENT CATEGORY

Cardiovascular Functic...-Deconditioning Countermeasures

OBJECTIVE AND SIGNIFICANCE

To determine the effectiveness of the short-radius centrifuge as a conditioning device.

MEASUREMENTS AND OBSERVATIONS

Spirometry
Arterial blood pressure
Heart rate
Electrocardiography (ECG)
Cardiac output
Expiratory pO_2 and pCO_2
Plethysmography
Electroencephalography (EEG)
Body temperature

EXPERIMENT DURATION

20 min. daily for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

4 crew members
Spirometer
Arterial pressure recorder
Cardiotachometer
Electrocardiograph
Cardiac output measurement equipment
Expiratory gas analyzer
Capacitance plethysmograph
Cine camera
Temperature recorder
Electroencephalograph
Mass measurement device

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

· physician and 1 technician

REFERENCES

Apollo Extension Systems Experiment List, NASA Washington, D. C., 15 March 1965.

EXPERIMENT REQUIREMENTS SUMMARY

1.2.2.3

EXPERIMENT TITLE — TEXT REF. NO. 1.2.2.3

Use of Occlusive Cuffs to Prevent Cardiovascular Deconditioning

EXPERIMENT CATEGORY

Cardiovascular Function--Deconditioning Countermeasures

OBJECTIVE AND SIGNIFICANCE

To measure the cardiovascular response to occlusive cuffs during weightlessness and to evaluate their use as a deconditioning countermeasure.

MEASUREMENTS AND OBSERVATIONS

Spirometry
Arterial blood pressure
Heart rate
Electrocardiography (ECG)
Cardiac output
Expiratory pO_2 and pCO_2
Temperature
Plethysmography

EXPERIMENT DURATION

20 min. daily for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Spirometer
Arterial pressure recorder
Cardiotachometer
Electrocardiograph
Cardiac output measurement equipment
Expiratory gas analyzer
Capacitance plethysmograph
Temperature recorder

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

1 [illegible]ician and 1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D. C. 15 March 1965.

EXPERIMENT REQUIREMENTS SUMMARY

1.2.2.4

EXPERIMENT TITLE

TEXT REF NO. 1.2.2.4

Cardiovascular Response to Shock Therapy--Pharmacologically and Volumetrically Induced Vascular Collapse

EXPERIMENT CATEGORY

Cardiovascular Function--Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the response of the cardiovascular system to pharmacological and volumetric shock during prolonged weightlessness.

MEASUREMENTS AND OBSERVATIONS

Arterial blood pressure
Venous pressure
Electrocardiography (ECG)
Cardiac output (Fick)
Expiratory pO_2 and pCO_2
Circulation time
Blood volume
Hematocrit
Body mass
Esophageal pressure
Venous pO_2 and pCO_2
Right atrial pressure and pO_2
Temperature
Spirometry

EXPERIMENT DURATION

4 hours, to be scheduled as convenient.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 dogs or miniature swine
Arterial pressure recorder
Electrocardiograph
Temperature recorder
Recording manometers
Limb pressure cuffs
Expiratory gas analyzer
Mass measurement devices (large and small)
Clinical centrifuge
Cardiac output measurement device
Cardiotachometer
Spirometer
Expiratory resistance device
Oscilloscope and recorder
Spectrophotometer

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

2 technicians

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

1.2.3.1

EXPERIMENT TITLE TEXT REF. NO. 1.2.3.1

Sensitivity of the Carotid Sinus-Arterial Pressure Control Loop

EXPERIMENT CATEGORY

Cardiovascular Function--Sensitivity of Homeostatic Mechanisms

OBJECTIVE AND SIGNIFICANCE

To determine if the sensitivity of the carotid sinus control mechanism is significantly altered during weightlessness.

MEASUREMENTS AND OBSERVATIONS

Arterial blood pressure
Heart rate
Electrocardiography (ECG)
Cardiac output
Respiratory amplitude
Plethysmography (forearm)

EXPERIMENT DURATION

20 min. first day; then, 20 min. every 2 days for first 2 weeks; then 20 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Arterial pressure recorder
Cardiotachometer
Electrocardiograph
Spirometer
Capacitance plethysmograph
Cardiac output measurement equipment
Carotid cuffs (individual)

SPECIAL REQUIREMENTS/REMARKS

Increase in transmural pressure in the carotid sinuses is obtained by subjecting neck to negative pressure with a molded plastic carotid cuff.

PERSONNEL REQUIRED

1 physician and 2 technicians

REFERENCES

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.2.3.2

Peripheral Arteriolar Reactivity

EXPERIMENT CATEGORY

Cardiovascular Function--Sensitivity of Homeostatic Mechanisms

OBJECTIVE AND SIGNIFICANCE

To determine the effect of weightlessness on arteriolar tone. This is an assumed index of vascular reactivity and cardiovascular conditioning.

MEASUREMENTS AND OBSERVATIONS

Arterial blood pressure
Plethysmography
Venous and arterial filling time

EXPERIMENT DURATION

15 min. daily for 5 days; then, 15 min. at a 5- to 10-day intervals for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 or more crew members, as available
Capacitance plethysmograph
Arterial pressure recorder
Still camera (color and infrared sensitive film)
Limb pressure cuffs

SPECIAL REQUIREMENTS/REMARKS

Physician is desirable.

PERSONNEL REQUIRED

1 technician

REFERENCES

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.2.3.3

Changes in Blood Volume and Distribution

EXPERIMENT CATEGORY

Cardiovascular Function--Blood Volume

OBJECTIVE AND SIGNIFICANCE

To determine the effect of weightlessness on fluid shifts among body compartments and the resulting influence on circulating blood volume.

MEASUREMENTS AND OBSERVATIONS

Plasma volume
Hematocrit
Extracellular fluid volume
Total body water
Red blood cell mass
Body mass
Body volume
Urinalysis

EXPERIMENT DURATION

1 hour daily for first 15 days; then, 1 hour weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

3 crew members
Clinical centrifuge
Radioactive tracers
Scintillation counter/scaler
Biochemistry analysis equipment
Mass measurement devices (large and small)
Body volumeter
Urine collection and storage equipment

SPECIAL REQUIREMENTS/REMARKS

Radioisotopic techniques are required for the measurement of plasma volume, red cell mass, extracellular fluid volume, and total body water. Physician is desirable for interpretation of results. Can be integrated with Experiments 1-33 and 1-45.

PERSONNEL REQUIRED

2 technicians

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D. C., 15 March 1965.
S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. **1.2.3.4**

Carotid Baroreceptor Electrical Activity in Primates

EXPERIMENT CATEGORY

Cardiovascular Function--Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the amount of afferent nervous discharge from the carotid baroreceptor during prolonged weightlessness.

MEASUREMENTS AND OBSERVATIONS

Arterial blood pressure
Electrocardiography (ECG)
Expiratory pO_2 and pCO_2
Temperature
Blood volume
Electrical activity from carotid sinus receptors
Hematocrit

EXPERIMENT DURATION

20-min. observations, 3 times weekly; thereafter, for indeterminate period.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 monkeys (rhesus or spider)
Arterial pressure recorder
Electrocardiograph
Temperature recorder
Oscilloscope and photographic recorder
Recording manometer
Radioactive tracers
Limb pressure cuffs
Scintillation counter/scaler
Expiratory gas analyzer
Cardiotachometer
Clinical centrifuge
Mass measurement device

SPECIAL REQUIREMENTS/REMARKS

Electrodes are implanted in animals prior to mission for measuring carotid sinus impulses.

PERSONNEL REQUIRED

2 technicians

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

MAJOR TITLES TEXT REF. NO. 1.2.4.1

Biomedical and Behavioral

EXPERIMENT TITLE

Long Duration Weightlessness - Primate Experiment

EXPERIMENT CATEGORY

Total Systems

OBJECTIVE AND SIGNIFICANCE

To determine cardiovascular deconditioning, neurological deconditioning, musculoskeletal deconditioning etc. on a complete body system in advance of manned flight.

MEASUREMENTS AND OBSERVATIONS

Pre and post flight complete examination including post flight biopsy in flight - TV pictures and work performance tests

EXPERIMENT DURATION

6 months to a year

SUBJECTS, MATERIALS, AND EQUIPMENT

2 Rhesus Primates with closed Life support

SPECIAL REQUIREMENTS/REMARKS

Astronaut retrieval in small canisters to be returned in command module

PERSONNEL REQUIRED

One Astronaut

REFERENCES REF. DOC. EXPERIMENT NO.____________ (MODIFIED)

1. Jones, Wallon L., "Orbiting Experiment for Study of Extended Weightlessness, 1967
2. Lockheed Missiles and Space Co., "Orbiting Experiment for Study of Extended Weightlessness," NASA CR 66520, 1968
3. Northrup Systems Laboratories, "Orbiting Experiment for Study of Extended Weightlessness," NASA CR 66507, 1967

1.3 RESPIRATION

Statement of the Problem

Weightlessness, increased acceleration forces, and artificial atmospheres have major effects on the respiratory gas exchange function of the body. These effects not only impose health hazards and limitations on man's performance capabilities, but they also impose severe design constraints on the spacecraft.

Scientific Objectives

The objectives of the respiration research program are to define the optimal atmosphere for long-duration space missions, to establish the mission contraints imposed by this atmosphere, to determine what mission constraints would be imposed by the choice of a less-than-optimal atmosphere.

Research Areas and Component Experiments

The research Areas and Component Experiments under Respiration are listed. They are followed by detailed sheets on each of the component experiments.

1.3 Respiration

- 1.3.1 Ventilatory Mechanics
  - 1.3.1.1 Pulmonary Mechanics
  - 1.3.1.2 Respiratory Control
- 1.3.2 Pulmonary Efficiency
  - 1.3.2.1 Blood Gas Exchange
  - 1.3.2.2 Lung Cleansing

1.3.2.3 Induced Pulmonary Infections

1.3.2.4 Recovery from Non-Infectious Lung Trauma

1.3.2.5 Gas Exchange and Blood Flow Distribution in Lungs

1.3.3 Atmosphere composition

1.3.3.1 No experiments yet proposed, but should include:

a. Composition
b. Dysbarism
c. Contaminants
d. Oxygen toxicity
e. Carbon Dioxide
f. Effects of Weightlessness

1.3.3.2 Advanced Aerosol Particle Analyzer

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.3.1.1

Pulmonary Mechanics

EXPERIMENT CATEGORY

Pulmonary Function--Ventilatory Mechanics

OBJECTIVE AND SIGNIFICANCE

To determine whether weightlessness produces shifts in lung volumes, changes in airway resistance, changes in respiratory muscle strength, or other alterations in pulmonary mechanics.

MEASUREMENTS AND OBSERVATIONS

Respiration rate
Total airway resistance (computed)
Maximum inspiratory and expiratory pressure
Spirometric volume and esophageal pressure (lung compliance)
Standard respiratory volumes
Maximum expiration flow rate
Esophageal pressure
Expired Air pO_2, pCO_2

EXPERIMENT DURATION

2 min. daily for first week; then, 2 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Spirometer
Recording apparatus

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

1 technician

REFERENCES

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.3.1.2

Respiration Control

EXPERIMENT CATEGORY

Pulmonary Function--Ventilatory Mechanics

OBJECTIVE AND SIGNIFICANCE

To determine the effect of weightlessness on the respiration control associated with possible changes in respiratory gases, acid-base balance, and body reflexes.

MEASUREMENTS AND OBSERVATIONS

Respiration rate
Respiratory volumes
Expiratory pO_2 and pCO_2
Breath-holding time
Arterialized venous blood pH, bicarbonate, pO_2, and pCO_2
O_2-Hb saturation

EXPERIMENT DURATION

Spirometry 10 min. daily for mission duration; chemistries 60 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Spirometer
Expiratory gas analyzer
pH meter
Specific ion electrodes
Blood gas analysis equipment
Oximeter
Timer

SPECIAL REQUIREMENTS/REMARKS

Available techniques need to be refined.

PERSONNEL REQUIRED

2 technicians

REFERENCES

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.3.2.1

Blood and Ventilatory Gas Exchange

EXPERIMENT CATEGORY

Pulmonary Function--Pulmonary Efficiency

OBJECTIVE AND SIGNIFICANCE

To measure the changes in ventilatory gas exchange and in blood aeration caused by the possible adaptations to prolonged weightlessness.

MEASUREMENTS AND OBSERVATIONS

Expired air pO_2 and pCO_2
Arterialized venous blood pH, pO_2, pCO_2, and bicarbonate
Hemoglobin O_2 saturation
Respiratory rate and volume

EXPERIMENT DURATION

60 min. per determination twice weekly for both resting and exercising conditions for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Expiratory gas analyzer
pH meter
Specific ion electrodes
Spirometer
Oximeter
Blood gas analysis equipment

SPECIAL REQUIREMENTS/REMARKS

Can be integrated with Experiment 1-21.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D. C., 15 March 1965.
S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.3.2.2

Lung Cleansing in Rats

EXPERIMENT CATEGORY

Pulmonary Function--Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the effectiveness of ciliary motion in removing small particles from the lung during prolonged weightlessness.

MEASUREMENTS AND OBSERVATIONS

Temperature
Tissue pathology (gross and microscopic)
White blood cell count

EXPERIMENT DURATION

60 min. daily for 15 days; then, 2 hours for termination and final sample preservation.

SUBJECTS, MATERIALS, AND EQUIPMENT

6 albino rats
Tissue fixatives
Nebulizer chamber
Temperature recorder
Aerosol particle analyzer
Dissecting microscope
Hemacytometer
Still camera (color film)

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

1 technician

REFERENCES

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.
MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.3.2.3

Induced Pulmonary Infections in Mice

EXPERIMENT CATEGORY

Pulmonary Function--Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the resistance of mice to induced pulmonary infections during prolonged weightlessness.

MEASUREMENTS AND OBSERVATIONS

Temperature
Tissue pathology (gross and microscopic)
Hematocrit
White blood cell count

EXPERIMENT DURATION

10 min. readings daily for 2 weeks.

SUBJECTS, MATERIALS, AND EQUIPMENT

6 albino mice
Tissue fixatives
Nebulizer chamber
Bacteriology equipment
Still camera (color film)
Expiratory gas analyzer
Temperature recorder

SPECIAL REQUIREMENTS/REMARKS

Animal isolation facilities are required.

PERSONNEL REQUIRED

1 technician

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.3.2.4

Recovery Rate from Noninfectious Lung Trauma in Rats

EXPERIMENT CATEGORY

Pulmonary Function--Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the rate of lung-tissue healing after noninfectious trauma induced by exposure to an irritant gas.

MEASUREMENTS AND OBSERVATIONS

Temperature
Tissue pathology (gross and microscopic)
White blood cell count

EXPERIMENT DURATION

10 min. daily for 2 weeks; 30 min. sample preparation every third day.

SUBJECTS, MATERIALS, AND EQUIPMENT

6 albino rats
Tissue fixatives
Nebulizer chamber
Temperature recorder
Still camera (color film)

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

1 technician

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

MAJOR TITLES TEXT REF. NO. 1.3.2.5

Biomedical and Behavioral

EXPERIMENT TITLE

Gas exchange and Blood Flow Distribution in Lungs

EXPERIMENT CATEGORY

Respiration

OBJECTIVE AND SIGNIFICANCE

To investigate the effects of weightlessness in lung Gas exchange and Blood Flow Distribution

MEASUREMENTS AND OBSERVATIONS

Mass Spectrometer measure of Breath by breath to determine gas exchange in lung

EXPERIMENT DURATION

Twice day/5 min. each

SUBJECTS, MATERIALS, AND EQUIPMENT

Human

SPECIAL REQUIREMENTS/REMARKS

PERSONNEL REQUIRED

Technician

REFERENCES

EXPERIMENT REQUIREMENTS SUMMARY

MAJOR TITLES

TEXT REF. NO. 1.3.2.6

Biomedical and Behavioral

EXPERIMENT TITLE

Advanced Aerosol Particle Analyzer

EXPERIMENT CATEGORY

Atmospher. Composition

OBJECTIVE AND SIGNIFICANCE

To provide information on the aerosol particle build up during missions.

MEASUREMENTS AND OBSERVATIONS

Aerosol particles will be measured in the concentration range 500 - 500,000 particles per cubic foot and will be classified into five size ranges between 0.5 and 10 microns. Samples will be collected for analysis

EXPERIMENT DURATION

2 min/day

SUBJECTS, MATERIALS, AND EQUIPMENT

5 lb. box

SPECIAL REQUIREMENTS/REMARKS

PERSONNEL REQUIRED

Technician

REFERENCES

1.4 GASTROINTESTINAL

Statement of the Problem

Available date indicates that prolonged stress could result in increased acid secretion with peptic ulceration. It is also known that changes in body position on earth alter renal function. The problem is to determine the effects of weightlessness and space flight on body functions associated with the gastrointestinal system.

Scientific Objectives

To study the influence of prolonged weightlessness on kidney function and possible urinary stone formation. To determine the rate of renal and bladder calculus formation under conditions of dietary and fluid balance extremes. To determine the effects of weightlessness on gastric secretion and gut motility and on the absorption rate of common food stuffs.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Gastro-intestinal are listed. They are followed by detailed sheets on each of the component experiments.

- 1.4 Gastrointestinal
  - 1.4.1 Gastrointestinal function and motility
    - 1.4.1.1 Motility and pH
    - 1.4.1.2 Intestinal Absorption
  - 1.4.2 General Renal Function
    - 1.4.2.2 Stone Formation
    - 1.4.2.3 Renal Infection

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.4.1.1

Gastrointestinal Motility and pH

EXPERIMENT CATEGORY

Gastrointestinal Function--Function and Motility

OBJECTIVE AND SIGNIFICANCE

To determine the effect of weightlessness on gastric secretion and gastrointestinal motility. Available data indicate that prolonged stress could result in increased acid secretion with peptic ulceration.

MEASUREMENTS AND OBSERVATIONS

Motility (pressure waves)
Stomach volume
Stomach contraction rate and force
Gastric pH
Hunger pain (subjective opinion)

EXPERIMENT DURATION

25 min. twice a day, every 7 days for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Imbibed transmitter (endoradiosonde)
Rubber balloon
Stomach tube (Rehfuss)
Pressure transducers and recorder or oscilloscope
pH meter

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

2 technicians

REFERENCES

Apollo Extension Systems Experiments. NASA, Washington, D. C., 15 March 1965.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.4.1.2

Intestinal Absorption

EXPERIMENT CATEGORY

Gastrointestinal Function

OBJECTIVE AND SIGNIFICANCE

To determine the absorption rates of common foodstuffs during prolonged weightlessness.

MEASUREMENTS AND OBSERVATIONS

Absorption rates (radioisotopically labelled foods)
Body and specimen masses

EXPERIMENT DURATION

60 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Radioactive tracers
Scintillation counter/scaler
Mass measurement devices (large and small)
Urine and feces storage unit

SPECIAL REQUIREMENTS/REMARKS

Waste management equipment with sampling capability is required.

PERSONNEL REQUIRED

1 technician

REFERENCES

Integrated Medical Behavioral Laboratory Measurement System. NASA RFP 10-1243, December 1966.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.4.2.1

Indices of Renal Function

EXPERIMENT CATEGORY

Renal Function

OBJECTIVE AND SIGNIFICANCE

To determine the influence of prolonged weightlessness on kidney function and possible urinary calculus formation. Changes in body position on Earth are known to alter renal function, but long-term effects associated with spaceflight are unknown.

MEASUREMENTS AND OBSERVATIONS

Blood urea nitrogen
Serum electrolytes
Serum creatinine
Urinalysis
Urine creatinine
Urine osmolality
Urine volume
Body and specimen mass

EXPERIMENT DURATION

2 hours weekly for mission duration (independent of number of subjects).

SUBJECTS, MATERIALS, AND EQUIPMENT

All crew members
Spectrophotometer
Specific ion electrodes
Osmometer
Mass measurement devices (large and small)
pH meter

SPECIAL REQUIREMENTS/REMARKS

Waste management system with sampling and measurement capability is required.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D. C., 15 March 1965.
S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

1.4.2.2

EXPERIMENT TITLE — TEXT REF. NO. **1.4.2.2**

Renal Calculus Formation in Rats

EXPERIMENT CATEGORY

Renal Function--Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine whether prolonged weightlessness affects the rate of renal and bladder calculus formation.

MEASUREMENTS AND OBSERVATIONS

Histology (kidney and bladder)
Serum electrolytes
Urinalysis
Urine calcium and phosphorus
Urine osmolality
Urine volume

EXPERIMENT DURATION

10 min. daily for 4 weeks. (1 hour for sample preparation at experiment conclusion.)

SUBJECTS, MATERIALS, AND EQUIPMENT

6 albino rats
Tissue fixatives
Spectrophotometer
Specific ion electrodes
Osmometer
Urine collection equipment
pH meter

SPECIAL REQUIREMENTS/REMARKS

Ground-based research required to establish techniques for enhancement of calculus formation. Provision for urine collection is required.

PERSONNEL REQUIRED

1 technician

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.4.2.3

Renal Infection in Rats

EXPERIMENT CATEGORY

Renal Function--Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine whether induced ascending renal infection is more rapidly progressive in weightlessness.

MEASUREMENTS AND OBSERVATIONS

Histology
Urinalysis
Urine culture
White blood cell count
Cultures of renal tissue

EXPERIMENT DURATION

30 min. daily for 2 weeks. (2 hours for sample preparation at experimental conclusion.)

SUBJECTS, MATERIALS, AND EQUIPMENT

4 albino rats with partial ureteral ligation
Tissue fixatives
Osmometer
Bacteriology equipment

SPECIAL REQUIREMENTS/REMARKS

Provision for urine collection is required.

PERSONNEL REQUIRED

1 technician

REFERENCES

MDAC originated.

1.5 METABOLISM AND NUTRITION

Statement of the Problem

Some changes related to metabolism and nutrition have been noted for astronauts exposed to 14 days of orbital flight, including reduction in body weight and loss of mineral material in the bones. These noted effects may become progressively more serious to the extent of impairing tolerance of bone structure against torque and shearing, weakening of muscle mass, and possible formation of kidney stones.

Scientific Objectives

The objectives of the program include the development of flight experiments on human metabolism and digestion; development of nonsurgical techniques for appraising the human metabolic state; identification and study of control mechanisms that regulate metabolism and energy requirements, and evaluation of the effects of the space environment and of drugs on the mobility, digestion, and absorption in the gastrointestinal tract. The following areas need detailed study.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Metabolism and Nutrition are listed. They are followed by detailed sheets on each of the component experiments.

1.5 Metabolism and Nutrition

1.5.1 General Metabolism

1.5.1.1 Energy Metabolism

1.5.2 Specific Metabolics

1.5.2.1 Carbohydrate and Fat Metabolism

1.5.2.2 Protein Metabolism

1.5.2.3 Body Fluid Composition

1.5.2.4 Mineral Metabolism

1.5.3 Cellular Metabolism

1.5.3.1 No experiments proposed yet

1.5.4 Muscle and Bone Metabolism

1.5.4.1 No experiments proposed yet

1.5.5 Nutrition

1.5.5.1 No experiments proposed yet

EXPERIMENT REQUIREMENTS SUMMARY

1.5.1.1

EXPERIMENT TITLE — TEXT REF. NO. 1.5.1.1

Energy Metabolism

EXPERIMENT CATEGORY

Nutrition, Metabolism--General Metabolism

OBJECTIVE AND SIGNIFICANCE

To determine the effect of prolonged weightlessness on metabolic rates and patterns.

MEASUREMENTS AND OBSERVATIONS

Body mass
Body volume
Expiratory pO_2 and pCO_2
Inspiratory pO_2 and pCO_2
Body temperature

EXPERIMENT DURATION

15 min. daily for first week; then, 15 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Body volumeter
Expiratory gas analyzer
Temperature recorder
Ergometer
Mass measurement devices

SPECIAL REQUIREMENTS/REMARKS

24-hour representative total energy metabolism can be made from selected short-duration measurements of typical activities determined by time-and-motion studies. Can be integrated with Experiment 1-31.

PERSONNEL REQUIRED

1 technician

REFERENCES

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.5.2.1

Carbohydrate and Fat Metabolism

EXPERIMENT CATEGORY

Nutrition, Metabolism--General Metabolism

OBJECTIVE AND SIGNIFICANCE

To determine to what extent prolonged weightlessness alters carbohydrate and fat metabolism.

MEASUREMENTS AND OBSERVATIONS

Body mass
Expiratory pO_2 and pCO_2
Blood glucose
Urine glucose
Blood-free fatty acids
Serum phosphorus

EXPERIMENT DURATION

1 hour per chemical measurement (independent of number of subjects) weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Mass measurement devices (large and small)
Specific ion electrodes
Expiratory gas analyzer
Biochemistry analysis equipment

SPECIAL REQUIREMENTS/REMARKS

Can be integrated with Experiment 1-30 for respiratory quotient determination and with Experiment 1-33. Additional development is required for blood fatty-acid determination technique.

PERSONNEL REQUIRED

1 technician

REFERENCES

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.5.2.2

Protein Metabolism

EXPERIMENT CATEGORY

Nutrition, Metabolism--General Metabolism

OBJECTIVE AND SIGNIFICANCE

To determine whether weightlessness affects nitrogen turnover rates to the extent that the disturbed metabolic function becomes incompatible with effective performance.

MEASUREMENTS AND OBSERVATIONS

Recorded nitrogen intake
Body Mass
Body volume
Urine nitrogen
Fecal nitrogen
Blood urea nitrogen

EXPERIMENT DURATION

60 min. per sample (after 24-hour collection periods) every other day for first 2 weeks; then, weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Mass measurement devices (large and small)
Body volumeter
Urine and feces collection equipment for 24-hr samples
Nitrogen analyzer
Urine and feces storage units

SPECIAL REQUIREMENTS/REMARKS

Waste management system is designed for aliquot samplings of 24-hour collections. Automated nitrogen analyzer requires development. Can be integrated with Experiment 1-33.

PERSONNEL REQUIRED

1 technician

REFERENCES

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.5.2.3

Fluid and Electrolyte Balance

EXPERIMENT CATEGORY

Nutrition, Metabolism--Body Fluids

OBJECTIVE AND SIGNIFICANCE

To determine the effect of prolonged spaceflight on water balance and electrolyte metabolism. Studies on Earth indicate that changes in fluid balance accompany changes in body position.

MEASUREMENTS AND OBSERVATIONS

Body mass and volume
Total body water
Blood volume
Plasma volume
Red blood cell mass
Extracellular fluid volume
Serum proteins
Serum electrolytes
Serum (blood) pH
Blood glucose
Urine titratable acidity
Urine osmolality
Urine glucose
Urine nitrogen
Urine creatine and creatinine

EXPERIMENT DURATION

1 hour weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Body volumeter
Radioactive tracer materials
Scintillation counter/scaler
Spectrophotometer
Electrophoresis apparatus
Expiratory gas analyzer
Mass measurement devices
Biochemistry analysis equipment
Specific ion electrodes
pH meter
Osmometer
Refrigeration unit
Ergometer
Nitrogen analyzer

SPECIAL REQUIREMENTS/REMARKS

Diet must be controlled. Can be integrated with Experiments 1-15, 1-31, and 1-32. Additional research and development is required for chemistry techniques.

PERSONNEL REQUIRED

2 technicians

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D. C., 15 March 1965.

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE TEXT REF. NO. 1.5.2.4

Mineral Metabolism

EXPERIMENT CATEGORY

Nutrition, Metabolism--General Metabolism

OBJECTIVE AND SIGNIFICANCE

To determine the effect of prolonged weightlessness and physical inactivity on mineral metabolism. Data will be used to develop corrective measures necessary for maintaining normal mineral balance.

MEASUREMENTS AND OBSERVATIONS

Serum, urinary, and stool calcium and phosphorus
Serum alkaline phosphatase
Fecal mass

EXPERIMENT DURATION

4 hours per measurement weekly (independent of number of subjects) for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Spectrophotometer
Ergometer
Biochemistry analysis equipment
Urine and feces collection and storage equipment

SPECIAL REQUIREMENTS/REMARKS

Can be integrated with Experiments 2-31, 2-32, and 2-33. Adc nal research is required to develop on board techniques for chemical analyses.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D. C., 15 March 1965.
S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

1.6 MUSCULOSKELETAL

Statement of the Problem

Limited space flight results indicate that muscle and skeletal changes can occur in the weightless environment but the ultimate extent and pattern of change is not defined. Secondary effects such as bone fracture or healing or work capabilities offer prolonged exposure are not yet determined.

Scientific Objectives

To determine calcium metabolism, absorption and secretion, fracture calcium kinetics and healing and skeletal decalcification. To study the effects of prolonged weightlessness on work capacity and muscle strength and to investigate remedial measures such as exercise.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Musculoskeletal are listed. They are followed by detailed sheets on each of the component experiments.

- 1.6 Musculoskeletal
  - 1.6.1 Skeletal Decalcification
    - 1.6.1.1 Bone Density
    - 1.6.1.2 Fracture healing
    - 1.6.1.3 Calcium mobilization
  - 1.6.2 Work Capacity, Exercise and Deconditioning
    - 1.6.2.1 Muscle Status

1.6.2.2 Induction of Pressure Atrophy

1.6.3 Deconditioning Indexes

1.6.3.1 Electromyographic Evaluation

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.6.1.1

Bone Density

EXPERIMENT CATEGORY

Musculoskeletal Function -- Skeletal Decalcification

OBJECTIVE AND SIGNIFICANCE

To determine whether prolonged weightlessness will result in significant skeletal decalcification. Limited results during brief orbital flights indicate that such changes are probable, but the ultimate extent and pattern of bone decalcification is unknown.

MEASUREMENTS AND OBSERVATIONS

Bone density
Blood, urine, and stool calcium and phosphorus
Serum alkaline phosphotase

EXPERIMENT DURATION

30 min. weekly for mission duration. (Preflight control measurements of bone density; post-flight measurements for 3 days.)

SUBJECTS, MATERIALS, AND EQUIPMENT

All crew members
Bone densitometer
Urine and feces collection and storage
Biochemistry analysis equipment

SPECIAL REQUIREMENTS/REMARKS

R&D is required for lightweight densitometry equipment. Investigation of isotope radiation source and ultrasound technique is under development. Chemical determinations done in Experiments 2-31, 2-32, 2-33, and 2-34.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D.C., 15 March 1965.

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.6.1.2

Fracture Healing in Animals

EXPERIMENT CATEGORY

Musculoskeletal Function -- Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the effect of weightlessness on the rate of fracture healing.

MEASUREMENTS AND OBSERVATIONS

Calcium turnover rate
Bone formation rate
Serum calcium, phosphorus, and alkaline phosphotase
Bone density
Histology

EXPERIMENT DURATION

10 min. daily and 1 hour weekly for 6 weeks. (2 hours for sample preparation at experiment conclusion.)

SUBJECTS, MATERIALS, AND EQUIPMENT

6 guinea pigs
Radioactive tracers
Radioactivity counter/scaler
Bone densitometer
Tissue fixatives
Biochemistry analysis equipment

SPECIAL REQUIREMENTS/REMARKS

Tests should be conducted early in the mission before appreciable deconditioning has occurred so that there can be a comparison with results obtained during end of mission.

PERSONNEL REQUIRED

2 technicians

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

MAJOR TITLES — TEXT REF. NO. 1.6.1.3

Biomedical and Behavioral

EXPERIMENT TITLE

Calcium Mobilization

EXPERIMENT CATEGORY

Skeletal Decalcification

OBJECTIVE AND SIGNIFICANCE

To delineate effects of weightlessness on calcium metabolism, fracture calcium kinetics and calcium absorption and secretion

MEASUREMENTS AND OBSERVATIONS

Plasma samples, calcium intake, excretion analysis, bone X-ray, radioactive isotope monitoring

EXPERIMENT DURATION

6 weeks

SUBJECTS, MATERIALS, AND EQUIPMENT

White Leghorn chickens
X-ray machine
Chemical analysis

SPECIAL REQUIREMENTS/REMARKS

PERSONNEL REQUIRED

One technician

REFERENCES

1. "Effect of Restraint, Stress and Fasting On Organ Size in the Domestic Fowl," Physiologist 10: 125, 1967.
2. "Physiological Limitations on Animal Restraint," Aerospace Med. 38: 1130, 1967
3. "Criteria for Physiologic Stress and Adaptation," Physiologist 10: 137, 1967

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.6.2.1

Muscle Mass and Strength

EXPERIMENT CATEGORY

Musculoskeletal Function -- Work Capacity, Exercise, and Deconditioning

OBJECTIVE AND SIGNIFICANCE

To determine the effect of prolonged weightlessness on work capacity and muscle strength and to determine the effectiveness of exercise as a means of preventing deconditioning.

MEASUREMENTS AND OBSERVATIONS

Muscle size
Urine creatinine
Urine creatine
Blood lactic acid
Blood creatinine
Muscle strength

EXPERIMENT DURATION

40-min. twice weekly for first 4 weeks; then, 40 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

3 crew members
Ergometer
Muscle dynamometer
Biochemistry analysis equipment
Urine collection equipment

SPECIAL REQUIREMENTS/REMARKS

Basic research required to correlate muscle size with work capacity. Chemical determinations done in Experiments 2-27 and 2-34.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D. C., 15 March 1965.

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study. NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.6.7.2.

Induction of Pressure Atrophy

EXPERIMENT CATEGORY

Musculoskeletal Function -- Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the rate of pressure-induced bone atrophy during weightlessness.

MEASUREMENTS AND OBSERVATIONS

Calcium turnover rate
Bone formation rate
Serum calcium, phosphorus, and alkaline phosphotase
Bone density
Histology

EXPERIMENT DURATION

2 hours weekly for 6 weeks.

SUBJECTS, MATERIALS, AND EQUIPMENT

3 guinea pigs
Radioactive tracers
Bone densitometer
Radioactivity counter/scaler
Biochemistry analysis equipment
Tissue fixatives

SPECIAL REQUIREMENTS/REMARKS

Best technique for determining turnover rates must be determined. This experiment will use analytic equipment of other biochemistry experiments.

PERSONNEL REQUIRED

1 technician

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.6.3.1

Electromyography as an Index of Deconditioning

EXPERIMENT CATEGORY

Musculoskeletal Function -- Deconditioning Indices

OBJECTIVE AND SIGNIFICANCE

To develop and apply the techniques of electromyography for determining the extent of deconditioning occurring during prolonged spaceflight.

MEASUREMENTS AND OBSERVATIONS

Serum calcium, phosphorus, and alkaline phosphotase
Bone density
Muscle size
Urine creatinine
Urine creatine
Electromyography
Blood lactic acid
Blood creatinine
Muscle strength

EXPERIMENT DURATION

20-min. twice weekly for first 4 weeks; then, 20 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

3 crew members
Ergometer
Electromyograph and recorder
Muscle dynamometer
Biochemistry analysis equipment
Bone densitometer

SPECIAL REQUIREMENTS/REMARKS

Chemical determinations done in Experiments 2-27 and 2-34.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D.C., 15 March 1965.

1.7 ENDOCRINOLOGY

Statement of the Problem

Space flight subjects man to a composite of increased and decreased stresses and as such could be expected to affect the endocrine system. Observations from past flights are too sketchy to present a precise picture of how the endocrine system responds to these stresses and, consequently, to those imposed by prolonged space flight. Minimal information gained thus far indicates decreased endocrine activity during flight and increased activity after re-entry.

Scientific Objectives

The objectives of the endocrine research program are to define the effect of space flight stresses (both simulated and actual) on the response of the endocrine system.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Respiration are listed. They are followed by detailed sheets on each of the component experiments.

- 1.7 Endocrinology
  - 1.7.1 Stress Effects
    - 1.7.1.1 Endocrine Assays
    - 1.7.1.2 Thermal Regulation
    - 1.7.1.3 Adrenal and Parathyroid, Histopathology and Function

1.7.1.4 Gonad Histopathological Evaluation

1.7.2 Remedial and Prophylactic measures

1.7.2.1 No experiments proposed yet

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.7.1.1

Endocrine Function and Stress Physiology

EXPERIMENT CATEGORY

Endocrine Function -- Stress

OBJECTIVE AND SIGNIFICANCE

To determine and quantitate the effect of prolonged spaceflight on pituitary, thyroid, adrenal, gonadal, and neurohumoral functions.

MEASUREMENTS AND OBSERVATIONS

Expiratory pO_2 and pCO_2
Urinary 17-hydroxy steroids
Urinary aldosterone
Urinary 17 ketosteroids
Urinary catecholamines
Urinary serotonin
Blood PBI, and ACTH
Sperm count and motility
(pre- and post-flight)
Histological evaluation
Urine volume and osmolality
Fluid electrolytes

EXPERIMENT DURATION

1-hour sample collection and preparation twice weekly for first 4 weeks; then, 1 hour weekly for missile duration. (Time for on-board analysis undetermined.)

SUBJECTS, MATERIALS, AND EQUIPMENT

2 or 3 crew members
Ergometer
Temperature recorder
Osmometer
Urine storage
Refrigeration unit
Specific ion electrodes
Frozen storage unit
Spectrophotometer
Biochemistry analysis equipment
Tissue fixatives
Expiratory gas analyzer
Specific hormone assay equipment

SPECIAL REQUIREMENTS/REMARKS

R&D is required for on-board hormone analysis. Ground determinations may be required.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D.C., 15 March 1965.

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.7.1.2

Temperature Regulation Mechanisms

EXPERIMENT CATEGORY

Endocrine Function -- Thermoregulation

OBJECTIVE AND SIGNIFICANCE

To determine the effect of various stresses of prolonged spaceflight on physiological mechanisms of temperature regulation.

MEASUREMENTS AND OBSERVATIONS

Blood PBI
Temperature (ambient)
Skin and core temperature
Humidity
Blood flow
Blood TSH
Airflow volume
Fluid electrolytes
Expiratory pO_2 and pCO_2

EXPERIMENT DURATION

30 min. daily for first week; then, 30 min. weekly for mission duration. (Time undetermined for on-board analysis of samples, but estimated at 6 hours.)

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Constantan-silver thermocouple
Specific hormone assay equipment
Temperature recorder
Specific ion electrodes
Expiratory gas analyzer
Spectrophotometer
Ergometer
Humidity recorder
Gas flowmeter

SPECIAL REQUIREMENTS/REMARKS

Methods for separating evaporative from nonevaporative heat losses are required. Methods for specific analyses have not yet been developed.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D.C., 15 March 1965.

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.7.1.3

Adrenal and Parathyroid Function in Rats

EXPERIMENT CATEGORY

Endocrine Function (Stress) -- Animal Research

OBJECTIVE AND SIGNIFICANCE

To observe both histological and biochemical parameters of adrenal and parathyroid activity in animals during weightlessness and extra imposed stresses.

MEASUREMENTS AND OBSERVATIONS

Urinary 17-hydroxy steroids
Urinary aldosterone
Urinary 17 ketosteroids
Urinary catecholamines
Histological evaluation
Urine volume and osmolality
Fluid electrolytes

EXPERIMENT DURATION

60-min. sample collection and preparation weekly; 4-hour on-board sample analysis weekly.

SUBJECTS, MATERIALS, AND EQUIPMENT

6 albino rats
Specific hormone assay equipment
Tissue fixatives
Urine storage
Refrigeration unit
Frozen storage unit

SPECIAL REQUIREMENTS/REMARKS

Development is required for specific hormone assays.

PERSONNEL REQUIRED

1 technician

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.7.1.4

Gonad Histopathology

EXPERIMENT CATEGORY

Endocrine Function (Stress) -- Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the effect of prolonged weightlessness and radiation flux on gonadal histopathology and function.

MEASUREMENTS AND OBSERVATIONS

Sperm count and motility
Histology

EXPERIMENT DURATION

30-min. sample preparation weekly. (Total number of samples to be determined by mission duration.)

SUBJECTS, MATERIALS, AND EQUIPMENT

2 to 6 albino rats (actual number to be determined)
Tissue fixatives
Radiation dosimeter
Microscope
Hemocytometer

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

1 technician

REFERENCES

MDAC originated.

1.8 HEMATOLOGY

Statement of the Problem

Decreases in plasma volume, blood volume and red cell mass were observed during manned spaceflight. The mechanism must be identified and remedial or preventive measures provided. In addition, the immune respons of the body must be thoroughly studied in order to insure that maximal defenses can be mobilized if the body is challenged by virulent organisms.

Scientific Objectives

To provide a total understanding of hemodynamics and immune response to the space environment and any possible microbial challenge.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Hematology are listed. They are followed by detailed sheets on each of the component experiments.

- 1.8 Hematology
  - 1.8.1 Blood Cytogenetics
    - 1.8.1.1 Chromatin Evaluations
  - 1.8.2 Blood Cell Dynamics
    - 1.8.2.1 Erythrocytes
    - 1.8.2.2 Leukocytes
    - 1.8.2.3 Platelets
    - 1.8.2.4 WBC Mobilization after chemical challenge
    - 1.8.2.5 Maximum Rate of RBC production

1.8.2.6 Wound Healing

1.8.3 Coagulation System Integrity

1.8.3.1 Hemostasis

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.8.1.1

Leukocyte Replication

EXPERIMENT CATEGORY

Hematologic Function -- Blood Cytogenetics

OBJECTIVE AND SIGNIFICANCE

To determine the effect of prolonged spaceflight on chromosomal activity of hemic cells during replication and division.

MEASUREMENTS AND OBSERVATIONS

White blood cell count (total and differential)
Cell morphology
Cytogenetic examination

EXPERIMENT DURATION

40 min. daily for first 2 days; then, every 10 days for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

All crew members
Cytology stains
Photomicrographic apparatus (color film)

SPECIAL REQUIREMENTS/REMARKS

Techniques for cytogenetic studies during spaceflight need to be developed.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D.C., 15 March 1965.

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.8.2.1

Erythrocyte Dynamics

EXPERIMENT CATEGORY

Hematologic Function -- Blood Cell Dynamics

OBJECTIVE AND SIGNIFICANCE

To determine the effect of the various combinations of spaceflight environment on the proliferation, distribution, and destruction of human erythrocytes.

MEASUREMENTS AND OBSERVATIONS

Hematocrit
Red blood cell mass, count, fragility, and survival time
Plasma volume
Reticulocyte count
Hemoglobin
Cell morphology

EXPERIMENT DURATION

1 hour every 4 days for first 4 weeks; then, 1 hour every 10 days for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Radioactive tracers
Scintillation counter/scaler
Cytology stains
Hemoglobinometer

SPECIAL REQUIREMENTS/REMARKS

Can be integrated with Experiment 1-15 for blood volume and red blood cell mass measurements.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washintgon, D.C., 15 March 1965.

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

M69

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.8.2.2

Leukocyte Dynamics

EXPERIMENT CATEGORY

Hematologic Function -- Blood Cell Dynamics

OBJECTIVE AND SIGNIFICANCE

To determine the effect of space environment on leukocyte proliferation, distribution, and destruction. Phagocytic action of leukocytes may be impaired in weightlessness.

MEASUREMENTS AND OBSERVATIONS

White blood cell count (total and differential)
White blood cell motility and phagocytosis
Cell morphology

EXPERIMENT DURATION

30 min. every 4 days for first month; then, 30 min. every 10 days for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 to 3 crew members
Incubator (37°C)
Microscope
Hemocytometer
Cytology stains
Photomicrographic apparatus (color film)

SPECIAL REQUIREMENTS/REMARKS

Standardized technique for phagocytic index must be determined.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List SA, Washington, D.C., 15 March 1965.

S.P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

1.8.2.3

EXPERIMENT TITLE — TEXT REF. NO. 1.8.2.3

Platelet Dynamics

EXPERIMENT CATEGORY

Hematologic Function -- Blood Cell Dynamics

OBJECTIVE AND SIGNIFICANCE

To measure the effect of prolonged weightlessness on platelet dynamics

MEASUREMENTS AND OBSERVATIONS

Cell morphology
Platelet count
Blood clotting time and clot retraction

EXPERIMENT DURATION

30 min. every 4 days for first 4 weeks; then, 30 min. every 10 days for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 or 3 crew members
Cytology stains
Photomicrographic apparatus (color film)
Incubator (37°C)

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D.C., 15 March 1965.

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.8.2.4

Leukocyte Mobilization in Mice after Chemical Challenge

EXPERIMENT CATEGORY

Hematologic Function -- Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine whether weightlessness affects leukocyte mobilization after challenge with a pharmacologically active agent (endotoxin).

MEASUREMENTS AND OBSERVATIONS

White blood cell count (total and differential)
White blood cell motility and phagocytic index
Cell morphology

EXPERIMENT DURATION

30 min. every hour for total of 12 hours.

SUBJECTS, MATERIALS, AND EQUIPMENT

4 albino mice
Cytology stains
Photomicrographic apparatus

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

1 technician

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.8.2.5

Maximum Rate of Erythrocyte Production in Rats

EXPERIMENT CATEGORY

Hematologic Function -- Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the influence of weightlessness on the rate of erythrocyte production in animals after maximum stimulation by blood loss.

MEASUREMENTS AND OBSERVATIONS

Hematocrit
Red blood cell mass, count, and survival time
Reticulocyte count
Cell morphology

EXPERIMENT DURATION

1 hour every 3 days for 2 weeks.

SUBJECTS, MATERIALS, AND EQUIPMENT

4 albino rats or mice
Cytology stains
Photomicrographic apparatus (color film)
Clinical centrifuge
Radioactive tracers
Radioactivity counter/scaler
Hemoglobinometer

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

1 technician

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.8.2.6

Wound Healing

EXPERIMENT CATEGORY

Hematologic Function -- Animal Research

OBJECTIVE AND SIGNIFICANCE

To determine the influence of weightlessness on the healing rates for lacerations, thermal burns, contusions, and abrasions.

MEASUREMENTS AND OBSERVATIONS

White blood cell count (total and differential)

EXPERIMENT DURATION

10 min. daily and 1-hour photography every third day for 2 to 6 weeks.

SUBJECTS, MATERIALS, AND EQUIPMENT

6 miniature swine
Still camera (color film)
Microscope
Hemacytometer

SPECIAL REQUIREMENTS/REMARKS

Experiments should include a variation in g level, if possible.

PERSONNEL REQUIRED

1 technician

REFERENCES

Medical Requirements in Support of Long Duration Manned Space Flight. Bellcomm, Inc.. Report No. TR-67-710-1, 1967.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.8.3.1

Blood Coagulation and Hemostatic Function

EXPERIMENT CATEGORY

Hematologic Function -- Coagulation System Integrity

OBJECTIVE AND SIGNIFICANCE

To determine if prolonged spaceflight changes blood coagulation and hemostatis. Possible pooling of blood may cause thrombosis. This experiment makes it possible for the first time to observe spontaneous blood clotting under conditions where the blood has no contact with external surfaces.

MEASUREMENTS AND OBSERVATIONS

Bleeding time
Platelet count
Blood clotting time
Clot retraction

EXPERIMEN[illegible]ON

30 min. every [illegible] days for first 4 weeks; then, 30 min. every 10 days for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 or 3 crew members
Cytology stains
Incubator (37°C)
Photomicrographic apparatus (color film)

SPECIAL REQUIREMENTS/REMARKS

None.

PERSONNEL REQUIRED

1 technician

REFERENCES

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

1.9 MICROBIOLOGY AND IMMUNOLOGY

Statement of the Problem

The microbiological aspects of manned space flight and the ability of crews to cope with potential infectious agents on extended flights are presently undefined.

The delicate balance between host animal (crew) and its microbial environment in closed and semiclosed ecological systems is a precarious one, and even minor alterations in diet, physiologic or immune state, or genetic constitution of cohabitant microorganisms may result in the shift of equilibrium to a new balance of microflora. The dominant species in this new balance may or may not be compatible with the host.

Scientific Objectives

This complex program has as its objective the definition of potential problem areas in long-term host/microflora relationships pertinent to closed or semiclosed ecological systems and the development of optimal methods of control to assure crew resistance to all potentially infectious or pathogenic microorganisms.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Microbiology and Immunology are listed. They are followed by detailed sheets on each of the component experiments.

1.9 Microbiology and Immunology

1.9.1 Microbiology

1.9.1.1 Microbiological Evaluation of Environment

1.9.1.2 Microbiological Evaluation of Crew Members

1.9.1.3 Air Sampling

1.9.2 Immunology

1.9.2.1 Immunological Evaluation of Crew Members

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.9.1.1

Microbial Evaluation of Surfaces

EXPERIMENT CATEGORY

Microbiology/Immunology -- Ecology

OBJECTIVE AND SIGNIFICANCE

To survey microbial profiles of equipment surfaces and to follow changes during mission progress.

MEASUREMENTS AND OBSERVATIONS

Bacterial and fungal enumerations and gross identification.

EXPERIMENT DURATION

1 hour twice weekly.

SUBJECTS, MATERIALS, AND EQUIPMENT

All crew members
Incubator (37°C)
Microbial culture media and equipment
Colony counter
Lyophilization apparatus
Refrigerated storage
Autoclave
Photomicrography equipment
Frozen storage unit

SPECIAL REQUIREMENTS/REMARKS

Design of equipment for null-gravity manipulations is required. Additional R&D on rapid identification methods is warranted.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D.C., 15 March 1965.

Integrated Medical Behavioral Laboratory Measurement System. NASA RFP 10-1243, 1966.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.9.1.2

Microbial Profiles of Crew Members

EXPERIMENT CATEGORY

Microbiology/Immunology -- Ecology

OBJECTIVE AND SIGNIFICANCE

To determine microbial profiles of crew members in a closed ecosystem under conditions of prolonged stress and weightlessness.

MEASUREMENTS AND OBSERVATIONS

Bacterial (aerobic and anaerobic) enumeration and identification
Sample collection

EXPERIMENT DURATION

10-min. sample collection and 6-hour evaluation and preservation of samples. (To be done weekly for mission duration or as required by clinical status of crew members.)

SUBJECTS, MATERIALS, AND EQUIPMENT

All crew members
Bacteriological culture media and equipment
Incubator (37°C)
Refrigerated storage
Frozen storage
Lyophilization apparatus
Photomicrographic equipment
Autoclave
Colony counter

SPECIAL REQUIREMENTS/REMARKS

Development of techniques applicable to zero-g environment and for rapid identification of bacteria is warranted.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D.C., 15 March 1965.

Integrated Medical Behavioral Laboratory Measurement System. NASA RFP 10-1243, 1966.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 1.9.1.3

Air Sampling for Microorganisms

EXPERIMENT CATEGORY

Microbiology/Immunology -- Ecology

OBJECTIVE AND SIGNIFICANCE

To determine possible alterations in airborne microbial contaminant loads caused by prolonged spaceflight.

MEASUREMENTS AND OBSERVATIONS

Bacterial and fungal enumeration and gross identification
Storage of representative microflora

EXPERIMENT DURATION

30 min. daily for first 2 weeks; then, 30 min. every other day for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

Anderson and Reyniers air samplers
Incubator (37°C)
Refrigerated storage
Lyophilization apparatus
Colony counter
Bacterial culture media and equipment
Frozen storage unit
Autoclave
Photomicrography equipment

SPECIAL REQUIREMENTS/REMARKS

Development of techniques to facilitate determinative bacteriology in zero-g environment is desirable.

PERSONNEL REQUIRED

1 technician

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE TEXT REF. NO. 1.9.2.1

Immunological Survey of Crew Members

EXPERIMENT CATEGORY

Microbiology/Immunology -- Ecology

OBJECTIVE AND SIGNIFICANCE

To assess changes which may occur in the amount and type of serum immune components in subjects exposed to prolonged spaceflight.

MEASUREMENTS AND OBSERVATIONS

Sample collection and preparation of serum immune components

EXPERIMENT DURATION

15 min. every 1 to 2 weeks for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

All crew members
Frozen storage unit

SPECIAL REQUIREMENTS/REMARKS

Analyses to be done after mission completion.

PERSONNEL REQUIRED

1 technician

REFERENCES

Apollo Extension Systems Experiment List. NASA, Washington, D. C., 15 March 1965.

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

1.11 SPACE PHARMACOLOGY

Statement of the Problem

No unfavorable effects have been reported in the limited use of drugs on space flights to date. The use of any drugs on longer missions will require a systematic exploration of the effects of drugs in the space environment and the effects of the space evnironment on the drugs which may be used. Such a study should include the mode of action, side effects, contamination effects, effects on performance, and drug compatability. These studies should be carried out in both animals and man under simulated (bedrest) and actual space flight conditions.

Scientific Objectives

The objective is to use pharmacology as a major means of applying protective measures to maintain and restore the mental and physical integrity of man in the space environment. The studies that will be described will be an aid in delineating the physiological effects of the space environment and in designing onboard diagnostic or prognostic tests.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Space Pharmacology are listed. They are followed by detailed sheets on each of the component experiments.

1.11 Pharmacology

1.11.1 Drug effects and stability

1.11.1.1 No experiments proposed yet

1.11.2 Pharmacological manipulations of sleep, behavior, biorhythms, etc.

1.11.2.1 No experiments proposed yet

1.11.3 Dose levels

1.11.3.1 No experiments proposed yet

1.12 RADIOBIOLOGY

Statement of the Problem

There is significant measurable radiation in the space environment. Exposure of biological materials including man to ionizing radiation may produce undesirable effects. The radiation in space is due to particulate radiation such as protons, alpha particles, and electrons. There has been little information available as to the biological effects of particulate ionizing radiation. The hazards of this type of radiation are being determined.

Scientific Objectives

The objective of the radiobiology program is to determine human tolerance levels to space radiation by means of fundamental and applied radiobiology research. The effects of acute and protracted doses of radiation relative to the production of nausea and to injury of critical organs such as the eyes, hematopoietic system, skin, and intestines will be determined in animals and humans where possible.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Radiobiology are listed.

1.12 Radiobiology

1.12.1 Molecular and Cellular Changes

1.12.1.1 No experiments proposed yet

1.12.2 Mammalian Systems Changes

1.12.2.1 No experiments proposed yet

1. 12.3 Combined Effects of Radiation and Other Stresses

1.12.3.1 No experiments proposed yet

1.13 CLINICAL MEDICINE

Statement of the Problem

The relatively short manned flights to date have posed no medical problems of the sort that would require onhand clinical diagnostic and/or therapeutic capabilities more elaborate than simple medications and dressings. Extended missions, particularly those which may be physician-attended, will require a considerable diagnostic and therapeutic capability which must provide for minor surgical procedures.

Scientific Objectives

The goal of this program is to define and develop the diagnostic and therapeutic procedures, medications, and equipment that will be required to maintain the health and well being of the crew.

Research Areas and Component Experiments

No further breakdown or experiments are yet proposed.

1.14 BIOINSTRUMENTATION

Statement of the Problem

Current flight qualified biomedical instrumentation is limited to simple vital-sign measurements and as such is grossly inadequate to meet the requirements for mission-rating man for extended flights, and prediction of malfunction at an early stage in degradation.

Scientific Objectives

The aim of the bioinstrumentation effort is to develop sophisticated state-of-the-art and advanced instrumentation (i.e. simple, nondestructive, noninvasive, and broad scope) in order to provide the required measurements and data analysis techniques.

Research Areas and Component Experiments

The Research Areas and Component Experiments are listed.

1.14 Bioinstrumentation

1.14.1 Implant Telemetry

1.14.1.1 No experiments proposed yet

1.14.2 External Instrumentation (i.e. oculometer)

1.14.2.1 No experiments proposed yet

1. 14.3 Dosimetry

1.14.3.1 No experiments proposed yet

FUNCTIONAL PROGRAM ELEMENT II

MAN-SYSTEMS INTEGRATION

REQUIREMENT

The Man-Systems Integration Functional Element Program has the technical objective of providing quantitative and qualitative information on the use of man and his behavior in space flight and on the moon. Man's capabilities in space systems can be optimized through the following approaches:

a. The identification of inflight tasks which can make optimum utilization of man's presence;

b. The determination of optimal measurement techniques required to assess crew proficiency;

c. The identification of crew skills and training needed to insure optimal performance;

d. The development of design requirements, equipment and techniques for critical operations such as command, control, rescue, transfer, assembly, maintenance, and repair inside and external to the space vehicle;

e. The development of methods and design criteria to produce habitable living areas in space and on the lunar surface; and

f. The extension of extravehicular performance design information and the development of effective work aids and translation devices.

JUSTIFICATION

Man's proficiency in space is dependent at least as much on systems design and the human interactions as it is on weightlessness and other factors of the space environment. Each spacecraft presents a new working environment. The changes in spacecraft evidenced from the Mercury Program through Gemini and into Apollo have been evolutionary. The changes in vehicle design and the complexity of operational activities. The Space Station Program, currently in a definition phase, again represents a marked advancement over previous manned space flight activities. It is imperative that the required additional information regarding the scope and limitations of human capabilities and the technology to support the augmentation of these capabilities be developed in a timely manner.

PROGRAM PHILOSOPHY

A basic assumption is that the AAP Program will have been completed successfully and that data will be made available for maximum utilization. This assumption is made with full realization that because of development problems and in-flight contingencies there will be a yield of somewhat less than 100% of the currently planned information. Nevertheless, this data bank, along with results of previous flight programs (Mercury, Gemini, and Apollo) will form the basis of developing a payload for space station activities.

The heart of the current effort is therefore founded in an aggressive ground-based program and in-flight experimentation will be viewed primarily as an opportunity to verify and validate design concepts and operational techniques. To the degree practical, operational type activities (including operation of experiments) will be utilized to accumulate information on crew capabilities, over time, in space. This approach required an extensive preflight program to develop observational methodologies and techniques. Also required is the opportunity to review flight plans in great detail to select those activities upon which assessment is required, and to develop the means to employ the assessment methodology within the context of the mission. In those instances where in-flight activities, capable of being assessed, are not planned, it will be necessary to provide experiment hardware aboard the space station as part of the experiment payload.

Included within the Man-Systems Integration Functional Program Element for orbital space flight are the following research categories:

2.1 - Space Systems Human Factors

2.2 - Extravehicular Technology

2.3 - Maintenance and Maintainability

2.4 - Behavior

2.1 SPACE SYSTEMS HUMAN FACTORS

Statement of the Problem

Since it is planned that man will work in the space environment for extended periods of time, it is necessary to determine his most efficient contribution; the effects of the space environment on his ability to maintain performance efficiency; the vehicle design and operational procedures which will enhance his long-term living and work proficiency; the factors which influence small group dynamics; and the display and information processing requirements.

Objectives

It is necessary to investigate human work capabilities in stress environments typical of space. This includes measurement and development of individual performance, psychological adjustment, effective tools and work relationships and changes in these adjustments and relationships as a function of time and stress. This information will provide crew, job, and equipment design data to minimize individual and crew performance degradation in space. Both work performance measures that are meaningful to the astronauts and survey techniques that can be assessed by the crew commander and ground support personnel are needed. Ground based simulation studies must be followed by studies of typical populations under stress in space.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Space Systems Human Factors are listed. They are followed by detailed sheets on each of the Component Experiments.

Research Areas and Component Experiments (Cont'd)

2.1 Space Systems Human Factors

2.1.1 Work Performance Studies

2.1.1.1 Measures of Work Performance

2.1.1.2 Performance Efficiency

2.1.1.3 Work Rest Cycles - No experiments yet proposed

2.1.2 Habitability

2.1.2.1 Artificial Gravity - No experiments yet proposed

2.1.2.2 Volume and Layout of Crew Work and Rest Areas and Modifications

2.1.2.3 Initial Illumination, Decor, and Changes

2.1.2.4 Crew Internal Mobility

2.1.2.5 Simulated Day-Night Cycles - No experiments yet proposed

2.1.2.7 Clothing Comfort

2.1.2.8 Off-Duty Recreational Facilities - no experiments yet proposed.

2.1.3 Small Group Dynamics and Selection

2.1.3.1 Crew Composition

2.1.3.2 Selection - no experiments yet proposed.

2.1.3.3 Off Duty Time

2.1.3.4 Advanced Methods of Training - no experiments yet proposed

2.1.4 Information Display and Processing

2.1.4.1 Processing Complex Information - no experiments yet proposed

2.1.4.2 Information retrieval - no experiments yet proposed

2.1.5 Manual Control Research

2.1.5.1 Influence of motion on simulation - no experiments yet proposed.

2.1.5.2 Manual navigation, guidance and control - no experiments yet proposed.

2.1.5.3 Manual backup to automatic control systems - no experiments yet proposed.

2.1.5.4 Human Transfer Function - Experiment needs final definition.

2.1.1. Work Performance

I. STATEMENT OF THE PROBLEM

Since it is planned that man will work in the space environment for extended periods of time on longer missions, we must determine what effects the space environment will have on his ability to perf n effectively.

II. OBJECTIVES

Investigations must be conducted to:

1. Establish feasible and valid performance measures.
2. Determine factors necessary for the maintenance of skill proficiency.
3. Determine effects of environmental and spacecraft stress on performance.

III. PROGRAM ACTIVITIES

1. Orbital Space Laboratory Performance Testing
2. Performance of Complex Tasks
3. Work-Rest Cycles
4. Motor Skill Retention

EXPERIMENT REQUIREMENTS SUMMARY

2.1.1.1

EXPERIMENT TITLE

TEXT REF. NO. 2.1.1.1

Restraint and Fine-Force Generation

EXPERIMENT CATEGORY

Mission Activities

OBJECTIVE AND SIGNIFICANCE

To assess the crew's manipulative dexterity in performing simulated mission tasks, and to evaluate related restraint techniques and metabolic costs. Results will be used in validating procedures, equipment, techniques, and training requirements.

MEASUREMENTS AND OBSERVATIONS

Manipulation
Force production
Time
Energy expenditure
Voice record
Event record
Subjective opinion

EXPERIMENT DURATION

20 min. (repeated 3 to 5 times, at 30-day intervals).

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Timer
Metabolic monitor
Torque-force apparatus
Audio recorder
Cameras (cine, still, and/or TV) and lights
Log book
Tools
Restraints
Questionnaires
Ergometer

SPECIAL REQUIREMENTS/REMARKS

May be integrated with command-control and display instrumentation. Standardized questionnaires must be developed.

PERSONNEL REQUIRED

1 observer

REFERENCES

Mission and Experiment Program Requirements for a One-Year Space Station. George C. Marshall Space Flight Center, February 1967.

NASA Experiment Descriptions for Extended Apollo Earth-Orbit Flights. NASA Headquarters, Washington, D.C., March 1965.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 2.1.1.1 2.1.1.1

Page 2 of 2

Restraint and Gross-Force Generation

EXPERIMENT CATEGORY

Mission Activities

OBJECTIVE AND SIGNIFICANCE

To assess the crew's gross motor behavior and ability to apply large forces, and to evaluate mission-task performance and related restraints and techniques. Results will be used in validating procedures, techniques, equipment training requirements, and metabolic costs.

MEASUREMENTS AND OBSERVATIONS

Locomotion
Dexterity
Force production
Time
Energy expenditure
Voice record
Event record
Subjective opinion

EXPERIMENT DURATION

30 min., (repeated 3 to 5 times at 30-day intervals).

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Timer
Metabolic monitor
Torque-force apparatus
Audio recorder
Cameras (cine, still, and/or TV) and lights
Log book
Tools
Restraints
Questionnaires
Ergometer

SPECIAL REQUIREMENTS/REMARKS

Standardized questionnaires must be developed.

PERSONNEL REQUIRED

1 observer

REFERENCES

Mission and Experiment Program Requirements for a One-Year Space Station. George C. Marshall Space Flight Center, February 1967.

NASA Experiment Descriptions for Extended Apollo Earth-Orbit Flights. NASA Headquarters, Washington, D. C., March 1965.

EXPERIMENT REQUIREMENTS SUMMARY

2.1.1.2

EXPERIMENT TITLE

TEXT REF. NO. 2.1.1.2

Psychomotor Functions

EXPERIMENT CATEGORY

Basic Behavioral Integrity

OBJECTIVE AND SIGNIFICANCE

To assess the functional integrity of selected psychomotor functions for intended time periods in orbit. Results will be used to provide monitoring requirements for future systems, and predictive information regarding changes in behavior and physiology.

MEASUREMENTS AND OBSERVATIONS

Reaction time
Complex sequence
Manipulation
Tracking
Time
Event record
Voice record
Energy expenditure
Subjective opinion

EXPERIMENT DURATION

30 min. at 21-day intervals. (Parameters to be varied from session to session.)

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Standard dexterity apparatus
Metabolic monitor
CRT and other displays
Display associated controls
Cameras (cine, still, and/or TV) and lights
Restraints
Timer
Log book
Audio recorder
Questionnaires

SPECIAL REQUIREMENTS/REMARKS

Experiment should utilize an integrated performance measurement apparatus, such as the Integrated Medical or Behavioral Laboratory Measurement System. Standardized questionnaires must be developed.

PERSONNEL REQUIRED

Subject only, if automatic recording available

REFERENCES

NASA Experiment Descriptions for Extended Apollo Earth-Orbit Flights. NASA Headquarters, Washington, D.C., March 1965.

Report on the Development of the Manned Orbital Research Laboratory (MORL) System Utilization Potential, Task Area 1, Analysis of Space-Related Objectives, Book 2. Douglas Report No. SM-48808, September 1965.

2.1.2 HABITABILITY AND VEHICLE DESIGN

Statement of the Problem

Design concepts, evolved from AAP experiences, regarding optimum volumes, crew station layout, experiment station layout, crew equipment, off-duty wardroom layout and recreational equipment will require integration into the Space Station design. Movable partitions, capability to modify illumination levels, etc., will be required to permit systematic assessment of various configurations.

Objectives

The primary objective is to generate through ground-based and feasibility studies and evaluation of previous flight data, the information and data appropriate to the fundamental aspects of spacecraft habitability. As required, design concepts will be validated by space flight experiments. Some of these experiments will consist of systematic observation and assessment of the operational systems.

Program Activities

1. Artificial Gravity
2. Volume and Layout of Crew Work and Rest Areas and Modifications.
3. Initial Illumination, Decor, and Changes
4. Crew Internal Mobility
5. Simulated Day-Night Cycles
6. Food Management and Eating Facility Concepts
7. Astronaut Safety During Free Internal Movement
8. Off-Duty Recreational Facilities

EXPERIMENT REQUIREMENTS SUMMARY

2.1.2.2

EXPERIMENT TITLE — TEXT REF. NO. 2.1.2.2

Volume and Layout

EXPERIMENT CATEGORY

Habitability

OBJECTIVE AND SIGNIFICANCE

To evaluate efficiency and acceptability of volumes and layouts associated with spacecraft compartments and areas designed for long-duration missions and to validate design criteria and operational procedures and techniques.

MEASUREMENTS AND OBSERVATIONS

Subjective opinion
Event record
Locomotion
Dexterity
Time
Voice record
Area/compartment utilization frequency

EXPERIMENT DURATION

10 min. at 30-day intervals.

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Cameras (cine, still, and/or TV) and lights
Audio recorder
Timer
Log book
Questionnaires

SPECIAL REQUIREMENTS/REMARKS

Standardized questionnaires and recreational facilities requirements must be developed. Movable partitions for investigation of volumetric provisions will be required. Relates to Experiments 2-1 and 2-21.

PERSONNEL REQUIRED

1 observer for event recording

REFERENCES

Mission and Experiment Program Requirements for a One-Year Space Station. George C. Marshall Space Flight Center, February 1967.

Medical Aspects of an Orbiting Research Laboratory. NASA Space Medicine Advisory Group. NASA Report No. SP-86, 1966.

EXPERIMENT REQUIREMENTS SUMMARY

2.1.2.3

EXPERIMENT TITLE

TEXT REF. NO. 2.1.2.3

Interior Design

EXPERIMENT CATEGORY

Habitability

OBJECTIVE AND SIGNIFICANCE

To evaluate interior design of spacecraft for long-duration missions, including reactions to lighting, color, and general atmosphere; to validate design requirements; and to improve operational efficiency through maintenance of high levels of morale and motivation.

MEASUREMENTS AND OBSERVATIONS

Subjective opinion
Mood assessment
Voice record
Event record

EXPERIMENT DURATION

10 min. at 30-day intervals.

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Questionnaires
Audio recorder
Log book
Paper and pen tests

SPECIAL REQUIREMENTS/REMARKS

Standardized questionnaires must be developed. Relates to Experiments 2-21 and 2-20.

PERSONNEL REQUIRED

Subject only

REFERENCES

Mission and Experiment Program Requirements for a One-Year Space Station. George C. Marshall Space Flight Center, February 1967.

Manned Space Flight Experiment Summary. George C. Marshall Space Flight Center, February 1967.

EXPERIMENT REQUIREMENTS SUMMARY

2.1.2.4

EXPERIMENT TITLE TEXT REF. NO. **2.1.2.4**

Flexible Airlock

EQUIPMENT CATEGORY

Crew Protection--Airlock

OBJECTIVE AND SIGNIFICANCE

To evaluate a flexible airlock.

MEASUREMENTS AND OBSERVATIONS

Power level
Pressure
Temperature
Time
Leakage

EXPERIMENT DURATION

4 hours.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Pressure sensor
Temperature sensor
Flow meter
Watt meter
Baseline EC/LS
Cine/still cameras
Tether/umbilicals
Timer
Leak detector
Special clothing/space suits
EC/LS back pack

SPECIAL REQUIREMENTS/REMARKS

Airlocks made of flexible material have been proposed to minimize weight and volume.

PERSONNEL REQUIRED

2 crew members

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

2.1.2.7

EXPERIMENT TITLE | TEXT REF. NO. 2.1.2.7

Clothing

EXPERIMENT CATEGORY

Habitability

OBJECTIVE AND SIGNIFICANCE

To evaluate efficiency and acceptability of constant-wear and protective clothing designed for long-duration missions and to provide design information.

MEASUREMENTS AND OBSERVATIONS

Subjective opinion
Event record
Body position
Energy expenditure
Voice record
Time
Dexterity
Locomotion

EXPERIMENT DURATION

15 min. at 30-day intervals.

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Cameras (cine, still, and/or TV) and lights
Audio recorder
Timer
Log book
Questionnaires
Metabolic monitor

SPECIAL REQUIREMENTS/REMARKS

Standardized questionnaires must be developed. Metabolic monitoring not necessary for all clothing configurations. All differential pressures to be encountered with EVA clothing must be evaluated. No proposed experiment considers clothing acceptability as a dependent variable.

PERSONNEL REQUIRED

1 observer for event recording

REFERENCES

Mission and Experiment Program Requirements for a One-Year Space Station. George C. Marshall Space Flight Center, February 1967.

National Multipurpose Space Station. NASA Manned Spacecraft Center, December 1964.

2.1.3 SMALL GROUP DYNAMICS

Statement of the Problem

Increasing duration of space flight, relative isolation of the crew, and restriction to limited living and work space place priority upon understanding small-group dynamics and developing methods to assess and influence alterations in this aspect of crew relations.

Objectives

The objectives of the program are as follows:

1. Determine methods of establishing optimal crew configuration.
2. Establish selection and training criteria.
3. Investigate and test advanced techniques for small-group training.
4. Provide facilities to enable appropriate utilization of off-duty periods, i.e., recreation, personal, study, etc.

Program Activities

1. Long Term Isolation and Confinement
2. Long Term Isolation and Its Effects on Group Interaction and Task Performance
3. Study of 20-Day Confinement of 2 and 3 Man Crews
4. Social Structure of Group Behavior in Extended Duration Missions
5. Crew Selection
6. Off-Duty Activities

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 2.1.3.1

Interpersonal Factors

EXPERIMENT CATEGORY

Habitability

OBJECTIVE AND SIGNIFICANCE

To evaluate internal group processes as a function of time in orbit. Results will be used to improve psychological adjustment and crew selection criteria.

MEASUREMENTS AND OBSERVATIONS

Event record
Voice record
Subjective opinion
Emotional assessment

EXPERIMENT DURATION

15 min. at 30-day intervals.

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Paper and pen tests
Audio recorder
Log book
Questionnaires

SPECIAL REQUIREMENTS/REMARKS

Reliable long-term Earth-based measures of group processes must be available for baseline comparison. It may be desirable to assess these parameters utilizing active spacecraft/ground communications link. Standardized questionnaires must be developed.

PERSONNEL REQUIRED

1 ground observer

REFERENCES

Mission and Experiment Program Requirements for a One-Year Space Station. George C. Marshall Space Flight Center, February 1967.

Medical Aspects of an Orbiting Research Laboratory. NASA Space Medicine Advisory Group. NASA Report No. SP-86, 1966.

EXPERIMENT REQUIREMENTS SUMMARY

2.1.3.3

EXPERIMENT TITLE

TEXT REF. NO. 2.1.3.3

Recreation

EXPERIMENT CATEGORY

Habitability

OBJECTIVE AND SIGNIFICANCE

To evaluate recreation provisions for long-duration missions; to validate design and provisioning requirements; and to improve operational efficiency of crew through maintenance of high levels of morale and motivation.

MEASUREMENTS AND OBSERVATIONS

Subjective opinion
Area/compartment utilization frequency
Event record
Voice record
Time

EXPERIMENT DURATION

10 min. at 30-day intervals.

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Cameras (cine, still, and/or TV) and lights
Log book
Questionnaires
Timer
Audio recorder

SPECIAL REQUIREMENTS/REMARKS

Standardized questionnaires must be developed.

PERSONNEL REQUIRED

1 observer

REFERENCES

MDAC originated.

2.1.4 INFORMATION DISPLAY AND PROCESSING

Statement of the Problem

A human information-processing error of any magnitude in space systems operations could prove disastrous. To insure against this eventuality, we must examine information processing requirements in space system operations and develop techniques that will lead to a minimization of error where human information processing is involved.

Objectives

A satisfactory solution to the problems in this area can be found through the accomplishment of the following tasks:

1. Development of techniques for displaying all necessary information promptly and unambiguously.
2. Discovery of principles which govern how information from various sources is effectively combined, how it is retrieved from the memory, and how unnecessary information can be eliminated.
3. Study of circumstances under which the probability of incorrect decisions is increased.
4. Study of causes of judgment biases.

Program Activities

1. Study of Problems in Information Processing.
2. Studies of Human Performance Sequential Decision Tasks.
3. Improved Discrimination by Stimulus Matching Training
4. Validation Study of Human Sampling Process.

2...5 MANUAL CONTROLS

Statement of the Problem

To insure successful control of the spacecraft, it is necessary to determine the effects of environmental factors and vehicle parameters on man's manual control capabilities.

Objectives

The objectives of the research in this area are to:

1. Establish procedures for man to control spacecraft in typical missions with minimal automatic equipment or no automatic equipment.
2. Determine the influence of motion on man's ability to operate spacecraft in typical simulated missions.

Program Activities

1. Study of Influence of Motion in Simulation
2. Manual Navigation, Guidance, and Control During Space Missions
3. Manual Backup to Automatic Control Systems.

Flight Experiments

Human Transfer Function (T-007)

2.2 EXTRAVEHICULAR TECHNOLOGY

Introduction

To achieve the scientific and technical goals of earth orbital space flight in the 1972-1975 period, it is essential that man perform useful work. This work will become increasingly elaborate as more and more intricate scientific research is done in space. In addition to the performance of scientific tasks, man must be prepared to perform whatever rescue operations become necessary. The successful accomplishment of any of these extravehicular (EVA) work tasks will require the development of special techniques and equipment to counteract the difficulties inherent in working in the weightless state.

The extravehicular technology study areas that are considered essential are specifically:

1. Work performance capability for EVA
2. Translation aids
3. Crew/systems interfaces

The extravehicular technology studies investigate and develop technology and procedures to enhance man's ability to move about in space outside a pressurized vehicle and to perform useful work.

This effort encompasses astronaut and equipment mobility and transfer, assembly, erection and repair of large objects such as orbital telescopes, refurbishment and resupply of telescopes and animal laboratories, docking of unmanned vehicles, astronaut rescue, retrieval of objects in space such as satellites, performance of scientific tasks outside the vehicle, remote control and use of manipulators, sensing and display of information from unmanned vehicles and the use of extensible booms and tether lines. Performing any of these tasks, while weightless, presents problems of safety and efficiency of movement. Problems inside the vehicle differ from those external to the pressure hull since spacesuits complicate mobility.

Equipment to facilitate crew movement inside the space vehicle will be needed. Guide bars, rails, and restraint systems, some fixed and some changeable are essential if the crew is required to move about to various stations and carry equipment. Various devices are required for locomotion external to the vehicle, such as guide bars, tracks, electroadhesive devices, simple and sophisticated propulsion units, and extensible booms. These devices must be designed and procedures for their use developed. Flight experiments are required to demonstrate design adequacy and usefulness. The ensuing pages discuss some of the more important locomotion problems and proposed solutions.

2.2 Extravehicular Technology

2.2.1 EVA Performance

2.2.1.1 Performance during EVA maintenance and assembly no experiments yet proposed.

2.2.1.2 Development of equipment and procedures for EVA - no experiments yet proposed.

2.2.1.3 Development of EVA assembly, maintenance and repair capability - no experiments yet proposed.

2.2.1.4 Unpowered locomotion in zero G - no experiments yet proposed.

2.2.2 Translation Aids

2.2.2.1 Integrated maneuvering life support system - no experiments yet proposed.

2.2.2.2 Handling qualities of maneuvering systems

2.2.2.3 Self stabilization and attitude control techniques - no experiments yet proposed.

2.2.2.4 Advanced control concepts for EVA stabilization and locomotion - no experiments yet proposed.

2.2.2.5 Foot controlled maneuvering units - Experiment needs final definition.

2.2.2.6 OMPRA - no experiments yet proposed

2.2.2.7 Astronaut and cargo transfer aids

2.2.3 Crew systems interface

2.2.3.1 Cargo transfer devices - no experiments yet proposed

2.2.3.2 Astronaut mobility through airlocks and passageways- no experiments yet proposed.

2.2.3.3 EVA display and control systems - no experiments yet proposed.

2.2.1 WORK PERFORMANCE CAPABILITY FOR EVA

Statement of the Problem

Information is required on the ability of man to perform EVA tasks and on the limitations imposed by space suits and reduced gravity on his performance.

Objectives

The tasks which need attention here are:

1. Astronaut positioning and repositioning with various foot and waist restraints.
2. Astronaut work performance while engaged in specific tasks involving manipulative functions unassisted force application, assisted force application, and flexion/extension functions.
3. Astronaut positioning of equipment of various sizes, shapes and masses at the worksite.

Finally, data correlations must be made for tasks conducted in ground simulations and actual space conditions.

Program Activities

1. Astronaut Performance During Extravehicular Maintenance and Assembly Tasks
2. EVA Performance Evaluation
3. Development of Equipment and Procedures for EVA
4. Develop and Establish Extravehicular Maintenance and Repair Capability.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 2.2.1.4

Orientation, Stability, and Restraint

EXPERIMENT CATEGORY

Mission Activities

OBJECTIVE AND SIGNIFICANCE

To evaluate the crew's integrated performance efficiency in maneuvering and orienting the body in relation to task location and to evaluate man/equipment combinations, related techniques, and metabolic costs.

MEASUREMENTS AND OBSERVATIONS

Body acceleration
Body position
Voice record
Energy expenditure
Event record
Time

EXPERIMENT DURATION

15 min. (repeat 3 to 5 times at 30-day intervals).

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Accelerometers and recorder
Metabolic monitor
Audio recorder
Cameras (cine, still, and/or TV) and lights
Log book
Timer
Locomotion aids
Restraints

SPECIAL REQUIREMENTS/REMARKS

Man's acceleration profile must be obtainable without interference with body motion. High-contrast grid pattern on background surfaces is desirable. (Measurements of linear and angular thresholds are included in biomedicine and human research experiments.)

PERSONNEL REQUIRED

1 observer

REFERENCES

Mission and Experiment Program Requirements for a One-Year Space Station. George C. Marshall Space Flight Center, February 1967.

EVEA Program Requirements Study, Final Report. North American Rockwell Report No. SD-68-304-7, 1968.

2.2.2 TRANSLATION AIDS

Statement of the Problem

Astronauts performing work outside the space vehicle will have to move themselves and their equipment from the airlock to the work-site. Maximum safety and minimum EVA time expenditure require the development of effective mobility equipment (powered and manual) and procedures for crew and equipment translation.

Objectives

The objective of this study area is to develop techniques and equipment for:

1. EVA transfer and locomotion of personnel and cargo.
2. Rescue and retrieval of crew personnel stranded during EVA.

The data obtained in ground based simulation tests must be correlated with those data obtained during actual space flight.

Program Activities

1. Integrated Maneuvering Life Support System
2. Handling Qualities of Maneuvering Systems
3. Self Stabilization and Attitude Control Techniques
4. Advanced Control Concepts for Astronaut Extravehicular Stabilization and Locomotion
5. Foot-Controlled Maneuvering Units

Flight Experiments

Evaluate and Develop the Capability to Control Advanced Maneuvering Systems in Space.

Self Stabilization and Attitude Control Environment.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 2.2.2.2

Personnel Translation

EXPERIMENT CATEGORY

Mission Activities

OBJECTIVE AND SIGNIFICANCE

To assess the crew's ability to translate by using various manual techniques; to validate procedures, equipment, techniques, and related matabolic costs; and to identify unusual training requirements.

MEASUREMENTS AND OBSERVATIONS

Dexterity
Locomotion
Time
Energy expenditure
Event record
Voice record
Subjective opinion

EXPERIMENT DURATION

25 min. (repeat 3 to 5 times--same subject with each device--at 30-day intervals).

SUBJECTS, MATERIALS AND EQUIPMENT

1 crew member
Timer
Metabolic monitor
Log book
Questionnaires
Audio recorder
Cameras (cine, still, and/or TV) and lights
Restraints
Locomotion aids

SPECIAL REQUIREMENTS/REMARKS

Standardized questionnaires must be developed. Grid pattern against at least one background surface is desirable. Randomized utilization of devices is required. Relates to Experiment 2-21.

PERSONNEL REQUIRED

1 observer

REFERENCES

Mission and Experiment Program Requirements for a One-Year Space Station. George C. Marshall Space Flight Center, February 1967.

EVEA Program Requirements Study, Final Report. North American Rockwell Report No. SD-68-304-7, 1968.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 2.2.2.7

Mass Translation

EXPERIMENT CATEGORY

Mission Activities

OBJECTIVE AND SIGNIFICANCE

To establish the limits of the crew's ability to move various mass configurations by using various restraint, tether, and maneuvering techniques and to validate procedures, training requirements, and metabolic costs.

MEASUREMENTS AND OBSERVATIONS

Locomotion
Mass motion and acceleration
Energy expenditure
Voice record
Event record
Time
Dexterity
Subjective opinion

EXPERIMENT DURATION

50 min. (repeated 3 to 5 times at 30-day intervals).

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Accelerometers and recorders
Metabolic monitor
Audio recorder
Cameras (cine, still, and/or TV) and lights
Log book
Timer
Questionnaires
Restraints
Locomotion aids

SPECIAL REQUIREMENTS/REMARKS

Standardized questionnaires must be developed. Preferably performed in large-volume compartment. Acceleration profiles of masses must be obtainable without interference with mass motion. Background grid pattern is desirable. Relates to Experiments 2-1 and 2-21.

PERSONNEL REQUIRED

1 observer

REFERENCES

EVEA Program Requirements Study, Final Report. North American Rockwell Report No. SD-68-304-7, 1968.

Manned Space Flight Experiment Summary. George C. Marshall Space Flight Center, February 1967.

2.2.3 CREW SYSTEMS INTERFACES

Statement of the Problem

When the astronaut reaches the EVA worksite, his work should be facilitated as much as possible so that he spends the minimum time outside the space vehicle. Research is needed on the most effective design of the worksite, methods of anchor to the worksite, vehicle design to permit rapid movement to the work area, and the packaging of tools and other equipment to be used in performing extravehicular activities.

Objectives

The objectives of crew/systems interfaces studies is to develop:

1. Egress/ingress technology
2. Airlocks-hatches
3. Systems packaging
4. Controls and displays
5. Optics and photography
6. Other EVA support equipment

Program Activities

Cargo Transfer Devices

Mobility of an Astronaut During Egress/Ingress Maneuvers Through Airlocks and Passageways

Display and Control Units for EVA

2.3 MAINTENANCE AND MAINTAINABILITY

Introduction

If long duration orbital and lunar missions are to be accomplished within the next 5 years, additional attention needs to be devoted to the problem of repairing and/or maintaining spacecraft systems, base systems, or equipment crucial to either mission success or to crew safety.

Elements of this problem include:

1. Evaluating man's capabilities to perform maintenance tasks of varying complexity both in shirt sleeves and in a pressure-suit.
2. Using a "design for maintainability" approach in systems design.
3. Developing astronaut assist devices for repair or maintenance tasks.

2.3.1 M115

MAINTENANCE PERFORMANCE CAPABILITIES IN REDUCED GRAVITY

I. Statement of the Problem

Information is needed on man's capability to perform typical maintenance tasks in space both inside and outside the space vehicle and on unmanned satellites. Maintenance task performance is essential to provide the reliability needed by many space vehicle systems (e.g., life support systems).

II. Objectives

The object of research in this area is to provide a continually updated body of data on suited and unsuited operator capability in reduced gravity so that allocation of functions to either man or machine can be consistent with man's capabilities. These data will be used in designing astronaut operated hardware.

III. Program Activities

1. Astronaut Motor Performance in Zero Gravity as a Function of Type of Suit.

2. Suit Mobility

3. Suited Crewman Performance Criteria Handbook

2.3 Maintenance and Maintainability

2.3.1 In-space maintenance

2.3.1.1 Suit effect on Astronaut Motor Performance - no experiments yet proposed

2.3.1.2 Suit Mobility - no experiments yet proposed

2.3.1.3 Suited crewman performance criteria handbook - no experiments yet proposed

2.3.2 System design for maintainability

2.3.2.1 Human engineering criteria for maintenance and repair - no experiments yet proposed

2.3.2.2 Integrated maintainability criteria - no experiments yet proposed

2.3.2.3 Checkout and fault isolation design requirements - no experiments yet proposed

2.3.3 Crew assistance systems

2.3.3.1 Space tools - power, manual, special

2.3.3.2 Worksite technology, Restraint Systems, Fastners, Bonding Techniques - no experiments yet proposed.

2.3.3.3 Manipulator design - no experiments yet proposed.

SYSTEM DESIGN FOR MAINTAINABILITY

I. Statement of the Problem

In order to optimize man's performance of maintenance tasks in space, space flight equipment must be designed according to maintainability criteria. Techniques and design data must be available concurrent with the hardware development stage in order to enhance the ability of the astronaut to maintain, repair, and assemble equipment in the space environment.

II. Objectives

The aim of research in this area is to provide the technology for design of maintainable and repairable systems. Such design should provide for:

1. Checkout and fault isolation
2. Accessible packaging
3. Nonmaintainable vs. maintainable tradeoff analysis

III. Program Activities

1. Human Engineering Criteria for Maintenance and Repair
2. Integrated Maintainability Criteria
3. Checkout and Fault Isolation Design Requirements

Flight Experiments

Integrated Maintenance and Repair Experiment

EXPERIMENT REQUIREMENTS SUMMARY

2.3.2.1

EXPERIMENT TITLE TEXT REF. NO. **2.3.2.1**

Accessibility

EXPERIMENT CATEGORY

Mission Activities

OBJECTIVE AND SIGNIFICANCE

To evaluate task performance involving various whole-body and body-extremity accesses; to establish performance level and access envelop characteristics; to evaluate related techniques, equipment, and metabolic costs.

MEASUREMENTS AND OBSERVATIONS

Locomotion	Event record
Dexterity	Time
Voice record	Energy expenditure

EXPERIMENT DURATION

30 min. (repeated 3 to 5 times at 30-day intervals).

SUBJECT, MATERIALS, AND EQUIPMENT

1 crew member	Cameras (cine, still, and/or TV) and lights
Audio recorder	Tape measure
Timer	Locomotion aids
Metabolic monitor	Restraints
Log book	

SPECIAL REQUIREMENTS/REMARKS

High-contrast grid pattern on two or more background surfaces is required for relatively accurate measurement and calibration of anthropometric data of body movements using photographic equipment. Relates to Experiments 2-4, 2-5, and 2-20.

PERSONNEL REQUIRED

1 observer

REFERENCES

Mission and Experiment Program Requirements for a One-Year Space Station. George C. Marshall Space Flight Center, February 1967.

Manned Space Flight Experiment Summary. George C. Marshall Space Flight Center, February 1967.

2.3.3

CREW ASSISTANCE SYSTEMS

I. Statement of the Problem

The maintenance and repair tasks that are to be performed in space will require tools and other devices designed especially to cope with the unique problems of work in the weightless state.

II. Objectives

T[illegible] aim of this program is to provide technology and develop design criteria for astronaut assist devices such as tools, tethers and worksite aids. This will enhance man's ability to perform maintenance and repair tasks in reduced gravity. Ground tests and simulations will be used to develop aids and to optimize crewman performance.

III. Program Activities

1. Space Tools--Power, Manual, Special
2. Worksite Technology--Restraint Systems, Fasteners, Bonding Techniques
3. Manipulators
4. Manipulator Research for Repair and Maintenance
5. Pyrotechnic Devices for Construction in Space

Flight Experiments

Maintenance Hardware Evaluation

EXPERIMENT REQUIREMENTS SUMMARY

2.3.3.1

EXPERIMENT TITLE — TEXT REF. NO. 2.3.3.1

Maintenance and Repair in Zero G

EXPERIMENT CATEGORY

All EC/LS Systems

OBJECTIVE AND SIGNIFICANCE

To evaluate the tools, materials, special equipment, and techniques required for the on-board maintenance and repair of EC/LS equipment.

MEASUREMENTS AND OBSERVATIONS

Performance
Reliability and maintainability
Temperature
Leakage
Pressure
Power level
Time (to overhaul, replace)

EXPERIMENT DURATION

Mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Timer
Watt meter
Pressure sensor
Temperature sensor
Baseline EC/LS
Leak detector
Flow meter
Humidity sensor
Cine/still cameras
Dew-point meter
Space suit
Illumination device
Crew special restraints
Work bench and tools

SPECIAL REQUIREMENTS/REMARKS

All scheduled and unscheduled maintenance, repair times, and spare parts inventory must be recorded. Both intra- and extravehicular tasks would be investigated. Data obtained from this experiment will be used for the design of future life support systems, as well as tools, crew restraints, positioning, and locomotion devices.

PERSONNEL REQUIRED

All on-board crew members

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

2.4 BEHAVIOR

Statement of the Problem

Long duration space flights in orbital space stations require astronauts to function as an integrated compatible team. Details are needed on the effects of long term exposure to space flight conditions on human behavior. Research is needed on the effects of isolation and confinement, weightlessness, and stress on the individuals and small crews. This information is required to permit the development of appropriate astronaut selection techniques, the development of appropriate procedures, and the design of work-rest areas.

Objectives

To under the effects of long term exposure to the space environment on human sensation, perception, and higher mental functions to permit development and design of space systems compatible with predicted human behavior in routine and stressful situations.

Program Activities

1. Confinement and Isolation
2. Man-Computer Behavior
3. Information Processing & Decision Makeup
4. Human Learning & Memory
5. Visual Skills
6. Other Sensation & Perception

2.4 Behavior

2.4.1 Confinement and Isolation

2.4.1.1 Astronaut response to environment

2.4.2 Man-Machine Behavior

2.4.2.1 No experiments yet proposed

2.4.3 Human Learning and Memory

2.4.3.1 No experiments yet proposed

2.4.4 Skill Rention

2.4.4.1 No experiments yet proposed

2.4.5 Visual Skills

2.4.5.1 Visual target acquisition - no experiments yet proposed

2.4.5.2 Color detection in small targets - no experiments yet proposed

2.4.5.3 Improved retinal image stabilization techniques - no experiments yet proposed

2.4.5.4 Visibility prediction - no experiments yet proposed

2.4.5.5 Contrast Sensitivity - no experiments yet proposed

2.4.5.6 High Luminance effects - no experiments yet proposed

2.4.5.7 Size and distance interrelations - no experiments yet proposed

2.4.5.8 Space perception - no experiments yet proposed

2.4.5.9 Oculometry for human engineering - no experiments yet proposed

2.4.5.10 Visual aids - no experiments yet proposed

2.4.5.11 Extraterrestrial scientific visual observations- no experiments yet proposed

2.4.6 Other Sensation and perception

2.4.6.1 Kinesthetic

2.4.6.2 Orientation - Temporal and Spatial

2.4.6.3 Chemical

2.4.6.4 Somesthetic

2.4.6.5 Intellectual

2.4.6.6 Auditory

EXPERIMENT REQUIREMENTS SUMMARY

2.4.1.1

EXPERIMENT TITLE TEXT REF. NO. 2.4.1.1

Intrapersonal Factors

EXPERIMENT CATEGORY

Habitability

OBJECTIVE AND SIGNIFICANCE

To assess the emotional stability of individual crew members as a function of time in orbit. Results will be used to improve psychological adjustment and crew selection criteria.

MEASUREMENTS AND OBSERVATIONS

Emotional assessment
GSR
Electroencephalography (EEG)
Subjective opinion
Voice record
Event record

EXPERIMENT DURATION

15 min. at 30-day intervals.

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Paper and pen tests
Galvanic skin response and EEG sensors and recorders
Audio recorder
Questionnaires
Log book

SPECIAL REQUIREMENTS/REMARKS

Standardized questionnaires must be developed. Reliable, long-term Earth-based measures must be available for baseline comparison. It may be desirable to assess these parameters utilizing active spacecraft/ground communications links.

PERSONNEL REQUIRED

1 ground observer

REFERENCES

National Multipurpose Space Station. NASA Manned Spacecraft Center, December 1964.

Medical Aspects of an Orbiting Research Laboratory. NASA Space Medicine Advisory Group. NASA Report No. SP-86, 1966.

2.4.5

VISUAL SKILLS

I. Statement of the Problem

The environment of space both inside and outside the space vehicle poses unique visual problems. Man's capabilities and limitations for receiving information through the visual sense modality in this environment must be determined and methods must be developed for optimizing his capabilities where limitations are discovered.

II. Objectives

The specific objectives of the visual skills research program are:

1. To develop techniques allowing compression of bandwidth in visual displays.
2. To develop information regarding target characteristics necessary for reliable detection and identification.
3. To develop methods (computer--aided) for precise calculation of the probability of target detection and identification.
4. To determine visual capabilities under adverse conditions (e.g., glare in the visual field) and to develop techniques for eliminating such adverse conditions where necessary to mission success.

III Program Activities

1. Visual Studies of Target Acquisition and Evaluation in Aerospace Systems.

2. The Detection of Color in Targets of Small Angular Subtense

3. Research on Improved Retinal Image Stabilization Techniques

4. Development of a Visibility Calculation Program

5. Contrast Sensitivity of the Central and Peripheral Visual Fields

6. A Study of Visual Factors Associated with High Luminance Environments

7. Interrelations of Perceived Size and Distance

8. Studies of Visual Space Perception

9. Oculometry for Human Engineering Studies

10. Visual Skills in Space Environment

11. Visual Aids

12. Extraterrestrial Scientific Visual Observations

Flight Experiments

Test Effects of Space Environment on Man's Visual Processes Involving Oculomotor Balance and Changes in Retinal Function

Tests to Evaluate Telescopic Stabilization on Man's Ability to Detect and Identify Earth Objects for Earth Resources Information

Human Vision (T-006)

M127

Tests to Evaluate the Influence of Eye-Protective Optical Devices on Man's Ability to Perform Visual Aspects of Space Operations

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 2.4.5

Visual Function

EXPERIMENT CATEGORY

Basic Behavioral Integrity

OBJECTIVE AND SIGNIFICANCE

To evaluate the integrity of the crew's visual processes as a function of time in orbit and to identify changes in discrete visual parameters which could degrade operational efficiency.

MEASUREMENTS AND OBSERVATIONS

Visual acuity
Depth perception (static and dynamic)
Light and dark adaptation
Eye movement
Form discrimination
Veridicality (perception of the vertical)
Critical flicker fusion
Color detection/discrimination
Brightness detection/discrimination
Voice record
Event record
Subjective opinion

EXPERIMENT DURATION

10 min. at 21-day intervals (alternate parameters measured.)

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Orthorater
Light source (static and dynamic-dual)
CFF source
Veridicality tester
Cameras (cine, still, and/or TV) and lights
Timer
Color plates
Audio recorder
Log book
Questionnaires
Electro-oculograph and recorder

SPECIAL REQUIREMENTS/REMARKS

Standardized questionnaires must be developed. Light source and veridicality tests may require design and development lead time. Many measurements can be combined through use of flexible testing device such as McDonnel Douglas Visual/Auditory Test or Integrated Medical or Behavioral Laboratory Measurement System. Most measurements require ability to extinguish cabin and/or background illumination.

PERSONNEL REQUIRED

1 observer

REFERENCES

NASA Experiment Descriptions for Extended Apollo Earth-Orbit Flights. NASA Headquarters, Washington, D.C., March 1965.

Report on the Optimization of the Manned Orbital Research Laboratory (MORL) System Concept, Phase IIa, Vols, XXII and XXIII, Experiment Program. Douglas Report Nos. SM-46083 and SM-46084, September 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 2-7

Communications and Recording

EXPERIMENT CATEGORY

Mission Activities

OBJECTIVE AND SIGNIFICANCE

To evalute the crew's ability to communicate information and record data as a function of exposure to orbital stressors.

MEASUREMENTS AND OBSERVATIONS

Dexterity
Manipulation
Event record
Voice record
Control/display dynamics
Time
Subjective opinion

EXPERIMENT DURATION

15 min. at 21-day intervals

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Paper and pen tests
Audio recorder
CRT and other information displays
Information display associated controls
Cameras (cine, still, and/or TV) and lights
Timer
Log book
Questionnaires

SPECIAL REQUIREMENTS/REMARKS

Standardized questionnaires must be developed. May be integrated with spacecraft control-display instrumentation. Major proportion of data may be automatically recorded.

PERSONNEL REQUIRED

1 observer for event recording

REFERENCES

NASA Experiment Descriptions for Extended Apollo Earth-Orbit Flights. NASA Headquarters. Washington, D. C., March 1965.

Manned Space Flight Experiment Summary. George C. Marshall Space Flight Center, February 1967.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 2.4.6.1

Kinesthetic Function

EXPERIMENT CATEGORY

Behavioral Research - Basic Behavioral Integrity

OBJECTIVE AND SIGNIFICANCE

Assess functional integrity of man's kinesthetic receptors as a function of exposure to prolonged space travel.

MEASUREMENTS AND OBSERVATIONS

Body Motion
Extremity Motion
Voice Record
Muscle Electropotentials
Written Record
Event Record
Time

EXPERIMENT DURATION

15-30 min. Interval to be selected based on mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

Photography (Motion, Still, and/or Video cameras and lights)
Electromyographic sensors and recorder
Audio Recorder
Log Book
Questionnaire
Timer

SPECIAL REQUIREMENTS/REMARKS

Tests body member position sense while subject is prevented from seeing.

PERSONNEL REQUIRED

Minimally one subject and one observer.

REFERENCES	REF. DOC. EXPERIMENT NO.
8. NASA EAEO Flight	M-466 and MDC Nos. 46,53
14. MSFC One Year Space Station	AES-0201
20. MORL Phase IIa, Vols, XXII and XXIII	D-019

EXPERIMENT REQUIREMENTS SUMMARY

2.4.6.2

EXPERIMENT TITLE

TEXT REF. NO. 2.4.6.2

Orientation Senses

EXPERIMENT CATEGORY

Basic Behavioral Integrity

OBJECTIVE AND SIGNIFICANCE

To assess the functional integrity of nonvisually augmented body-position sense in relation to time in orbit and to evaluate the crew's ability to maintain cognizance of body and extremity position in relation to the spacecraft.

MEASUREMENTS AND OBSERVATIONS

Time
Body position
Event record
Voice record
Subjective opinion

EXPERIMENT DURATION

30 min. at 30-day intervals.

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Questionnaires
Cameras (cine, still, and/or TV) and lights
Log book
Audio recorder
Timer

SPECIAL REQUIREMENTS/REMARKS

Standardized questionnaires must be developed. Assessment of spatial orientation may require high-contrast grid backgrounds within large volumetric enclosure. Related to Experiment 1-2.

PERSONNEL REQUIRED

1 observer

REFERENCES

NASA Experiment Descriptions for Extended Apollo Earth-Orbit Flights. NASA Headquarters, Washington, D.C., March 1965.

Experiment Selection and Definition for S-IVB applications. Douglas Report No. SM-60569, December 1966.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 2.4.6.3

Chemical Sense Function

EXPERIMENT CATEGORY

Basic Behavioral Integrity

OBJECTIVE AND SIGNIFICANCE

To assess the functional integrity of the crew's sense of taste and smell as a function of exposure to prolonged space travel and to identify discrete changes in chemical sense parameters which could indicate physiological degradation.

MEASUREMENTS AND OBSERVATIONS

Taste thresholds and anomalies (sour, salty, bitter, and sweet)
Olfactory thresholds and anomalies (fragrant, acid, burnt, and caprylic)
Event record
Voice record
Time

EXPERIM[illegible]ATION

1.5 hou[illegible]ay intervals (with alternating sessions for taste and olfactory measur[illegible].

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Standard olfactory aerosols
Standard gustatory solutions
Microsyringes
Dionized sterile water
Log book
Audio recorder
Timer

SPECIAL REQUIREMENTS/REMARKS

Accurate thermal control of all equipment is mandatory. Control of aerosols and solutions may present development problems. Special training in introducing stimulus is required.

PERSONNEL REQUIRED

1 observer

REFERENCES

MDAC originated.

M133

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 2.4.6.4

Somesthetic Function

EXPERIMENT CATEGORY

Basic Behavioral Integrity

OBJECTIVE AND SIGNIFICANCE

To evaluate the integrity of the crew's somesthetic function for extended time in orbit and to identify changes in discrete sensory processes which could degrade operational efficiency and/or indicate an undesirable physiological condition.

MEASUREMENTS AND OBSERVATIONS

Skin sensitivity
Event record
Voice record

EXPERIMENT DURATION

30 min. at 21-day intervals.

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Cotton tufts
Needles
Tuning fork
Audio recorder
Log book

SPECIAL REQUIREMENTS/REMARKS

Method of controlled heating and cooling of needles may be required. Special training of test conductor in the method of stimulus introduction is required.

PERSONNEL REQUIRED

1 observer

REFERENCES

Symposium on Psychophysiological Aspects of Space Flight. B. Flaherty, editor. Columbia University Press, New York, 1961.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 2.4.6.5

Intellectual Function

EXPERIMENT CATEGORY

Behavioral Research - Basic Behavioral Integrity

OBJECTIVE AND SIGNIFICANCE

Assess functional integrity of man's cognitive processes as a function of exposure to prolonged space travel.

MEASUREMENTS AND OBSERVATIONS

Standardized Intellectual Measures
Voice Record
Written Record
Time
Event Record

EXPERIMENT DURATION

1-2 hours. Interval to be selected based on mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

Paper and Pen Tests
Audio Recorder
Log Book
Timer
Questionnaires

SPECIAL REQUIREMENTS/REMARKS

None

PERSONNEL REQUIRED

Subject and observer-experimenter

REFERENCES

16. SPAMAG
17. MORL SM-48808
18. MORL Phase IIa, Vols, XXII and XXIII

REF. DOC. EXPERIMENT NO.

T-007 and MDC Nos.
AES-0201 44, 49, 63, 64, 66-68

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE | TEXT REF. NO. 2.4.6.5

Higher Mental Function

EXPERIMENT CATEGORY

Mission Activities

OBJECTIVE AND SIGNIFICANCE

To assess the crew's operational efficienc through the measurement of readily observable behavior, such as the performance of command and control tasks or other tasks involving higher level functions. Results will be used to validate crew composition and training requirements, procedures, techniques, and related equipment.

MEASUREMENTS AND OBSERVATIONS

Vigilance
Attention
Problem solving
Memory
Judgment
Event record
Voice record
Time
Subjective opinion

EXPERIMENT DURATION

20 min. at 30-day intervals. (Parameters may vary from session to session.)

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
CRT displays and controls
Information displays and associated controls
Analog recorder
Audio recorder
Paper and pen tests
Questionnaires
Log book

SPECIAL REQUIREMENTS/REMARKS

May be integrated with spacecraft control-display instrumentation. Standardized questionnaires must be developed.

PERSONNEL REQUIRED

1 observer

REFERENCES

NASA Experiment Descriptions for Extended Apollo Earth-Orbit Flights. NASA Headquarters, Washington, D. C., March 1965.

Medical Aspects of an Orbiting Research Laboratory. NASA Space Medicine Advisory Group. NASA Report No. SP-86, 1966.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 2.4.6.6

Auditory Function

EXPERIMENT CATEGORY

Basic Behavioral Integrity

OBJECTIVE AND SIGNIFICANCE

To evaluate the integrity of the crew's auditory processes as a function of time in orbit. Results will be used to identify changes in discrete visual parameters which could degrade operational efficiency.

MEASUREMENTS AND OBSERVATIONS

Auditory detection/discrimination
Event record
Noise sensitivity
Voice record
Time

EXPERIMENT DURATION

10 min. at 21-day intervals

SUBJECTS, MATERIALS, AND EQUIPMENT

1 crew member
Pure tone source
Timer
Audio recorder
Noise and vibration source
Log book

SPECIAL REQUIREMENTS/REMARKS

Pure tone source may require design development for flight qualification.

PERSONNEL REQUIRED

Subject only

REFERENCES

Mission and Experiment Program Requirements for a One-Year Space Station. George C. Marshall Space Flight Center, February 1967.

NASA Experiment Descriptions for Extended Apollo Earth-Orbit Flights. NASA Headquarters, Washington, D. C., March 1965.

FUNCTIONAL PROGRAM ELEMENT III

LIFE SUPPORT AND PROTECTIVE SYSTEMS

DISCIPLINE

Space Medicine and Biotechnology

PROGRAM ELEMENT

Life Support and Protective Systems

REQUIREMENT

The objective of life support and protective systems technology is to provide a controlled and physiologically acceptable environemet for flight crews during all phases of a space mission. The life support system must, therefore, provide a pressurized shirtsleeve environment that also allows for pressure suit operation during normal or emergency conditions. It must supply food, water, and oxygen, provide for personal hygiene, and remove waste and contaminants. Lastly the system must provide a thermal balance through utilization of available energy and dispersion of any excess heat. A basic assumption is that the AAP Program will have been completed successfully and that data will be made available for future utilization.

JUSTIFICATION

a. As mission duration and crew size increase, it becomes necessary to recover useful materials from onboard wastes to reduce launch weight, volume of stored supplies and resupply requirements.

b. Prolonged space missions increase the probability of in-flight malfunctions while more ambitious crew activities impose additional requirements on work performance especially under suited conditions. Both underline the need for advanced crew protective systems.

Under the life Support and Protective Systems Functional Program Element, we have the following research categories.

3.1 Water Management

3.2 Waste Management

3.3 Thermal Control

3.4 Personal Hygiene and Sanitation

3.5 Atmosphere Supply, Control and Oxygen Regeneration

3.6 Carbon Dioxide Removal

3.7 Trace Contaminants Control

3.8 Astronaut Protective Systems

3.9 Subsystems Integration

3.10 Closed Life Support Systems

3.11 Sensors and Instrumentation

3.12 Food Management

3.13 Maintenance and Repair

Research Categories

3.1 WATER MANAGEMENT

Statement of the Problem

Current spacecraft life support requirements, as represented by Apollo, do not require water reclamation systems because of the low weight penalty for storing water for these time periods and because potentially potable water is available from the fuel cell power system. However, for future mission classes now under consideration, the availability of sufficient water from fuel cells is doubtful and the weight of stored water is prohibitive. Therefore, water reclamation systems utilizing the several waste sources available are necessary. These sources are, in order of their ease of purification, humidity condensate, wash water, urine, and feces.

The extent to which these sources of water are utilized will depend greatly on mission class, e.g., oxygen reclamation requires water electrolysis for a closure of the oxygen cycle and, therefore, a greater utilization of waste water for reclamation in order to balance the water cycle. In all of these mission classes, attention must be given to efficient, reliable systems using a minimum of expendables that are capable of providing water for consumption which meets both chemical and biological quality standards.

Scientific Objectives

The objectives of this work are to advance the technology and develop prototype subsystems to provide for the purification and sterilization of spacecraft waters.

For early missions only the purification of humidity condensate and urine (w/flush) will be required with the possible addition of sponge wash water. Chemical purification must be accomplished with minimum power consumption and vehicle interfaces and with a system which has an advanced development status. Sterilization will be required to eliminate bacteriological contamination.

For the intermediate duration missions, full body washing and automatic water flush-fecal collection and processing will also be included. Since the vehicle power source will constrain the desirability of the several subsystem concepts for water reclamation and sterilization (i.e., waste heat availability), multiple subsystem developments will be pursued for both purification functions until a power source is selected. However, even then, due to the different contaminant levels (both chemical and biological), use of a single concept is not likely.

For extended missions water from fecal matter, food wastes, etc., also will be reclaimed. Both thermal and oxidation techniques will be followed.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Water Management are listed. They are followed by detailed sheets on each of the Component experiments.

3.1 Water Management

3.1.1 Water Reclamation

3.1.1.1 Water Recovery

3.1.1.2 Recovery System Pre-treatment

3.1.2 Potability Monitor

3.1.2.1 Potability Verification

3.1.3 Thermal Control

3.1.3.1 Condensing Heat Transfer and Rate

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 3.1.1.1

Water Recovery Methods and Components

EXPERIMENT CATEGORY

Water Management--Potable Water and Wash Water

OBJECTIVE AND SIGNIFICANCE

To compare the performance of the most promising concepts which have been proven in the manned space cabin simulator or other tests.

MEASUREMENTS AND OBSERVATIONS

pH and COD
Microbiological contaminants
Chemical contaminants
Power level
Pressure
Temperature
Flow rate
Reliability and maintainability
Time
Dew point
Performance
Water conductivity
Water-generation rate

EXPERIMENT DURATION

8 hours daily of crew time for 30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Chemical laboratory
Microbia laboratory
Flow meter
Pressure sensor
Leak detector
Baseline EC/LS
Timer
Dew-point meter
Watt meter
Temperature sensor
Work bench and tools

SPECIAL REQUIREMENTS/REMARKS

Recovery of potable water from urine, humidity, or wash water can be accomplished by many processes such as air evaporation, vapor compression, electrodialysis, and reverse osmosis. Experiment can be conducted in conjunction with Experiments 4-1, 4-2, 4-17, 4-22, and 4-23.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Space Marketing Intelligence-National Multipurpose Space Station (NMSS) Experimental Listing. Published by Space Station Study Office, National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas, 17 December 1964.

Mars Landing and Reconnaissance Mission Environmental Control and Life Support System Study, Vol. 3, System Studies (Contract No. NAS9-1701). 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE TEXT REF. NO. 3.1.1.2

Water Recovery System Pretreatment Mixing

EXPERIMENT CATEGORY

Water Management--Liquid and Liquid Mixing

OBJECTIVE AND SIGNIFICANCE

To determine if a mixing device is necessary for water recovery unit pre-treatment devices.

MEASUREMENTS AND OBSERVATIONS

Diffusion rates
Electrical conductivity
Chemical analysis of liquid
Time
Efficiency

EXPERIMENT DURATION

30 days. (Analyze liquid, mix intermittently as required.)

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Diffusion columns
Chemical laboratory
Liquid container
Stirring unit
Timer
Pretreatment unit
Baseline EC/LS

SPECIAL REQUIREMENTS/REMARKS

Recovery of potable water from urine generally requires the use of pretreatment chemical such as chromic or sulphuric acid. In the absense of gravity, simple diffusion may not be sufficiently rapid to provide proper mixing. Shaking or positive motion may be required to obtain desired results. The test can be performed within the on-board EC/LS system.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Final Technical Report Study of Zero Gravity Capabilities of Life Support System Components and Processes. Convair Division of General Dynamics Report No. GDC-DBD67-004, February 1968.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 3.1.2.1

Flight-Type Potability Monitoring System

EXPERIMENT CATEGORY

Water Management--Potability Verification

OBJECTIVE AND SIGNIFICANCE

To flight test a potability monitoring system.

MEASUREMENTS AND OBSERVATIONS

pH and COD
Microbiological contaminants
Power level
Pressure
Temperature
Flow rate
Time
Reliability and maintainability
Chemical contaminants
Dew point
Water conductivity
Water-generation rate

EXPERIMENT DURATION

8 hours daily of crew time for 30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Chemical laboratory
Microbia laboratory
Flow meter
Pressure sensor
Baseline EC/LS
Timer
Dew-point meter
Watt meter
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

Regenerative water-recovery units recovering potable water from humidity, urine, and wash water will require constant monitoring for potability. Experiment can be conducted in conjunction with Experiments 4-1 and 4-22.

PERSONNEL REQUIRED

1 crew member

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

3131

EXPERIMENT TITLE TEXT REF. NO. 3.1.3.1

Condensing Heat Transfer and Condensation Rate in Heat Exchangers

EXPERIMENT CATEGORY

Thermal Control/Water Management--Condensation

OBJECTIVE AND SIGNIFICANCE

To evaluate heat transfer and water separation in heat exchangers/condensers at low g in order to provide test information needed for adequate design.

MEASUREMENTS AND OBSERVATIONS

Heat transfer effectiveness
Water removal rate
Temperature
Humidity
Flow rate
Time
Orientation
Gas-generation rate
Velocity/velocity profile
Density

EXPERIMENT DURATION

4 hours for each test; repeat 20 times.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Flow meter
Gas liquid separator
Pressure sensor
Timer
Pumps, fans, and blowers
Temperature sensor
Baseline EC/LS
Watt meter
Humidity sensor
Dew-point meter
Zero-g scale
Cine camera
Orientation device

SPECIAL REQUIREMENTS/REMARKS

The performance of a heat exchanger/condenser is a function of liquid film thickness on the heat transfer surfaces and the method by which the water is removed from the heat exchanger.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Final Technical Report Study of Zero Gravity Capabilities of Life Support System Components and Processes. Convair Division of General Dynamics Report No. GDC-DBD67-004, February 1968.

3.2 WASTE MANAGEMENT

Statement of the Problem

A system for the management of biological waste material must be developed that will meet medical and vehicle integration requirements.

Scientific Objectives

The objective of the work in this area is to design and develop an integrated waste management system that will (a) provide an inoffensive means of waste collection, mass measurement, and sampling (if required); (b) process biological and other solid waste materials; (c) prevent contamination of the environment with waste material, odors, and micro-organisms; (d) provide for sample preservation and storage; and (e) provide an interface with water reclamation systems.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Waste Management are listed. They are followed by detailed sheets on each of the Component Experiments.

3.2 Waste Management

- 3.2.1 Collection
  - 3.2.1.1 Gas Transport of Solids
  - 3.2.1.2 Gas Transport of Liquids
  - 3.2.1.3 Manual Transport of Solids
  - 3.2.1.4 Collector Tests
- 3.2.2 Processing - no experiments yet proposed
- 3.2.3 Sampling - no experiments yet proposed

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 3.2.1.1

Transport of Solids by Gas Drag

EXPERIMENT CATEGORY

Water and Waste Management--Solid Transport by Gas Drag

OBJECTIVE AND SIGNIFICANCE

To obtain data on devices that require solid transport and retention by gas drag.

MEASUREMENTS AND OBSERVATIONS

Velocity/velocity profile
Friction
Density
Efficiency

EXPERIMENT DURATION

40 hours.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Cine/still cameras
Reference background grid
Solid/gas separator
Pressure sensor
Temperature sensor
Friction-measuring equipment
Flow meter
Timer
Zero-g scale

SPECIAL REQUIREMENTS/REMARKS

Transport of solids by gas drag is used for such things as the removal and retention of carbon particles from the Bosch reaction in oxygen recovery, the removal of solid contaminants in the atmosphere, the transport of debris, and the direction control and retention of fecal matter in a commode. A range of solids of densities representative of those requiring transport must be used. A variation in flow velocity must be investigated for each particle type.

PERSONNEL REQUIRED

1 crew member

REFERENCES

MDAC originated.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO.- 3.2.1.2

Transport of Liquids by Gas Drag

EXPERIMENT CATEGORY

Thermal Control/Water and Waste Management--Liquid Transport by Gas Drag

OBJECTIVE AND SIGNIFICANCE

To obtain zero-g data on the performance of the transport of liquids by gas drag using the thermal control and waste and water management on board equipment.

MEASUREMENTS AND OBSERVATIONS

Motion characteristics	Pressure
Density	Time
Flow rates	Acceleration
Humidity	Gas velocity
Temperature	Friction/drag

EXPERIMENT DURATION

200 hours at 8-hour intervals.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens with blower	Liquid container
Cine camera	Timer
Reference background grid	Zero-g scale
Pressure sensor	Electron microscope
Temperature sensor	Humidity sensor
Work bench and tools	Baseline EC/LS
Flow meter	Dew-point meter
Velocity meter	Gas-liquid separator

SPECIAL REQUIREMENTS/REMARKS

Transport of free liquid droplets by gas drag is involved in water/gas separation after condensation and urine/gas separation and direction control of the liquids. The test specimens can be placed in a by-pass loop within the normal EC/LS system.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Final Technical Report Study of Zero Gravity Capabilities of Life Support System Components and Processes. Convair Division of General Dynamics Report No. GDC-DBD67-004, February 1968.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 3.2.1.3

Manual Transport of Solids

EXPERIMENT CATEGORY

All Life Support--Solid Transport

OBJECTIVE AND SIGNIFICANCE

To evaluate devices and techniques for the manual transport of solids.

MEASUREMENTS AND OBSERVATIONS

Subjective opinion of crewmen

EXPERIMENT DURATION

Intermittently for 30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Transport container
Vacuum cleaner
Baseline EC/LS
Cine/still cameras
Debris disposal/container

SPECIAL REQUIREMENTS/REMARKS

Feces transfer from the waste management bowl to the drier and then to the storage containers involves solid transport by the crew. Another example is the recovery of solid waste from the atmosphere. In the absence of gravity, loss of the material during transport or opening/closing of containers is a hazard for which handling methods should be evaluated in zero-g. This can be performed as a part of the normal space station housekeeping.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Final Technical Report Study of Zero Gravity Capabilities of Life Support System Components and Processes. Convair Division of General Dynamics Report No. GDC-DBD67-004, February 1968.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE TEXT REF. NO. 3.2.1.4

Waste Management Methods and Components

EXPERIMENT CATEGORY

Waste Management--Feces and Urine Collection

OBJECTIVE AND SIGNIFICANCE

To evaluate waste management methods and components.

MEASUREMENTS AND OBSERVATIONS

Heat requirement	Temperature
Vacuum requirement	Pressure
Time	Flow rate
Power level	Performance
Chemical contaminants	Reliability and maintainability
Efficiency	Microbiological contaminants

EXPERIMENT DURATION

30 days for each major unit; crew time is 1 hour twice daily.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens	Cine camera
Pressure sensor	Temperature sensor
Chemical laboratory	Flow meter
Microbial laboratory	Watt meter
Baseline EC/LS	Timer

SPECIAL REQUIREMENTS/REMARKS

Urine collection devices, such as gas entrainment and centrifugation, diaphragm units, and sleeve attachments, must be evaluated in zero g. Waste disposal and processing techniques must be compared. The most favorable devices can be tested as an integrated system and qualified in Experiment 4-25. Experiment can be performed in conjunction with Experiments 4-1 or 4-2.

PERSONNEL REQUIRED

All on-board crew members.

REFERENCES

Life Support Systems for Space Flight of Extended Time Periods. General Dynamics Report No. 64-26203 (Contract No. NAS9-2934).

N. Belasco and D. Perry. Waste Management and Personal Hygiene for Extended Spacecraft Missions. National Aeronautics and Space Administration Manned Spacecraft Center, Houston, Texas, April 1964.

3.3 THERMAL CONTROL

Statement of the Problem

Thermal control devices must be developed for maintenance of optimum temperatures during both IVA and EVA. Low temperature waste heat must be collected and rejected to space, while high-temperature thermal energy must be conserved for use in $CO/_2$ water desorption, water reclamation, etc.

Scientific Objectives

The objectives of the Thermal Control study program are to assure thermal comfort during prolonged space flight.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Thermal Control are listed. They are followed by detailed sheets on each of the component experiments.

- 3.3 Thermal Control
  - 3.3.1 Heat Transfer - Cooling
    - 3.3.1.1 Advanced Cooling Methods
    - 3.3.1.2 Gas to Solid Heat Transfer
  - 3.3.2 Heat Transfer - Heating
    - 3.3.2.1 Radio isotope Thermal Heat
    - 3.3.2.2 Heat Source Comparisons
    - 3.3.2.3 Solid to Gas Heat Transfer
    - 3.3.2.4 Thermal Insulation and Surface Coatings
    - 3.3.2.5 Convective Heat Transfer at Zero G

3.3.2.6 Material Solar Absorptivity and Thermal Emissivity

3.3.2.7 Nucleate Boiling Mechanism

3.3.2.8 Parameters Affecting Comfort Level

3.3.3 Atmosphere Circulation

3.3.3.1 Cabin Air Distribution and Control

3.3.4 Thermal Storage Systems - No experiments yet proposed

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 3.3.1.1

Advanced Cooling Methods and Components

EXPERIMENT CATEGORY

Thermal Control--Process Cooling

OBJECTIVE AND SIGNIFICANCE

To evaluate advanced cooling methods.

MEASUREMENTS AND OBSERVATIONS

Flow rate
Pressure
Temperature
Power level
Efficiency
Humidity
Reliability and maintainability
Performance
Heat transfer rate/heat balance

EXPERIMENT DURATION

90 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Flow meter
Pressure sensor
Temperature sensor
Watt meter
Baseline EC/LS
Humidity sensor
Pumps, fans, and blowers

SPECIAL REQUIREMENTS/REMARKS

One advanced radiator configuration that is currently a potential test candidate is a heat pipe. Absorption and vapor cycle heat pumps are other typical experiment candidates.

PERSONNEL REQUIRED

2 crew members

REFERENCES

R. S. Osborne, R. W. Johnson, and W. C. Thornton. Experiments for an Engineering Technology Satellite. National Aeronautics and Space Administration Langley Research Center, Virginia, 23 April 1965.

Temperature Control Systems for Space Vehicles: Parts I and II. North American Aviation, Inc. Report No. ASD-TDR-62-493, 1962-63.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 3.3.1.2

Gas-to-Solid Heat Transfer in Cabin Air Cooling

EXPERIMENT CATEGORY

Thermal Control--Atmosphere Circulation

OBJECTIVE AND SIGNIFICANCE

To obtain zero-g heat transfer data for design purposes; and to verify proper operation of thermal control systems being used as the experiment.

MEASUREMENTS AND OBSERVATIONS

Pressure
Temperature
Flow rate
Gas velocity
Gas composition
Humidity
Heat exchanger effectiveness
Time
Heat transfer rate/heat balance

EXPERIMENT DURATION

30 min. for each of 80 tests.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens (heat exchanger and heat sink)
Pressure sensor
Flow meter
Velocity meter
Gas chromatograph
Timer
Baseline EC/LS
Humidity sensor
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

Gas-to-solid heat transfer is involved in absorbing heat from the atmosphere by heat exchangers or cold surfaces. This type of heat transfer is gravity dependent because of the lack of free convection. Gas-to-solid heat transfer involves atmosphere cooling and condensation. The data can be obtained as part of an integrated EC/LS experiment.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Final Technical Report Study of Zero Gravity Capabilities of Life Support System Components and Processes. Convair Division of General Dynamics Report No. GDC-DBD67-004, February 1968.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 3.3.2.1

Integration of Radioisotope Power and EC/LS

EXPERIMENT CATEGORY

Integrated EC/LS and Power Systems--Life Support

OBJECTIVE AND SIGNIFICANCE

To flight verify a radioisotope power system integrated with a life support system that uses both the power system's waste heat and electrical energy.

MEASUREMENTS AND OBSERVATIONS

Ionized radiation level
Heat requirement
Power level
Temperature
Pressure
Flow rate
Debris generation
pH and COD
Water conductivity
Waste-generation rate
Water-generation rate
Biomedical data
Time
Humidity
Gas composition
Performance
Reliability and maintainability
Contaminant level
Leakage
Metabolic rate
Use rate

EXPERIMENT DURATION

30 days, minimum.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Dosimeter
Watt meter
Flow meter
Pressure sensor
Temperature sensor
Dew-point meter
Gas chromatograph/mass spectrometer
Leak detector
Baseline EC/LS
Timer
Cine/still cameras
Zero-g scale
Humidity sensor
Isotope heater/power source
Work bench and tools

SPECIAL REQUIREMENTS/REMARKS

Major EC/LS candidates that can use waste heat are molecular sieve/silica gel CO_2 collectors, Bosch oxygen recovery, water sterilization and recovery units, water heaters, and toxin burners.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE | TEXT REF. NO. 3.3.2.2

Integrated Thermal Control System Utilizing Waste Heat and Electrical Energy

EXPERIMENT CATEGORY

Thermal Control--Process Heating

OBJECTIVE AND SIGNIFICANCE

To compare the effectiveness of life support systems using electrical energy, waste heat, isotope energy, and the combination of these sources for process heating.

MEASUREMENTS AND OBSERVATIONS

Efficiency	Ionized radiation level
Flow rate	Performance
Pressure	Heat requirement
Temperature	Reliability and maintainability
Power level	Heat transfer rate/heat balance

EXPERIMENT DURATION

30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens	Isotope heater
Flow meter	Dosimeter
Pressure sensor	Work bench and tools
Temperature sensor	Biomedical monitoring equipment
Watt meter	Radiation laboratory
Baseline EC/LS	Radioisotope shielding

SPECIAL REQUIREMENTS/REMARKS

Experiment can be conducted in conjunction with or as part of Experiments 4-1, 4-2, 4-3, 4-4, 4-13, 4-14, 4-15, 4-22, and 4-25.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

Thermal Integration of Electrical Power and Life Support Systems for Manned Spacecraft. General Electric Company. NASA Report No. CR-316 (Contract No. NAS3-2799), November 1965.

EXPERIMENT REQUIREMENTS SUMMARY

TEXT REF. NO. 3.3.2.3

EXPERIMENT TITLE

Solid-to-Gas Heat Transfer in Cabin Air Heating

EXPERIMENT CATEGORY

Thermal Control--Atmosphere Circulation

OBJECTIVE AND SIGNIFICANCE

To obtain zero-g heat-transfer effectiveness data between the atmosphere and solid surfaces at various forced-convection rates.

MEASUREMENTS AND OBSERVATIONS

Temperature
Surface temperature
Gas velocities and flow rate
Gas composition
Pressure
Humidity
Time
Power level
Flow rate
Heat transfer rate/ heat balance
Velocity/velocity profile

EXPERIMENT DURATION

30 min. for each of 80 tests.

SUBJECTS, MATERIALS, AND EQUIPMENT

Temperature sensor
Pressure sensor
Baseline EC/LS (heat source device and heat sink)
Gas chromatograph
Flow meter
Velocity meter
Timer
Watt meter

SPECIAL REQUIREMENTS/REMARKS

Solid-to-gas heating in space is primarily dependent on condition and forced convection since free convection is dependent on gravity. Failure to provide adequate forced convection will cause increased temperature differentials between exposed surfaces and the atmosphere. Solid-to-gas heat transfer involves removing heat from pumps, waste processing, lights, fans, electronics, and similar components.
The data can be obtained as a part of an integrated EC/LS experiment.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Final Technical Report Study of Zero Gravity Capabilities of Life Support System Components and Processes. Convair Division of General Dynamics Report No. GDC-DBD67-004, February 1968.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE TEXT REF. NO. 3.3.2.4

Effectiveness of Thermal Insulation and Surface Coatings

EXPERIMENT CATEGORY

Thermal Control--Heat Transfer

OBJECTIVE AND SIGNIFICANCE

To evaluate insulation types and configurations and the effect of surface coating.

MEASUREMENTS AND OBSERVATIONS

Pressure
Surface finish
Reflective index
Temperature
Absorbtivity/emissivity
Velocity/velocity profile
Gas composition
Heat transfer rate/heat balance

EXPERIMENT DURATION

Intermittent tests during life of spacecraft; measurements should be taken daily first month, then monthly for each test specimen; each test evaluation period is estimated at 8 hours.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens (minimum of 120)
Temperature sensor
Pressure sensor
Timer
Integrating reflectometer
Velocity meter
Chemical laboratory (chemical analysis kit)
Work bench and tools
Dew-point meter
Flow meter

SPECIAL REQUIREMENTS/REMARKS

The data are needed to provide more optimum thermal control design.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

IBM Experiment Program for Manned Earth Orbital Missions: Vol. I. IBM Report No. 65-928-63 (Contract No. NAS1-4667), August 1965.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 3.3.2.5

Convective Heat Transfer at Zero-G

EXPERIMENT CATEGORY

Thermal Control/Atmosphere Supply--Heat Transfer

OBJECTIVE AND SIGNIFICANCE

To determine the heat transfer coefficients in a low-g environment to supplement or to confirm existing information.

MEASUREMENTS AND OBSERVATIONS

Pressure	Acceleration
Temperature	Power level
Amps	Time
Volts	Velocity

EXPERIMENT DURATION

24 hours for each test.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens (vent systems, containers and reservoir, test fluids, instrumented test chamber and heater, and motor and control mechanism)	Zero-g scale
	Baseline EC/LS
	Shadowgraph
	Accelerometers
	Illumination device
Oscillograph	Watt meter
Volt meter	Temperature sensor
Amp meter	Pressure sensor
Cine/still cameras	Humidity sensor

SPECIAL REQUIREMENTS/REMARKS

One technique for supplying an atmosphere to a manned space vehicle is the stored atmosphere supply system; such a system utilizes liquid oxygen and liquid nitrogen. In the design of future spacecraft, it would be desirable to know the heat transfer characteristics of liquid containers in a low-g space environment. The information gained from this experiment could be used to determine boiloff rates and insulation requirements for the liquid containers. Although the experiment is intended for a life support system, the test results could be applied to other systems requiring a cryogenic supply.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

IBM Experiment Program for Manned Earth Orbital Missions: Vol. I. IBM Report No. 65-928-63 (Contract No. NAS1-4667), August 1965.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. **3.3.2.6**

Measurement of Solar Absorptivity and Thermal Emissivity of Various Materials by Spectrometry

EXPERIMENT CATEGORY

Thermal Control--Heat Transfer

OBJECTIVE AND SIGNIFICANCE

To evaluate the effects of a change in absorptivity and emissivity for spacecraft and radiator surfaces as related to thermal control design.

MEASUREMENTS AND OBSERVATIONS

Temperature
Time
Effectiveness
Surface finish
Absorbtivity/emissivity
Reflective index
Visual observation

EXPERIMENT DURATION

Intermittently during life of space station.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens (sample carrier)
Infrared spectrophotometer
Cine/still cameras
Integrating reflectometer
Baseline EC/LS
Chemical laboratory
Work bench and tools
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

Periodic emittances, absorbances, and reflectance tests must be made on samples that have been exposed to the space environment. The degree of changes in absorptivity and emissivity must be determined. In addition, visual observations, surface measurements, and chemical analyses can be made so that changes in α and ϵ may be correlated to both physical and/or chemical variations. Spacecraft radiator and normal surfaces can be used for part of the test. Additionally, small test specimens can be designed with a variety of surface coatings and finishes.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

Descriptive Titles of Experiments Selected by Langley Research Center. 15 November 1963.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 3.3.2.7

Pool Boiling in Long-Term Zero-G

EXPERIMENT CATEGORY

Thermal Control/Water Management--Heat Transfer and Liquid/Gas Behavior

OBJECTIVE AND SIGNIFICANCE

To gain insight into bubble growth rate, the interaction of growing bubbles, the hydrodynamic stability of bubble columns, and nucleation processes.

MEASUREMENTS AND OBSERVATIONS

Pressure
Temperature
Power level
Heat transfer rate

EXPERIMENT DURATION

1 hour for each of 20 tests.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Transport container
Baseline EC/LS (heat source)
Pressure sensor
Shadowgraph
Watt meter
Cine/still cameras
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

Observations would be made of the growth histories of isolated bubbles, the interaction of bubbles and the thickness history of the thermal layer. The heat flux and local thermodynamic state of the fluid would also be studied. Boiling phenomena are encountered in numerous applications in spacecraft, and a better understanding of zero-g boiling is important. For example, thermal control water boiler design is directly effected by this phenomenon.

PERSONNEL REQUIRED

1 crew member

REFERENCES

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 3.3.2.8

Effect of Wall Temperature, Ventilation Rate, Cabin Pressure, Gas Composition, and Crew Clothing on Comfort Level

EXPERIMENT CATEGORY

T.ermal Control/Protective System--Crew Comfort

OBJECTIVE AND SIGNIFICANCE

To obtain comfort criteria for spacecraft operation and the resulting effect on fan and pumping power.

MEASUREMENTS AND OBSERVATIONS

Temperatures
Pressure
Comfort criteria
Gas velocity
Humidity
Gas composition
Metabolic rate
Power level

EXPERIMENT DURATION

5 hours for each test condition. (Several hundred test conditions may be evaluated.)

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Baseline EC/LS (atmosphere supply)
Pressure sensor
Humidity sensor
Gas chromotograph
Ergometer
Velocity meter
Comfort simulator
Zero-g scale
Temperature sensor
Cine/still cameras
Timer
Metabolic measuring device
Watt meter
Flow meter
Biomedical monitoring equipment
Dew-point meter
Special clothing/space suits

SPECIAL REQUIREMENTS/REMARKS

Comfort zone refers to the combination of pressure, atmosphere, wall temperature, gas velocity, and humidity that creates a comfortable environment for the crew. Heat transfer is the major parameter resulting from these variables, and it will be different at zero g than at 1 g because of the lack of free convection at zero g.

PERSONNEL REQUIRED

4 crew members for each test condition

REFERENCES

Engineering Criteria for Spacecraft Cabin Atmosphere Selection. Douglas Report No. DAC-59169 (Contract No. NAS2-1371), November 1966.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE | TEXT REF. NO. 3.3.3.1

Cabin Air Distribution and Control

EXPERIMENT CATEGORY

Thermal Control--Atmosphere Circulation

OBJECTIVE AND SIGNIFICANCE

To determine the distribution and control of cabin gas and temperature in low gravity. Additionally, the removal and control of contaminants will be evaluated.

MEASUREMENTS AND OBSERVATIONS

Temperature
Flow rate
Humidity
Gas composition
Power level
Pressure
Velocity/velocity profile
Visual observation

EXPERIMENT DURATION

1 hour daily for 30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Baseline EC/LS (thermal control unit)
Flow meter
Velocity meter
Humidity sensor
Dew-point meter
Gas chromatograph
Chemical laboratory (calibration gas)
Infrared spectrophotometer
Temperature sensor
Watt meter

SPECIAL REQUIREMENTS/REMARKS

Control of the spacecraft temperature is accomplished by maintaining a balance between heat input from various sources and heat absorbed in various heat exchangers or by low temperature walls. On-board thermal control system can be used with adapters for flow modulation.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

3.4 PERSONAL HYGIENE AND SANITATION

Statement of the Problem

Because of the short duration of the Gemini and Apollo missions, personal hygiene and sanitation did not, nor were they anticipated to, pose major health problems. With the advent of extended missions, however, it becomes essential to consider personal hygiene and sanitation as a major problem area from both medical and crew social requirement aspects.

Scientific Objectives

The objective of this portion of the Life Support and Protective System Program is to develop personal hygiene and sanitation subsystems that will meet crew requirements during extended missions.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Personal Hygiene and Sanitation are listed. They are followed by detailed sheets on each of the Component Experiments.

3.4 Personal Hygiene and Sanitation

- 3.4.1 Body Cleansing
  - 3.4.1.1 Evaluation of equipment
- 3.4.2 Whole Body Washing - No experiments yet proposed
- 3.4.3 Technology for clothing maintenance and cleaning - no experiments yet proposed
- 3.4.4 Oral Hygiene - No experiments yet proposed
- 3.4.5 Hair Removal - No experiments yet proposed

M165

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 3.4.1.1

Equipment and Procedures for Personal Hygiene

EXPERIMENT CATEGORY

Crew Protection--Personal Hygiene

OBJECTIVE AND SIGNIFICANCE

To flight verify body bathing, dental hygiene, hair cutting, shaving, and other personal hygiene equipment.

MEASUREMENTS AND OBSERVATIONS

Visual observations
Flow rate
Equipment effectiveness
Pressure
Temperature
Power level
Performance

EXPERIMENT DURATION

40 hours.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Baseline EC/LS
Pressure sensor
Temperature sensor
Watt meter
Work bench and tools
Cine camera

SPECIAL REQUIREMENTS/REMARKS

Behavioral tests can also be conducted simultaneously with this experiment.

PERSONNEL REQUIRED

All on-board crew members

REFERENCES

IBM Experiment Program for Manned Earth Orbital Missions: Vol. I. IBM Report No. 65-928-63 (Contract No. NAS1-4667), August 1965.

3.5 ATMOSPHERE SUPPLY, CONTROL AND OXYGEN REGENERATION

Statement of the Problem

Oxygen regeneration was not required on short duration missions (Mercury, Gemini, and Apollo), since the penalty of storing in tanks all the breathing oxygen required was relatively small. As mission durations increase, however, a saving in weight must be effected by breaking down the metabolic carbon dioxide and water given off by man and recovering the oxygen for rebreathing.

Concepts must be evaluated and systems developed to provide oxygen and nitrogen for atmospheric supply and oxygen for metabolic consumption, with the least weight and volume penalty commensurate with the incurrence of reliability loss. Also, adequate development status at the time of the mission must be insured.

Scientific Objectives

The objectives of this task is to evaluate concepts and develop systems to provide oxygen and nitrogen for atmospheric supply and oxygen for metabolic consumption by (a) developing cryogenic tankage, (b) progressively closing the regenerative cycle and reclaiming oxygen from carbon dioxide and water, and (c) determining a chemically inert, dense source of nitrogen.

For early missions, cryogenic storage systems with their attendant expulsion techniques must be provided. For intermediate duration missions, storage system improvements may be required; however, the emphasis must be on development of reclamation systems for obtaining oxygen from metabolic by-products. Existing (or quickly achieved) advanced development status is a requirement. For extended missions, the emphasis should shift to improved recovery efficiency, operational simplicity, and long life in oxygen reclamation. Also another source of atmospheric diluent, rather than cryogenic tankage is required.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Atmosphere Supply, Control and Oxygen Regeneration are listed. They are followed by detailed sheets on each of the Component Experiments.

3.5 Atmosphere Supply, Control and Oxygen Regeneration

3.5.1 Nitrogen and Oxygen Supply and Recovery

3.5.1.1 Test of Storage Technology

3.5.1.2 Oxygen Generation from Water

3.5.1.3 Oxygen Recovery from CO_2

3.5.1.4 Airlock Gas Conservation

3.5.1.4 Density Profile of Cryogenic Fluid

3.5.1.5 Capillary Studies

3.5.1.6 Kinetics and Dynamics of Gas Bubbles

3.5.1.7 Gas Free Liquid Maintenance

3.5.1.8 Interface Phenomena in Liquid-Gas Separation

3.5.1.9 Supply Gauging

3.5.2 Trace Contaminant Control

3.5.2.1 Absorption of Gases by Liquids

3.5.3 Humidity Control

3.5.3.1 Water Condenser - Separator

3.5.4 Two Gas Control - no experiments yet proposed

3.5.4.1 Two gas Control

3.5.5 Carbon Dioxide Control - No experiments yet proposed

3.5.6 Microbiological Control and Monitoring - No experiments yet proposed

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE | TEST REF. NO. 3.5.1.1(1 of 3)

Atmosphere Supply Methods and Components

EXPERIMENT CATEGORY

Atmosphere Supply and Pressurization--Nitrogen and Oxygen Supply

OBJECTIVE AND SIGNIFICANCE

To flight verify a subcritical storage system which will enable a weight and volume savings for many proposed Earth-orbital missions.

MEASUREMENTS AND OBSERVATIONS

Delivery rate (without heat input)
Delivery rate (with heat inputs)
Performance
Pressure
Temperature
Leakage
Power level
Time
Humidity
Heat requirement
Flow rate

EXPERIMENT DURATION

90 days, with data taken twice a day for 1-hour intervals.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Flow meter
Pressure sensor
Timer
Watt meter
Leak detector
Gaging unit
Baseline EC/LS
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

Recommended as a "piggy back" experiment where supercritical or gaseous atmospheric supply is used as the primary system until a subcritical unit has been flight qualified. This experiment can be conducted in conjunction with Experiments 4-1, 4-2, and 4-47.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Experiment Program for One-Year Space Station Mission. Memorandum, George C. Marshall Space Flight Center, Huntsville, Alabama, 10 February 1967.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 3.5.1.1 (2 of 3)

Atmosphere Supply Methods and Components (Chemical Storage and Supply)

EXPERIMENT CATEGORY

Atmosphere Supply--Nitrogen and Oxygen

OBJECTIVE AND SIGNIFICANCE

To obtain operational data in space on atmosphere supply subsystems that provide gas from superoxides, chlorate candles, hydrogen peroxide, nitrogen producing chemicals, etc.

MEASUREMENTS AND OBSERVATIONS

Temperature
Performance
Reliability and maintainability
Chemical contaminants
Contaminant level
Heat requirement
Pressure
Time
Humidity
Power requirement
Flow rate

EXPERIMENT DURATION

40 hours.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Flow meter
Pressure sensor
Gas chromatograph
Gas compressor
Accumulator
Baseline EC/LS
Timer
Humidity sensor
Chemical laboratory
Work bench and tools
Watt meter
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

Chemical storage of atmosphere gas supply may be used for application where long-term storage is a requirement. Applications include emergency breathing supply, space suit biopacks, and inflation of various devices.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Analytical Methods for Space Vehicle Atmospheric Control Processes, Part II. Airesearch Manufacturing Company Report No. ASD-TDR-61-162 (Contract No. AF33[616]-8323).

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE TEXT REF. NO. 3.5.1.1 (3 of 3)

Atmosphere Supply Methods and Components (Refrigeration/ Reliquefaction)

EXPERIMENT CATEGORY

Atmosphere Supply and Pressurization--Nitrogen and Oxygen Supply

OBJECTIVE AND SIGNIFICANCE

To evaluate a refrigeration of a reliquefaction subsystem.

MEASUREMENTS AND OBSERVATIONS

Pressure
Temperature
Flow rate (boiloff and recovery rate)
Heat requirement
Power level
Efficiency
Time
Heat transfer rate/heat balance

EXPERIMENT DURATION

30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Flow meter
Pressure sensor
Temperature sensor
Special space radiator
Holding tanks
Cryogenic supply
Baseline EC/LS
Timer
Work bench and tools
Watt meter

SPECIAL REQUIREMENTS/REMARKS

The storage of cryogenic fluids for long missions using passive insulation techniques can involve excessive weight and volume penalties. An active refrigeration/reliquefaction system combined with thermal insulation may be necessary to conserve boiloff and minimize vehicle penalty. This experiment could be used to evaluate the performance for boiloff recovery systems for Interplanetary vehicle systems.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Effects of the Reliquefaction System on the Auxiliary Power System Requirements for Interplanetary Missions. Douglas Paper No. DP-3003, 30 November 1964.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 3.5.1.2

Electrolysis Methods and Components

EXPERIMENT CATEGORY

Atmosphere Supply and Pressurization--Oxygen Supply

OBJECTIVE AND SIGNIFICANCE

To evaluate electrolysis subsystems that ground tests have proved to be operational.

MEASUREMENTS AND OBSERVATIONS

Power level
Flow rate (O_2 and H_2 generation and water usage)
Pressure
Temperature
Leakage
Reliability and maintainability
Time
Gas composition
Performance
Chemical contaminants
Contaminant level

EXPERIMENT DURATION

90 days continuous operation, with intermittent shut-down and start-up transients imposed.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens (Electrolysis Cells)
Flow meter
Pressure sensor
Gas chromatograph
Watt meter
Timer
Leak detector
Baseline EC/LS
Work bench and tools
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

The use of water for O_2 supply or as part of a closed-cycle oxygen recovery system can apply to future vehicles. A major problem in the use of electrolysis involves operation in zero g. Many concepts have been proposed, such as a rotating cell, ion exchange membrane, and KOH liquid matrix unit. This experiment should be conducted with Experiment 4-1.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

EXPERIMENT REQUIREMENTS SUMMARY

3.5.1.3

EXPERIMENT TITLE — TEXT REF. NO. 3.5.1.3

Oxygen Recovery Methods and Components

EXPERIMENT CATEGORY

Atmosphere Supply and Pressurization -- Oxygen Recovery

OBJECTIVE AND SIGNIFICANCE

To evaluate oxygen recovery devices.

MEASUREMENTS AND OBSERVATIONS

- Temperature
- Pressure
- Gas composition
- Power level
- Flow rate
- Time
- Contaminant level
- Chemical contaminants

EXPERIMENT DURATION

90 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

- Test specimens
- Flow meter
- Pressure
- Baseline EC/LS sensor
- Gas chromatograph
- Holding tanks
- Pumps, fans, and blowers
- Humidity sensor
- Timer
- Chemical laboratory
- Work bench and tools
- Watt meter
- Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

Various methods are used to recover O_2 from CO_2, with the Sabatier and Bosch hydrogenation reactions being the most common for the production of water. The water can be electrolyzed to produce oxygen and hydrogen. The Sabatier process has proven successful in manned space cabin integrated EC/LS tests and should be the first unit flight qualified. Other O_2 recovery devices should be flight qualified as "piggy back" experiments when they have been proven operational in ground based testing. Experiment 4-1 would be used as the baseline EC/LS system during this particular test.

PERSONNEL REQUIRED

2 crew members

REFERENCES

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

Descriptive Titles of Experiments Selected by Langley Research Center. 15 November 1963.

EXPERIMENT REQUIREMENTS SUMMARY

3.5.1.4

EXPERIMENT TITLE — TEXT REF. NO. 3.5.1.4

Airlock Gas Conservation

EXPERIMENT CATEGORY

Crew Protection--Airlock

OBJECTIVE AND SIGNIFICANCE

To evaluate airlock gas conservation equipment and methods for flight verification of an airlock gas conservation subsystem.

MEASUREMENTS AND OBSERVATIONS

Pressure
Temperature
Flow rate
Power level
Time
Leakage

EXPERIMENT DURATION

8-hour intervals for 2 weeks, for each type of gas conservation unit tested.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens (airlock, motor/pump combination, and controls)
Flow meter
Pressure sensor
Temperature sensor
Watt meter
Holding tanks (if the cabin is not used as a reservoir)
Space suits
Timer
Baseline EC/LS (atmospheric supply system)
Tether/umbilicals
Illumination device
Special clothing/space suits

SPECIAL REQUIREMENTS/REMARKS

The atmosphere used in the operation of an airlock can be recovered by a pumpdown system pumping the gas from the airlock into the cabin or into low pressure storage vessels. An airlock and vent system required for the experiment. The airlock gas can be pumped into the cabin or into a holding tank for reuse.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Engineering Criteria for Spacecraft Cabin Atmosphere Selection. Douglas Report No. DAC-59169 (Contract No. NAS2-1371), November 1966.

EXPERIMENT REQUIREMENTS SUMMARY

3.5.14

EXPERIMENT TITLE — TEXT REF. I.O. 3.5.14

Density Profiles of Liquid At and Near the Critical State

EXPERIMENT CATEGORY

Atmosphere Supply--Cryogenic Fluids

OBJECTIVE AND SIGNIFICANCE

To validate Meyers' theory of condensation.

MEASUREMENTS AND OBSERVATIONS

Density
Pressure
Temperature
Time

EXPERIMENT DURATION

2-1/2 hours for each of 6 tests.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Cryogenic supply
Chemical laboratory
Pressure sensor
Temperature sensor
Cine/still cameras
Timer
Optical density sensor

SPECIAL REQUIREMENTS/REMARKS

The density profile of a column of near-critical-state liquid has been found to be much larger than that attributable to the static head. Sedimentation or condensation are possible explanations. Meyers theory involves condensation with the belief that the saturation line is a region which permits two phases to exist. Low-gravity tests are required to validate the theory. The resulting data would be useful in designing liquid-handling equipment, gauging, and expulsion devices.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights. 15 March 1965.

Descriptive Titles of Experiments Selected by Langley Research Center. 15 November 1963.

EXPERIMENT REQUIREMENTS SUMMARY

3.5.1.5

EXPERIMENT TITLE — TEXT REF. NO. 3.5.1.5

Capillary Studies

EXPERIMENT CATEGORY

Atmosphere Supply/Thermal Control/Water Management--Liquid Gas Separation

OBJECTIVE AND SIGNIFICANCE

To obtain a better understanding of the interactions of matter at solid/liquid/vapor interfaces.

MEASUREMENTS AND OBSERVATIONS

Time	Acceleration
Pressure	Wetting angle
Temperature	Surface tension
Flow rate	Viscosity

EXPERIMENT DURATION

30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens (spiral and straight tube of different I. D., and flat plate sample surfaces)
Timer
Accelerometer
Test container with bladder
Baseline EC/LS (hot and cold fluid and pressure sources)
Cine/still cameras
Pressure sensor
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

The behavior of such interfaces is an important factor in the design of heat exchangers, gas separators, and many other life support hardware. Theory requires correction or verification to enable proper design.

PERSONNEL REQUIRED

1 crew member

REFERENCES

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

EXPERIMENT REQUIREMENTS SUMMARY

3.5.1.6

EXPERIMENT TITLE TEXT REF. NO. 3.5.1.6

Kinetics and Dynamics of Gas Bubbles

EXPERIMENT CATEGORY

Atmosphere Supply/Thermal Control/Water Management Systems--Liquid Gas Behavior

OBJECTIVE AND SIGNIFICANCE

To obtain a better understanding of nucleated boiling and the kinetics of bubble growth and collapse under transient conditions free from convection in the liquid or bubble migration.

MEASUREMENTS AND OBSERVATIONS

Heat transfer rate/heat balance
Surface tension
Pressure
Temperature
Heat flux
Acceleration
Time
Density

EXPERIMENT DURATION

1 hour daily for 30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Cine camera
Illumination device
Pressure sensor
Temperature sensor
Pressure controller
Timer
Accelerometer
Bubble chamber

SPECIAL REQUIREMENTS/REMARKS

This type of basic information can be applied in the better design of life support components that involve heat transfer and liquid/gas separation. Bubble growth and collapse rate for both large (≥5 mm) and small (≤5 mm) bubbles, bubble surface oscillations, and oscillation modes induced both by external pressure pulses and bubble movement, and bubble migration rates under low vehicle accelerations ($<10^{-2}$ g).

PERSONNEL REQUIRED

1 crew member

REFERENCES

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights. 15 March 1965.

EXPERIMENT REQUIREMENTS SUMMARY

3.5.1.7

EXPERIMENT TITLE TEXT REF. NO. 3.5.1.7

Gas-Free Liquid Maintenance

EXPERIMENT CATEGORY

Atmosphere Supply/Thermal Control/Water Management--Liquid Gas Separation

OBJECTIVE AND SIGNIFICANCE

To test gas-free liquid maintenance devices applicable to thermal control, electrolysis, and other subsystems.

MEASUREMENTS AND OBSERVATIONS

Gas composition
Pressure
Temperature
Power level
Flow rate
Time
Effectiveness
Humidity
Liquid composition

EXPERIMENT DURATION

1 hour daily for 30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens (semi-permeable membrane, porous plate, or other gas/liquid separators)
Mass spectrometer
Flow meter
Humidity sensor
Pressure sensor
Watt meter
Timer
Temperature sensor
Pyrex flask
Heating element

SPECIAL REQUIREMENTS/REMARKS

The maintenance of gas-free liquids in zero g may require specialized devices or gas separators.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Final Technical Report Study of Zero Gravity Capabilities of Life Support System Components and Processes. Convair Division of General Dynamics Report No. GDC-DBD67-004, February 1968.

EXPERIMENT REQUIREMENTS SUMMARY

3.5.1.8

EXPERIMENT TITLE — TEXT REF. NO. 3.5.1.8

Static and Motion Tests of Interface Phenomena

EXPERIMENT CATEGORY

Atmosphere Supply/Thermal Control/Water Management--Liquid Gas Separation

OBJECTIVE AND SIGNIFICANCE

To measure various interface phenomena in zero-g conditions.

MEASUREMENTS AND OBSERVATIONS

Surface tension	Temperature
Wetting angle	Orientation
Surface shapes	Pressure
Damping	Time
Motion characteristics	Density

EXPERIMENT DURATION

1 hour daily for 30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens	Pressure sensor
Cine camera	Timer
Pyrex flask	Dialectrophorese device
Heating element	Shadowgraph
Orientation device	

SPECIAL REQUIREMENTS/REMARKS

In a series of static tests, surface shapes of liquid-liquid, liquid-gas, liquid-vapor, and liquid-liquid-gas systems would be measured to determine intermolecular forces and forces resulting from surface tension and wetting. In addition, solid-liquid interfaces would be studied by means of models of baffles and pick-up tubes. Observations would also be made during period when the laboratory spacecraft is being accelerated during orbit keeping. The data from the experiment can be used to design such items as gaging and expulsion devices.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

Descriptive Titles of Experiments Selected by Langley Research Center. 15 November 1963.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE — TEXT REF. NO. 3.5.1.9

Advanced Fluid Management and Gaging Subsystem

EXPERIMENT CATEGORY

Atmosphere Supply and Pressurization--Gaging

OBJECTIVE AND SIGNIFICANCE

To evaluate available methods for determining the amount of fluid remaining in the tanks as well as the location of the fluids.

MEASUREMENTS AND OBSERVATIONS

Pressure
Temperature
Boiloff rate
Delivery rate
Power level
Acceleration
Ionized radiation level
Time

EXPERIMENT DURATION

40 hours for each test specimen.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Pressure sensor
Temperature sensor
Flow meter
Radioisotope shielding
Cine camera
Accelerometer
Dosimeter
Timer
Work bench and tools
Watt meter

SPECIAL REQUIREMENTS/REMARKS

Conductivity grids and radioisotopes are representative proposed techniques.

PERSONNEL REQUIRED

2 crew members

REFERENCES

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

Douglas 21i Mission Experiment List. April 1966.

EXPERIMENT REQUIREMENTS SUMMARY

3.5.2.1

EXPERIMENT TITLE — TEXT REF. NO. 3.5.2.1

Absorption of Gases by Liquids at Zero-G

EXPERIMENT CATEGORY

Atmosphere Supply/Thermal Control/Water Management--

OBJECTIVE AND SIGNIFICANCE

To determine the amount of vital gases, carbon dioxide, oxygen, and contaminants that can be absorbed by fluids.

MEASUREMENTS AND OBSERVATIONS

Gas flow distribution
Absorption rate
Pressure
Temperature
Gas composition
Liquid composition
Time

EXPERIMENT DURATION

1 hour daily for 30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens (filters and membranes)
Pyrex flask
Plastic squeeze container
Hand pump
Shadowgraph
Chemical laboratory (liquid analysis)
Pressure sensor
Timer
Heating element
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

The absorption rate and gas distribution within the liquid can also be investigated. This type of information furnishes a background for life support systems that use liquid suspension systems.

PERSONNEL REQUIRED

1 crew member

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL) System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

Descriptive Titles of Experiments Selected by Langley Research Center. 15 November 1963.

EXPERIMENT REQUIREMENTS SUMMARY

3.5.3.1

EXPERIMENT TITLE — TEXT REF. NO. 3.5.3.1

Water Condenser-Separator Methods and Components

EXPERIMENT CATEGORY

Thermal Control--Humidity Control

OBJECTIVE AND SIGNIFICANCE

To test and evaluate the most promising advanced water condenser-separator systems.

MEASUREMENTS AND OBSERVATIONS

Power level
Condensation rate
Heat balance
Flow rate
Temperature
Pressure
Water removal efficiency
Humidity
Time
Water conductivity

EXPERIMENT DURATION

24 hours for each test specimen; crew time is 30 min. every 8 hours.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Cine camera
Flow meter
Pressure sensor
Humidity sensor
Watt meter
Liquid pump
Baseline EC/LS
Timer
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

Experiments 4-51 and 4-52 can be performed as part of this experiment.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Apollo Systems Earth Orbital Mission Definition Document. National Aeronautics and Space Administration Headquarters, Washington, D.C., January 1965.

R.S. Osborne, R.W. Johnson, and W.C. Thornton. Experiments for an Engineering Technology Satellite. National Aeronautics and Space Administration Langley Research Center, Virginia, 23 April 1965.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE | TEXT REF. NO. 3.5.4.1

Advanced Two-Gas Atmosphere Supply and Control Subsystem

EXPERIMENT CATEGORY

Atmosphere Supply and Pressurization--Two-Gas Control

OBJECTIVE AND SIGNIFICANCE

To flight verify a two-gas supply and control system.

MEASUREMENTS AND OBSERVATIONS

Pressure
Temperature
Gas composition
Flow rate
Power level
Time
Reliability and maintainability

EXPERIMENT DURATION

30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Baseline EC/LS
Pressure sensor
Temperature sensor
Gas chromatograph
Chemical laboratory (calibration gas bottles and gases)
Flow meter
Humidity sensor
Timer
Watt meter
Work bench and tools

SPECIAL REQUIREMENTS/REMARKS

An advanced multigas mass spectrometer sensor and control have been tested and proven in a simulator. This device, as well as others, is available for flight test in conjunction with an atmosphere supply and storage system. This experiment can be completed as part of Experiments 4-1 and 4-2.

PERSONNEL REQUIRED

All on-board crew members

REFERENCES

IBM Experiment Program for Manned Earth Orbital Missions: Vol. I. IBM Report No. 65-928-63 (Contract No. NAS1-4667), August 1965.

3.6 CARBON DIOXIDE REMOVAL

Statement of the Problem

In any manned flight situation, the need exists to remove metabolically produced carbon dioxide from the gaseous environment. In longer missions, the requirement exists for concentrating the carbon dioxide for subsequent reduction in order to minimize or help eliminate the requirement for stores oxygen.

Scientific Objectives

The objective of this task is to develop, through extension of the technology now available, carbon dioxide removal and concentration subsystems with improved reliability and maintenance characteristics. Efforts are also under way to extend adsorption technology and develop water-tolerant adsorption media while reducing system weight and power requirements. Long-term mission systems are being sought which will have inherently longer life and higher reliability than current adsorption systems.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Carbon Dioxide Removal are listed. They are followed by detailed sheets on each of the Component Experiments.

3.6 Carbon Dioxide Removal - no further breaddown yet identified

- 3.6.1.1 Collection Methods and Components
- 3.6.1.1 Atmosphere Purification

EXPERIMENT REQUIREMENTS SUMMARY

3.6.1.1

EXPERIMENT TITLE — TEXT REF. NO. 3.6.1.1

Carbon Dioxide Collection Methods and Components

EXPERIMENT CATEGORY

Atmosphere Purification and Control -- Carbon Dioxide Control

OBJECTIVE AND SIGNIFICANCE

To flight verify advanced carbon dioxide removal subsystems.

MEASUREMENTS AND OBSERVATIONS

Flow rate
Efficiency
Pressure
Temperature
Power level
CO_2 removal rate
Time
Leakage
Gas composition
Performance
Heat requirement

EXPERIMENT DURATION

Qualification test data taken 15 min. twice daily for 90 days; reliability data for the life of equipment

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Flow meter
Pressure sensor
Gas chromatograph
Timer
Baseline EC/LS
Work bench and tools
Humidity sensor
Watt meter
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

Regenerative molecular sieves, carbonation cells, and other advanced CO_2 removal methods that permit vehicle penalty savings must be flight qualified. Currently, only the regenerative molecular sieve system has had sufficient development to be ready for flight qualification. Other advanced techniques look promising and will become available for qualification once they have been proven in ground-based tests.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Analytical Methods for Space Vehicle Atmospheric Control Processes, Part II. Airesearch Manufacturing Company Report No. ASD-TDR-61-162 (Contract No. AF33 616 -8323).

Life Support Systems for Space Flight of Extended Time Periods. General Dynamics Report No. 64-26203 (Contract No. NAS9-2934).

A. D. Babinsky, et al. Carbon Dioxide Concentration System. NASA Report No. CR-72086. 30 July 1966.

T.C. Secord and M. S. Bonura. Life Support Data from Sixty-two Days of Testing in a Space Cabin Simulator. Douglas Paper No. DC-3397, October 1965.

3.6.1.2

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE TEXT REF. NO.- 3.6.1.2

Advanced Integrated Atmosphere Purification and Thermal Control Subsystems

EXPERIMENT CATEGORY

Atmosphere Purification and Control -- Carbon Dioxide Control

OBJECTIVE AND SIGNIFICANCE

To test and flight verify advanced life support subsystems regenerated with waste heat.

MEASUREMENTS AND OBSERVATIONS

Gas composition	Power level
Temperature	Humidity
Pressure	Time
Flow rate	Heat transfer rate/heat balance

EXPERIMENT DURATION

1 hour of crew time, twice daily, for 30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens	Baseline EC/LS
Flow meter	Gas chromatograph
Dew-point meter	Holding tanks
Pressure sensor	Timer
Temperature sensor	Humidity sensor
CO_2 sensor	Pumps, fans and blowers
Watt meter	

SPECIAL REQUIREMENTS/REMARKS

A molecular sieve CO_2 removal system cyclically uses thermal energy and vacuum to regenerate the sieve beds and to help transfer, with the assistance of a pump, the CO_2 in the sieves to the O_2 recovery system. Additionally, the silica gel beds are regenerated by the heat from the thermal control system. The beds are also cooled after regeneration by the thermal control system.

Experiment can be conducted with Experiment 4-1 or as part of Experiment 4-13.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Final Technical Report Study of Zero Gravi[illegible] [illegible]bilities of Life Support System Components and Processes. Conv[illegible] [illegible]n of General Dynamics Report No. GDC-DBD67-004, February 19[illegible]

Space Marketing Intelligence-National Multipurpo[illegible] Space Station (NMSS) Experimental Listing. Published by Space Station Study Office, National Aeronautics and Space Administration Manned Spacecraft Center, Houston, Texas, 17 December 1964.

3.7 TRACE CONTAMINANTS CONTROL

Sta[illegible] of the Problem

Odors and trace contaminants, both physical and biological, must be removed to provide habitable semi-closed and closed environments.

Scientific Objectives

The objective of this task is to provide technology for the control and/or elimination of trace contaminants in spacecraft atmospheres. This includes chemical oxidation techniques, regenerable charcoal sorption of contaminants, and advanced processing techniques.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Trace Contaminants Contr[illegible] are listed. They are followed by detai[illegible]d sheets on each of the Component Experiments.

3.7 Trace Contaminants Control - no further breakdown yet identified

3.7.1.1 Biological Contamination

3.7.1.2 Trace Contaminant Control

EXPERIMENT REQUIREMENTS SUMMARY

3.7.1.1

EXPERIMENT TITLE

TEXT REF. NO. 3.7.1.1

Biological Control and Monitoring of Life Support Subsystems

EXPERIMENT CATEGORY

Atmosphere Purification and Control--Microbial Control and Monitoring

OBJECTIVE AND SIFNIFICANCE

To evaluate optical measurement, resistance measurement, viable sampling by membrane filtration, and the Coulter Counter monitoring technique.

MEASUREMENTS AND OBSERVATIONS

Microbiological contaminants
Chemical contaminants
Effectiveness
Temperature
Pressure
Humidity
Leakage
Time
Power level
Flow rate

EXPERIMENT DURATION

Mission duration (as required).

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Microbiological laboratory
Chemical laboratory
Still camera
Gas chromatograph
Baseline EC/LS
Pressure sensor
Temperature sensor
Humidity sensor
Flow meter
Leak detector
Timer
Watt meter
Pumps, fans, and blowers

SPECIAL REQUIREMENTS/REMARKS

Microbial control chemical control and monitoring equipment and methods must be evaluated in zero. Experiment can be performed in conjunction with Experiments 4-1, 4-2, 4-3 4-4, 4-22, 4-23, and 4-25.

PERSONNEL REQUIRED

1 technician

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

Descriptive Titles of Experiments Selected by Langley Research Certer. 15 November 1963.

EXPERIMENT REQUIREMENTS SUMMARY

3.7.1.2

EXPERIMENT TITLE — TEXT REF. NO. 3.7.1.2

Integrated Trace Contaminant Control and Monitoring Subsystem

EXPERIMENT CATEGORY

Atmosphere Purification and Control -- Trace Contaminant Control

OBJECTIVE AND SIGNIFICANCE

To flight verify a catalytic burner in conjunction with particulate filters and chemisorbent beds for trace contaminant removal and control, and an on-board monitoring and gas analysis device.

MEASUREMENTS AND OBSERVATIONS

Temperature
Pressure
Efficiency
Flow rate
Gas composition
Humidity
Time
Leakage
Power level
Performance
Reliability and maintainability
Chemical contaminants

EXPERIMENT DURATION

30 min. twice daily for 90 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Infrared spectrophotometer
Gas chromatograph/mass spectrometer
Chemical laboratory (calibration gas mixtures)
Baseline EC/LS
Temperature sensor
Pressure sensor
Flow meter
Humidity sensor
Timer
Watt meter
Leak detector

SPECIAL REQUIREMENTS/REMARKS

Experiment can be performed in conjunction with Experiments 4-1, 4-2, or 4-3

PERSONNEL REQUIRED

1 crew member

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

3.8 ASTRONAUT PROTECTIVE SYSTEMS

Statement of the Problem

Present and future manned space flight orbital and surface missions require astronaut protective systems that will maintain and support an environmental condition in which useful work may be performed in any operational mode. These systems will protect man from harsh thermal radiation, micro-meteroroids, and the vacuum conditions of the extravehicular (EV) environs. They also will provide optimal personal environmental conditions within the spacecraft under both normal and emergency conditions.

Scientific Objectives

The objectives of this task are to protect, sustain and support man against environmental extremes which may occur in all phases of extravehicular or intravehicular (IV) orbital or surface operational manned spaceflight missions. This will be accomplished by utilization of spacesuit systems and space life support systems, which will have high reliability and will be designed for ease of maintenance. Specific weight, volume, power, and overall systems impact objectives will vary according to the specific class of missions.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Astronaut Protective Systems are listed. They are followed by detailed sheets on each of the Component Experiments.

3.8 Astronaut Protective Systems

3.8.1 Intra Vehicular Space Suit/clothing

3.8.1.1 No experiments yet proposed

3.8.2 Extra Vehicular Space Suit

3.8.2.1 Advanced space suit

3.8.3 Portable Life Support System

3.8.3.1 Bio-pack Evaluation

EXPERIMENT REQUIREMENTS SUMMARY 3.8.2.1

EXPERIMENT TITLE | TEXT REF. NO. 3.8.2.1

Protective Clothing and Advanced Space Suit Assemblies

EXPERIMENT CATEGORY

Crew Protection--Clothing/Space Suit

OBJECTIVE AND SIGNIFICANCE

To evaluate advanced space suits and other protective equipment.

MEASUREMENTS AND OBSERVATIONS

Comfort criteria
Mobility
Pressure
Temperature
Gas composition
Power level
Flow rate
Time
Humidity
Performance
Ionized radiation level
Leakage
Biomedical monitoring

EXPERIMENT DURATION

1 hour for each of 20 tests.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimen
Pressure sensor
Leak Detector
Baseline EC/LS
Temperature sensor
Flow meter
Humidity sensor
Gas chromatograph
Biomedical monitoring equipment
Cine camera
Work bench and tools
Ignition device
Watt meter

SPECIAL REQUIREMENTS/REMARKS

Space suits and cooled undergarments, as well as constant wear garments, will be required for EVA, IVA, and emergency operations. Experiment can be done in conjunction with Experiment 4-28 and behavioral experiments.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

IBM Experiment Program for Manned Earth Orbital Missions: Vol. I. IBM Report No. 65-928-63 (Contract No. NAS1-4667), August 1965.

Experiment Program for One-Year Space Station Mission. Memorandum, George C. Marshall Space Flight Center, Huntsville, Alabama, 10 February 1967.

EXPERIMENT REQUIREMENTS SUMMARY 3.8.3.1

EXPERIMENT TITLE

TEXT REF. NO. 3.8.3.1

EVA Suit and Biopack

EXPERIMENT CATEGORY

Crew Protection--Backpack and Space Suit

OBJECTIVE AND SIGNIFICANCE

To evaluate a crewman clothed in the spacesuit, and to evaluate the effectiveness and durability of the spacesuit and biopack through a complete spectrum of motion and environment.

MEASUREMENTS AND OBSERVATIONS

Humidity	Power level
Pressure	Time
Temperature	Leakage
Flow rate	Performance
Mobility	Contaminant level
Gas composition	Metabolic rate
Comfort criteria	Biomedical monitoring

EXPERIMENT DURATION

1 hour for each of 20 tests.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens	Tethers/umbilicals
Pressure sensor	Biomedical monitoring equipment
CO_2 sensor	Watt meter
Gas Chromatograph	Leak detector
Baseline EC/LS	Timer
Flow meter	Humidity sensor
Cine camera	Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

Experiment can be done in conjunction with Experiment 4-27 and behavioral experiments.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

Descriptive Titles of Experiments Selected by Langley Research Center. 15 November 1963

3.9 SUBSYSTEMS INTEGRATION

Statement of the Problem

Long term manned missions will require life support and environmental control systems of proven performance with demonstrated reliability, maintainability, vehicle i gration, and control automation at the total system level.

Scientific Objectives

The objective of the task is, first, to accomplish research and development on individual subsystems so as to prove the technical feasibility of processes and hardware designs. Subsequently, total systems efforts are needed to identify and solve the problems of scale-up, integration, and control automation. It then is necessary to develop integrated flight prototype systems which will be used to establish design verification through a long term ground test program.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Subsystems Integration are listed. They are followed by detailed sheets on each of the Component Experiments.

3.9 Subsystems Integration

3.9.1 no breakdown yet proposed

3.10 CLOSED SPACECRAFT SYSTEM PROBLEMS

Statement of the Problem

In addition to the identified technology problems there are some systems problems which involve more than one area.

Objectives

Research Areas and Component Experiments

The Research Areas and Component Experiments under closed Spacecraft Systems Problems are listed. They are followed by detailed sheets on each of the Component Experiments.

3.10 Closed Spacecraft Systems Problems

- 3.10.1 Life Support
  - 3.10.1.1 Advanced Intergrated Life Support System I
  - 3.10.1.2 Advanced Intergrated Life Support System II
  - 3.10.1.3 Animal Research Facility Life Support System
- 3.10.2 Solid and Liquid Control
  - 3.10.2.1 Vapor Purge of Liquid Systems in zero G
  - 3.10.2.2 Solid and Liquid Rention during maintenanc
  - 3.10.2.3 Solid and Liquid Spillage Recovery
- 3.10.3 Fire Prevention
  - 3.10.3.1 Combustion mixing and heat transfer
  - 3.10.3.2 Flame Propogation

EXPERIMENT REQUIREMENTS SUMMARY

3.10.1.1

EXPERIMENT TITLE

TEXT REF. NO. 3.10.1.1

Advanced Integrated Life Support System I

EXPERIMENT CATEGORY

Advanced Integrated EC/LS--Life Support

OBJECTIVE AND SIGNIFICANCE

To flight verify an advanced integrated baseline life support system for post-Apollo missions.

MEASUREMENTS AND OBSERVATIONS

Flow rate	Debris generation	Reliability and maintainability
Pressure	Gas composition	Metabolic rate
Temperature	Performance	Use rate
Contaminant level	Visual observation	Leakage
Water conductivity	Time	Biomedical data
Humidity	Food- and water-use rate	Ionized radiation level
Power level	Waste-generation rate	
	Water-generation rate	

EXPERIMENT DURATION

Life of space station and/or equipment.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test Specimens as follows:	Chemical laboratory	Leak detector
Atmosphere supply and Pressurization	Microbial laboratory	Zero-g scale
Atmosphere purification and control	Flow Meter	Timer
Thermal control	Pressure sensor	Cine/still cameras
Waste and water management	Dew-point meter	Metabolic measuring device
Food management	Watt meter	Work bench and tools
	Gas chromatograph/mass spectrometer	Dosimeter
	Infrared spectrophotometer	Humidity sensor
		Baseline EC/LS
		Humidity sensor

SPECIAL REQUIREMENTS/REMARKS

The experiment selected must have been proven operational in a simulator. The experiment will not include O_2 and food recovery but will include water recovery.

PERSONNEL REQUIRED

All on-board crew members

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

EXPERIMENT REQUIREMENTS SUMMARY 3.10.1.2

EX RIMENT TITLE — TEXT REF. NO. 3.10.1.2

Advanced Integrated Life Support System II

EXPERIMENT CATEGORY

Advanced Integrated EC/LS--Life Support

OBJECTIVE AND SIGNIFICANCE

To flight verify an integrated life support system that is more advanced than the baseline system qualified in Experiment 4-1.

MEASUREMENTS AND OBSERVATIONS

Flow rate
Pressure
Temperature
Contaminant level
Humidity
Power level
Debris generation

Gas composition
Performance
Time
Waste-generation rate
Water-generation rate
Reliability and maintainability

Water conductivity
Metabolic rate
Use rate (of all materials)
Leakage
Biomedical data
Ionized radiation level
pH and COD

EXPERIMENT DURATION

Life of space station and/or equipment.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test Specimens as follows:
- Atmosphere supply and pressurization
- Atmosphere purification and control
- Thermal control
- Waste and water management
- Food management

Baseline EC/LS
Flow meter
Pressure sensor
Temperature sensor
Dew-point meter
Watt meter
Gas chromatograph/mass spectrometer
Infrared spectrophotometer

Emergency backup EC/LS
Leak detector
Zero-g scale
Timer
Cine/still cameras
Metabolic measuring device
Work bench and tools
Dosimeter
Humidity sensor
Isotope heater

PERSONNEL REQUIRED

All on-board crew members

R RENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

NASA Experiment Descriptions for Extended Apollo Earth Orbit Flights, 15 March 1965.

EXPERIMENT REQUIREMENTS SUMMARY 3.10

EXPERIMENT TITLE

TEXT REF. NO. 3.10.4.3

Advanced Integrated Life Support Systems for Animals

EXPERIMENT CATEGORY

Animal EC/LS--Life Support

OBJECTIVE AND SIGNIFICANCE

To determine the compatibility and workability of a totally integrated animal facility/manned facility.

MEASUREMENTS AND OBSERVATIONS

Food- and water-use rate
Pressure
Temperature
Waste-generation rate
Power level
Gas composition
Biomedical data
Visual observation
Time
Humidity
Performance
Microbiological contaminants
Chemical contaminants
Contaminant level
Water-generation rate
Urine/blood/biological samples
Debris generation
Reliability and maintainability
Flow rate

EXPERIMENT DURATION

2 hours daily of crew time for 6 months.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Test food and water dispensers
Pressure sensor
Temperature sensor
Flow meter
Special sampling equipment
Biomedical monitoring equipment
Gas chromotograph/mass spectrometer
Biomedical monitoring equipment
Animal housing
Refrigerator
Humidity sensor
Timer
Cine/still cameras
Chemical laboratory
Microbial laboratory
Radiation laboratory
Infrared spectrophotometer
Zero-g scale
Work bench and tools
Watt meter
Baseline EC/LS

SPECIAL REQUIREMENTS/REMARKS

This experiment requires long-duration testing with minimum monitoring by the crew. Life support systems for animals on board a manned spacecraft should consist of the EC/LS system for man, augmented with special equipment for contaminant control, waste control, and feeding. Hardware for collection and storage of blood, urine, and biological samples must be provided.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

Study of an Animal Research Facility Using SIV-B for Manned Orbital Biotechnology Laboratory. Douglas Report No. DAC-58039, September 1967.

EXPERIMENT REQUIREMENTS SUMMARY

5.10.2.1

EXPERIMENT TITLE — TEXT REF. NO. -3.10.2.1

Vapor Purge of Liquid Systems in Zero-G

EXPERIMENT CATEGORY

Atmosphere Supply/Thermal Control/Water Management/Waste Management--Solid and Liquid Retention

OBJECTIVE AND SIGNIFICANCE

To evaluate separating techniques of small quantities of noncondensable gases from spacecraft liquid systems.

MEASUREMENTS AND OBSERVATIONS

Water use
Vapor removal efficiency
Visual observation
Temperature
Pressure

EXPERIMENT DURATION

15 min. for each test; repeat 16 times.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens (fluid test rig and pump)
Baseline EC/LS (water supply and heat transport fluid supply)
Temperature sensor
Pressure sensor
Photo cell

SPECIAL REQUIREMENTS/REMARKS

Small quantities of noncondensable gases in liquid systems may contribute to corrosion, pump cavitation, heat-exchanger inefficiency, and other problems. Examples of such problem areas in spacecraft life support systems are air carry-over into urine, cabin air condensate, and wash water storage tanks. In addition, heat transfer loops should be purged periodically to remove dissolved gas that may be desorbed because of pressure or temperature changes.

PERSONNEL REQUIRED

1 crew member

REFERENCES

R. S. Osborne, R. W. Johnson, and W. C. Thornton. Experiments for an Engineering Technology Satellite. National Aeronautics and Space Administration Langley Research Center, Virginia, 23 April 1965.

EXPERIMENT REQUIREMENTS SUMMARY

3.10.2.2

EXPERIMENT TITLE TEXT REF. NO. - 3.10.2.2

Retention Techniques for Liquids and Solids during Equipment Servicing, Repair, and Maintenance

EXPERIMENT CATEGORY

All Life Support--Solid and Liquid Retention

OBJECTIVE AND SIGNIFICANCE

To evaluate devices and techniques for the retention of solids and liquids.

MEASUREMENTS AND OBSERVATIONS

Subjective opinion of retention technique by crewmen.

EXPERIMENT DURATION

30 min. for each of 80 tests.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Baseline EC/LS
Cine camera
Chemical laboratory
Microbial laboratory
Debris/disposal container
Carbon bag
Plumbing purge unit
Vacuum cleaner
Porous plate water separator

SPECIAL REQUIREMENTS/REMARKS

Liquid retention in plumbing or equipment during manually controlled servicing operations will require special zero-g procedures. The handling of solids, wastes, or mixtures will also require new retention techniques. The experiment can be conducted with the normal on-board EC/LS hardware.

PERSONNEL REQUIRED

Undetermined

REFERENCES

Final Technical Report Study of Zero Gravity Capabilities of Life Support System Components and Processes. Convair Division of General Dynamics Report No. GDC-DBD67-004, February 1968.

EXPERIMENT REQUIREMENTS SUMMARY

3.10.2.3

EXPERIMENT TITLE

TEXT REF. NO. 3.10.2.3

Spillage Recovery and/or Cleanup

EXPERIMENT CATEGORY

All Life Support--Liquid and Solid Recovery and Retention

OBJECTIVE AND SIGNIFICANCE

To evaluate devices for recovering liquids and solids that have escaped into the atmosphere and for controlling the debris.

MEASUREMENTS AND OBSERVATIONS

Subjective opinion of crewmen
Power level
Pressure

EXPERIMENT DURATION

30 min. for each of 10 tests.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Cine/still
Flow meter
Pressure sensor
Vacuum cleaner
Watt meter
Baseline EC/LS
Work bench and tools

SPECIAL REQUIREMENTS/REMARKS

None

PERSONNEL REQUIRED

1 crew member

REFERENCES

Final Technical Report Study of Zero Gravity Capabilities of Life Support System Components and Processes. Convair Division of General Dynamics Report No. GDC-DBD67-004, February 1968.

EXPERIMENT REQUIREMENTS SUMMARY 3.10.3.1

EXPERIMENT TITLE | TEXT REF. NO. 3.10.3.1

Composition Mixing and Heat Transfer

EXPERIMENT CATEGORY

Crew Protection--Fire Prevention

OBJECTIVE AND SIGNIFICANCE

To evaluate composition mixing and heat transfer of flames to permit a better understanding of control requirements.

MEASUREMENTS AND OBSERVATIONS

Pressure
Gas velocity
Power level
Gas composition
Ignition time
Thermal radiation
Total energy
Chemical contaminants
Contaminant level
Heat transfer rate/heat balance

EXPERIMENT DURATION

4 hours for each experiment.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Fans
Humidity sensor
Pressure sensor
Watt meter
Timer
Cine camera
Optical pyrometer
Baseline EC/LS (atmosphere supply source and gas analyzer)
Gas chromatograph
Infrared spectrophotometer
Temperature sensor

SPECIAL REQUIREMENTS/REMARKS

Flame control is generally accomplished by limiting the introduction of combustibles and/or heat removal which forces a reduction of flame temperature. The gravity-sensitive processes generally are natural convection, which tends to provide necessary oxygen; and blanketing by a smothering gas or other material. In zero g, with natural convection absent, control of flames should be enhanced, but the smothering effectiveness of a heavy gas or blanket may be markedly reduced.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Final Technical Report Study of Zero Gravity Capabilities of Life Support System Components and Processes. Convair Division of General Dynamics Report No. GDC-DBD67-004, February 1968.

EXPERIMENT REQUIREMENTS SUMMARY

3.10.3.2

EXPERIMENT TITLE | **TEXT REF. NO. 3.10.3.2**

Solids and Fluids Combustion

EXPERIMENT CATEGORY

Crew Protection--Fire Prevention

OBJECTIVE AND SIGNIFICANCE

To determine the propagation of a flame front and the rate of propagation of the flame in a zero-g or low-g environment with various atmospheric compositions and pressures, and an extinguish technique applicable to each or all types of fires.

MEASUREMENTS AND OBSERVATIONS

Pressure
Temperature
Gas composition
Ignition time
Burning rate
Thermal radiation
Total energy
Chemical contaminants
Contaminant level
Heat transfer rate/heat balance
Volts
Amps

EXPERIMENT DURATION

4 hours for each experiment.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Pressure sensor
Temperature sensor
Baseline EC/LS (atmosphere supply)
Fire extinguishing agents
Cine camera
Timer
Optical pyrometer
Humidity sensor
Watt meter
Volt meter
Amp meter
Chemical laboratory
Fire detector
Ignition device

SPECIAL REQUIREMENTS/REMARKS

These tests could include materials to represent all classes of fires.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

Descriptive Titles of Experiments Selected by Langley Research Center. 15 November 1963.

3.11 SENSORS AND INSTRUMENTATION

Statement of the Problem

For manned spacecraft, a variety of s nsors and instruments are required to (a) measure atmospheric constituents for monitoring and control purposes; (b) detect and identify trace contaminants, including chemical and biological contaminants, in order to demonstrate the suitability of the atmosphere and proper operation of the contaminant control systems; (c) assess water potability; (d) show proper operation of the entire life support system; and (3) provide the capability for manual override.

Scientific Objectives

The objective of this task is to perform research and development in the area of sensors and instruments to assure that instrumentation will be available to adequately solve currently recognized and anticipated problems for future space missions, especially intermediate and extended duration missions. Currently, the sensing and potential control outputs of the atmospheric constituents p02 and pH_2 are being provided by both polarographic and total pressure sensors and by a recently developed mass spectrometer two-gas atmosphere sensor. This latter development includes the capability of measurement of pCO_2 and pH_2O in addition to oxygen and nitrogen (or another inert gas).

In the area of contaminant sensing, limited development of flight qualifiable sensors for early space missions is being undertaken by modification of the two-gas atmosphere sensor and the Apollo gas chromacograph. The development of microwave spectrometers, and others are essential in order to: (a) monitor ground simulator atmospheres, (b) evaluate contaminant control systems, (c) establish TLVs, (d) perform materials outgassing measurements, and (e) demonstrate candidate flight sensor techniques for intermediate and extended duration manned missions. Biological sensors for spacecraft atmospheres, and chemical and biological sensors to assure potability of water on manned spacecraft, have not yet received adequate attention. The techniques and associated sensors to accomplish potability assessment of reclaimed water will be developed and tested.

In addition, the development to flight qualified status of a variety of sensors, such as flowmeters and oxygen and carbon dioxide suite sensors, must be accomplished in order to verify the proper operation of these systems and provide control functions where necessary.

<u>Research Areas and Component Experiments</u>

The Research Areas and Component Experiments under Sensors and Instrumentation are listed. They are followed by detailed sheets on each of the Component Experiments.

3.11 Sensors and Instrumentation

3.11.1 Cabin Atmosphere Sensors

3.11.1.1 Leak Defection

3.11.1.2 Aerosol Particle Analyzer (T-003) - Component Experiment sheet to be filled out

3.11.1.3 No other experiments yet proposed - suggested areas are oxygen and nitrogen sensing, contaminant sensing etc.

3.11.2 Fire Prevention

3.11.2.1 Fire sensing

3.11.2.2 No other experiments yet proposed-suggested combustion reproduct sensing.

EXPERIMENT REQUIREMENTS SUMMARY

3.11.1.1

EXPERIMENT TITLE — TEXT REF. NO. 3.11.1.1

Leak Detection

EXPERIMENT CATEGORY

Crew-Protection--Leakage

OBJECTIVE AND SIGNIFICANCE

To qualify leak detection devices.

MEASUREMENTS AND OBSERVATIONS

Flow rate
Temperature
Pressure
Humidity
Power level
Time
Leakage

EXPERIMENT DURATION

1 hour daily for 7 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Baseline EC/LS
Pressure sensor
Temperature sensor
Humidity sensor
Watt meter
Timer
Flow meter
Leak detector

SPECIAL REQUIREMENTS/REMARKS

The experiment can be conducted with Experiments 4-1 and 4-9. Leak location and repair methods can be evaluated as part of this experiment when they become available.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Douglas 211 Mission Experiment List. April 1966.

Engineering Criteria for Spacecraft Cabin Atmosphere Selection. Douglas Report No. DAC-59169 (Contract No. NAS2-1371), November 1966.

EXPERIMENT REQUIREMENTS SUMMARY

3.11.2.1

EXPERIMENT TITLE — TEXT REF. NO. 3.11.2.1

Fire Prevention and Sensing in Zero-G or Reduced-Gravity

EXPERIMENT CATEGORY

Crew Protection--Fire Protection

OBJECTIVE AND SIGNIFICANCE

To evaluate and flight verify fire sensing, control, and extinguishing methods.

MEASUREMENTS AND OBSERVATIONS

Total energy
Temperature
Ignition time
Gas-generation rate
Gas composition
Burning rate
Humidity
Power level
Pressure
Time
Velocity/velocity profile

EXPERIMENT DURATION

4 hours for each experiment.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens
Cine camera
Temperature sensor
Pressure sensor
Fire detector
Fire-extinguishing agents
Gas chromatograph
Baseline EC/LS
Optical pyrometer
Timer
Chemical laboratory
Humidity sensor
Flow meter
Watt meter
Ignition device

SPECIAL REQUIREMENTS/REMARKS

This experiment may be performed in conjunction with or as part of Experiments 4-54 and 4-55.

PERSONNEL REQUIRED

2 crew members

REFERENCES

Report on the Development of the Manned Orbital Research Laboratory (MORL): System Utilization Potential, Analysis of Space Related Objectives. Douglas Report No. SM-48808, September 1965.

3.12 FOOD MANAGEMENT

Statement of the Problem

For future missions food must be tasty, nutritious, store for long periods and simple to prepare. Current space foods only partly meet these requirements.

Scientific Objectives

The objective of this task is to find ways to prepare and package food for space flight that retains its flavour and appeal and serves as a positive moral factor in space missions. In addition it must be light weight and small in volume and be easily prepared for consumption in flight.

Research Areas and Component Experiments

The Research Areas and Component Experiments under Food Management are listed. They are followed by detailed sheets on each of the Component Experiments.

3.12 Food Management

- 3.12.1 Food Storage and Flight Preparation
  - 3.12.1.1 Food Storage and Flight Preparation
- 3.12.2 Nutrition-no experiments yet proposed
- 3.12.3 Packaging-no experiments yet proposed

EXPERIMENT REQUIREMENTS SUMMARY

3.12.1.1

EXPERIMENT TITLE

TEXT REF. NO. 3.12.1.1

Food Storage, Preparation, and Feeding Methods

EXPERIMENT CATEGORY

Food Management--Food Supply

OBJECTIVE AND SIGNIFICANCE

To evaluate food, feeding methods, storage, preparation techniques, and waste disposal methods that have been proven in ground-based space cabin simulator tests.

MEASUREMENTS AND OBSERVATIONS

Food palatability	Humidity	Use rate
Diet	Temperature	Food and water use rate
Debris generation	Pressure	Waste-generation rate
Power level	Metabolic rate	Food storage and preparation

EXPERIMENT DURATION

30 days.

SUBJECTS, MATERIALS, AND EQUIPMENT

Test specimens (food preparation equipment)	Temperature sensor	Chemical laboratory
Baseline EC/LS	Pressure sensor	Microbial laboratory
Zero-g scale	Humidity sensor	Ergometer
Watt meter	Biomedical monitoring equipment	Metabolic measuring device

SPECIAL REQUIREMENTS/REMARKS

Food management for long-duration flight involves food storage, preparation, feeding devices, and debris disposal. Freeze dried or possibly frozen food cooked in small microwave ovens may be used. Other possibilities involve algae or synthesis of sugars for food on prolonged space missions. Human engineering and medical experiments can be conducted in conjunction with this test.

PERSONNEL REQUIRED

All on-board crew members

REFERENCES

IBM Experiment Program for Manned Earth Orbital Missions: Vol. I. IBM Report No. 65-928-63 (Contract No. NAS1-4667), August 1965.

Space Marketing Intelligence-National Multipurpose Space Station (NMSS) Experimental Listing. Published by Space Station Study Office, National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas, 17 December 1964.

FUNCTIONAL PROGRAM ELEMENT IV

SPACE STATION FUNCTIONAL PROGRAM ELEMENT: MEDICAL/BEHAVIORAL EXPERIMENTS

Medical/Behavioral experiments aboard the Space Station will be devoted to the evaluation of changes in human function and capabilities which may be induced by very long duration space flight. The Space Station will afford the opportunity to (1) explore in greater detail the functional alterations already encountered in our manned space flight experience, and (2) to accomplish the in depth monitoring required to ascertain physiological and behavioral effects which have not so far become evident.

The overall objectives of the Medical/Behavioral experiments program exist as two categories. The first is oriented toward the support and enhancement of man and his abilities in manned space flight, and consists of four major elements or sub-objectives. The second is oriented toward the advancement of medical science by availing the medical community and its researchers of the opportunity to utilize the peculiar environmental factors of space flight as feasible and relevant to the hypothesis of their research. In outline form, these objectives are:

A. To extend man's capabilities in manned space flight be determining:

1. The effects of space flight on man, and the time course of these effects.

2. The specific etiologies and mechanisms by which these effects are mediated.

3. Means of predicting the onset and severity of undesirable effects.

4. The most effective means of prevention or correction of undesirable effects.

B. To obtain scientific information of value to conventional medical research and practice.

The objectives outlined for this study will be obtained by means of individual measurements to explore each of the eight areas of body function toward which the Medical/Behavioral experiments program effort has been directed. These eight areas of study include: (1) Neurophysiology, (2) Cardiovascular Function, (3) Pulmonary Function and Energy Metabolism, (4) Nutrition and Musculoskeletal Functions, (5) Endocrinology, (6) Hematology and Immunology, (7) Microbiology, and (8) Behavioral Effects.

In pursuing these objectives, basic principles apply which relate clearly to flight program planning.

1. The key variable in the evaluation of man in space is duration of flight.

2. It is important to obtain as great a redundancy of pertinent measurements of individual crew members as is practicable in any given flight configuration to establish statistical validity.

3. A major practical aim of this effort is to utilize these observations for the preparation of appropriate preventive or remedial techniques such as lower body negative pressure, special exercises, and other conditioning methods for maintaining man in a satisfactory condition during future long-duration missions. This will include the evaluation of the long term effects of zero-G to determine the desirability or need for artificial gravity, i.e., to conduct the observations required in order to make the so-called "g decision."

The Medical/Behavioral experiments program is functionally organized in the following manner:

I. Medical/Behavioral Experiments

   A. Determination of requirements and maintaining relationships, support, and participation of the scientific community.

   B. Review of experiment proposals for scientific merit.

   C. Support of experiments in definition.

   D. Selection, conversion, and support of experiments for development phase.

   E. Support and guidance during operational data gathering, and post mission data reduction and reporting phases.

   F. Application of data to the Medical/Behavioral experiments program, manned space flight, and the civilian community as indicated.

II. R&D Support of Medical/Behavioral Experiments Program

   A. IMBLMS (Integrated Medical and Behavioral Laboratory Measurement System)

   B. Parallel development efforts to advance states of the art in measurement techniques and equipment to enhance the capabilities of IMBLMS and proposed experiments.

C. Simulations and ground based data, i.e., the support of ground based simulation and other studies in order to obtain a body of pertinent data as a normative or control base to permit the extraction of valid conclusions from flight data.

The experimental package proposed for AAP 1/2 through AAP 5 consists of individual experiments. Seven of the eight areas of investigation are presently included in this minimum package, namely, (1) nutrition and musculoskeletal function, (2) cardiovascular function, (3) hematology and immunology, (4) neurophysiology, (5) behavioral effects, (6) pulmonary function and energy metabolism, (7) microbiology. Within these seven areas, 14 individual experiments are presently approved. In addition to these fourteen MSFEB approved experiments, six more are currently in various stages of review prior to submission to the MSFEB for approval for the AAP program. Three of these are in the hematology area, and three are in microbiology. Appendix A is a list of the presently approved AAP Medical/Behavioral experiments with areas, personnel, and designators identified. Experiment implementation plans (EIP's) are available for more detailed information on each experiment.

The IMBLMS program will develop a highly flexible and sophisticated laboratory system to accommodate the Medical and Behavioral measurements required for all existing experiments as well as those anticiapted for the future. It is basically a rack and module system which can be assembled into working consoles according to the requirements of the spacecraft and the Medical/Behavioral experiments program for any particular mission. Hardware modules or submodules for specific experiments can be developed to fit the specifications of the IMBLMS and utilized on an "as needed" basis for any particular mission. The flexibility afforded by the modular approach will thus significantly reduce lead-time requirements, enhance in-flight maintenance, and enable the relatively inexpensive introduction of updated techniques and equipment. The IMBLMS will consist of five functional elements: (1) physiological, (2) behavioral, (3) biochemical, (4) microbiological, and (5) data management. Together they will accommodate required measurements of all eight areas of investigation to which the Medical/Behavioral experiments program is directed. For the Space Station, the IMBLMS will be composed of two or three consoles plus four to six pieces of peripheral equipment hard mounted to the spacecraft. Examples of the peripheral equipment are the bicycle ergometer, rotating litter chair, body mass measurement system, and lower body negative pressure device.

Phase B3 of the IMBLMS effort was begun in December 1968. Two contractors are continuing to work competitively in this 13-month phase. The first flight unit of IMBLMS can be completed in the summer of CY72. However, schedules will be altered in accordance with manned space flight requirements.

The IMBLMS will be completed and, perhaps, several of its original measurement techniques and equipments updated for inclusion aboard the Space Station. All or most of the AAP experiments, candidate AAP experiments, and Medical/Behavioral experiments currently in definition will be served, according to present planning, by the IMBLMS aboard the Space Station. During the time period between now and the flight of the Space Station, new Medical/Behavioral experiment proposals will be received, some of which will be approved for support and ultimate flight. It is believed that the planning of the IMBLMS has provided for most of these, but if additional equipment should be necessary, Space Station planning must remain flexible enough to accommodate it. Appendix B is a listing of the planned measurement capability of the IMBLMS. Appendix C gives IMBLMS specifications and operational requirements according to present best judgments. It must be noted that these are at best provisional in nature and will be subject to alteration as the developmental effort continues.

AAP MEDICAL/BEHAVIORAL EXPERIMENTS
APPROVED AS OF DECEMBER 1968

M070 - NUTRITION AND MUSCULOSKELETAL FUNCTION (Governing Protocol)

Principal Coordinating Scientist: Paul C. Rambaut, Ph.D., MSC

Assistant Coordinating Scientists: Richard Boster, D.V.M., MSC
Miss Rita Rapp, MSC
Malcolm Smith, D.V.M., MSC

Individual Experiments or Measurements:

M071 - Mineral Balance

Principal Investigator: G. Donald Whedon, M.D., NIH

Co-Investigator : Leo Lutwak, M.D., Ph.D.
Cornell University

M072 - Bone Densitometry

Principal Investigator: Pauline B. Mack, Ph.D.
Texas Women's University

M073 - Bioassay of Body Fluids

Principal Investigator: Craig L. Fischer, M.D., MSC

Co-Investigator : Carolyn Leach, Ph.D., MSC

M074 - Specimen Mass Measurement

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator : William Thornton, M.D., MSC

* * * * *

M090 - CARDIOVASCULAR FUNCTION (Governing Protocol)

Principal Coordinating Scientist: Robert L. Johnson, M.D.

Individual Experiments or Measurements:

M091 - LBNP (Pre- and post-flight)

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator : Robert L. Johnson, M.D., MSC

M092 - Inflight LBNP

Principal Investigator: R. L. Johnson, M.D., MSC

Co-Investigator : John Ord, Colonel, USAF, MC
Brooks AFB, Texas

M093 - Vectorcardiogram

Principal Investigator: Capt. N.W. Allebach, Bureau of
Medicine & Surgery, Washington,D.C.

Co-Investigator : R. F. Smith, M.D., Naval Aerospace
Medical Institute, Pensacola, Fla.

* * * * *

M110 - HEMATOLOGY AND IMMUNOLOGY (Governing Protocol)

Principal Coordinating Scientist: Craig Fischer, M.D., MSC

Individual Experiments or Measurements:

M111 - Cytogenetic Studies of Blood (Pre- and post-flight)

Principal Investigator: Michael Bender, Ph.D.,
ORNL, Tenn.

Co-Investigator : Miss P. Carolyn Gooch,
ORNL, Tenn.

M110 - HEMATOLOGY AND IMMUNOLOGY (Continued)

M113 - Blood Volume and Red Cell Life Span

Principal Investigator: Phillip C. Johnson, M.D.
Baylor University, Texas

Consultants: Wallace N. Jensen, M.D., Ohio State University
David Turner, Ph.D., Hospital for Sick Children
Scott N. Swisher, M.D., Michigan State University
Vernon Knight, M.D., Baylor University
Wolf Vishniac, Ph.D., University of Rochester

* * * * *

M130 - NEUROPHYSIOLOGY (Governing Protocol)

Principal Coordinating Scientist: Milton R. DeLucchi, Ph.D., MSC

Individual Experiments or Measurements:

M131 - Human Vestibular Function

Principal Investigator: Ashton Graybiel, M.D., Naval Aerospace Medical Inst., Pensacola, Florida

Co-Investigator : Earl F. Miller, Ph.D., Naval Aerospace Medical Institute, Pensacola, Florida

M132 - Neurological Experiment - EEG

Principal Investigators: Adey and Kelloway

Consultant: Maitland Baldwin, M.D.

* * * * *

M150 - BEHAVIORAL EFFECTS (Governing Protocol)

Principal Coordinating Scientist: Edward C. Moseley, Ph.D., MSC

Individual Experiments or Measurements:

M151 - Time and Motion Study

Principal Investigator: Joseph F. Kubis, Ph.D., Fordham, N.Y.

Co-Investigator : Edward J. McLaughlin, Ph.D., NASA Headquarters

Consultants: John T. Elrod, Ph.D.
Jesse Orlansky, Ph.D

M170 - PULMONARY FUNCTION AND ENERGY METABOLISM (Governing Protocol)

Principal Coordinating Scientist: Edward L. Beckman, M.D.

Individaul Experiments or Measurements:

M171 - Metabolic Activity

Principal Investigator: Mr. Edward Michel, MSC

Co-Investigator : J. A. Rummel, Ph.D., MSC

M172 - Body Mass Measurement

Principal Investigator: John Ord, Colonel, USAF, MC
Brooks AFB, Texas

Co-Investigator : William Thornton, M.D., MSC

Consultants: Ulrich Luft, M.D., Lovelace Foundation
Wayland Hull, Ph.D., MSC
George C. Armstrong, Jr., M.D., MSC

* * * * *

ADDITIONAL AREA OF INVESTIGATION:

M190 - MICROBIOLOGY (Governing Protocol)

Principal Coordinating Scientist: James McQueen, D.V.M.

Assistant Coordinating Scientist: James K. Ferguson, Ph.D.

M219

MEDICAL/BEHAVIORAL MEASUREMENT CAPABILITY

of

INTEGRATED MEDICAL AND BEHAVIORAL LABORATORY MEASUREMENT SYSTEM

INCLUDE

I. NEUROLOGICAL

Clinical Evaluation (to include reflexes and sensory and motor pathways)

Agravic Perception of Personal and Extra-Personal Space (Minimum restraint device)

Ocular Counter-Rolling
Oculogyral Illusion
Visual Task with Head Rotation
Electronystagmogram
Angular Acceleration Threshold
} To be done with litter-chair

EEG

II. CARDIOVASCULAR

Clinical Evaluation

ECG (Frank Lead System)

Phonocardiogram

Cardiac Output - (By impedance if technique verified; by indicator-dilution if necessary)

Arterial Blood Pressure

Venous Pressure - Peripheral

Blood Volume and Fluid Compartments - See Hematology and Metabolism

Regional Blood Flow - Limb (or Digit) (Distribution of Blood Volume)
Venous Compliance
Arteriolar Reactivity
} (Limb Plethysmography)

INCLUDE

Arterial Pulse Contour

In-Flight Exercise

LBNP

Elastic Leotards

PROVIDE FOR INSTALLATION IF REQUIRED:

Ballistocardiogram

Carotid Body Stimulation

Thoracic Blood Flow

Venous Pressure - Central
(By Catheter if Necessary)

III. RESPIRATORY

Clinical Evaluation

Respiratory Rate

Lung Volumes Including Residual Volume
(For total lung capacity, and mixing efficiency)

Pressure, Flow, and Volume (Simultaneously)
(Airway Resistance)

Compliance - Lung or Total
(Lung if can)

INCLUDE

Distribution of Blood Flow and Gas in Lungs

Includes: Capillary Blood O_2, CO_2, and pH

Breath by Breath O_2 Consumption and CO_2 Production

O_2 Consumption - With Measured Exercise

Alveolar to Arterial Gradient Breathing Air and 100% Oxygen

Diffusion Capacity (if suitable technique) (Look into $O_2{}^{18}$ method - Dr. Richard W. Hyde, U. of Pennsylvania, Dept. of Physiology)

IV. METABOLISM AND NUTRITION

Clinical Evaluation

Energy Metabolism (Continuous O_2 and CO_2 Analysis with Breath by Breath Sensitivity) with various Levels of Activity

Oral Temperature

Skin Temperature

Caloric Intake

Body Mass In-Flight (Thornton Technique - GFE)

(Lean Body Mass Pre- and Post-Flight (Not a Part of IMBLMS)

Muscle Size and Strength

Balance Studies
- Fluid, including Sweat
- Nitrogen (See Area IX)
- Mineral (See Area IX)
- Electrolyte (See Area IX)

INCLUDE

Provide for : Accurate Urine Volume Measurement

Accurate Wet Weight of Feces

Return of Total Dry Stool

Accurate Fluid Intake Measurement

Return of all Food Packages Marked by Date Time and Individual

Sweat Measurement and Sample Return

Total Body Water (Breatholator or Deuterium)

Clinical Laboratory Evaluations - See List Under Area IX

PROVIDE FOR INSTALLATION IF REQUIRED:

EMG

Bone Densitometry - Isotope Technique

Gastric Pressure and pH (Endoradiosonde)

Plasma Volume On-Board

Mineral Metabolism by Isotopic Techniques

V. ENDOCRINOLOGY

Clinical Evaluation

Clinical Laboratory Evaluations - See List

INCLUDE

VI. HEMATOLOGY

Clinical Evaluation

Rumple - Leede

Blood Volume and Fluid Compartment
Plasma Volume
RBC Mass - DFP^{32} or Cr^{51}
Total Body Water

RBC Survival - DFP^{32}

Clinical Laboratory Evaluations - See List

VII. MICROBIOLOGY AND IMMUNOLOGY

Clinical Evaluation

Body Microflora (Bacterial, Viral, and Fungal)

Environmental Culturing (Bacterial, Viral, and Fungal)

Clinical Laboratory Evaluations - See List

VIII. BEHAVIORAL EFFECTS

Clinical Evaluation

Sensory Test Battery (See Also Neurology)

Perceptual Evaluation (If validity of Tests Established)

Higher Thought Processes

Memory - Short and Long Term

Vigilance (By measurement of operational tasks)

INCLUDE

Learned Activity (Tracking and Reaction Time)

Recording of Crew Intercommunication with Automatic Erase in 15 Minutes if not Sampled

Time and Motion Study

IX. CLINICAL LABORATORY EVALUATIONS	Reference Area
Creatine and Creatinine - Urinary	IV
Urinary and Fecal: N, Ca, P, Na, K, Cl, and Mg	IV
Mucoproteins - Urinary (Pi)**	IV
Pyrophosphates - Urinary (Pi)**	IV
Hydroxyprolines - Urinary (probably Pi)**	IV
Total Amino Acids - Urinary (Pi)**	IV
Urinary: Osmolality, Color, Sp Gr. pH, Glucose, Protein, Bile, Blood, and Microscopic (i.e., Routine Urinalysis - Inflight)	IV
Plasma Volume (probably P&P)*	IV & VI
Electrolytes - Serum	IV
Total Protein - Plasma	IV
Protein Electrophoresis - Plasma	IV
Glucose - Blood (Inflight)	IV
Ca and PO_4 - Serum (probably Pi)	IV
Bilirubin - Serum	

*P&P - pre & post-flight
**Pi - Post-flight evaluation of inflight samples

INCLUDE	Reference Area
Cholesterol - Serum (probably Pi)	IV
BUN (probably Pi)	IV
Uric Acid - Blood (Pi)	IV
Alkaline Phosphatase - Serum (probably Pi)	IV
pH, pO_2, and pCO_2 - Blood	III & IV
Bicarbonate - Blood	III & IV
CPK (Creatine Phosphokinase - Serum) (Pi)	IV
LDH and LDH Isoenzymes - Serum (On-board if have electrophoresis)	IV
SGOT - Serum	IV
SGPT - Serum	IV
Aldosterone - Urine (Pi)	IV & V
ADH - Urinary and Serum (Pi)	V
ACTH - Blood (Pi)	V
Serum Free Thyroxin (T_4 - Serum) (If in-flight, will require thin layer chromatography)	V
TBPA (Probably Pi)	V
17-hydroxycorticonteroids - Urine and blood (Pi)	V
17-Ketosteroids - Urine (Pi)	V
VMA - Urine (probably Pi)	V
Metanephrines - Urine (Pi)	II & V
Catechols - Urine (Pi)	II & V
Histamine - Blood and Urine (Pi)	II & V

INCLUDE	Reference Area
5 Hydroxy indolacetic acid - Urinary (Probably Pi)	V
Blood Cell Morphology (RBC, WBC, and Diff - Smear will suffice for platelets	VI
Reticulocyte Count	VI
Hematocrit	VI
Hemoglobin	VI
RBC Fragility (Osmotic)	VI
RBC Mass and Survival	VI
Bleeding Time	VI
Clotting Time	VI
Prothrombin Consumption	VI
Clot Retraction	VI
Lymphocyte Karotyping (probably Pi)	VI
WBC Mobilization (Rebuck Technique)	VI
Immunoglobulins and Fibrinogen . Transferins Hemoglobin Methenoglobin	VI & VII onboard if have electrophoresis
RBC Enzyme Studies (Pi) (ref. Governing Protocol M110)	VI
Complement Titration	V.I
Antibody Titration	VII

PROVIDE FOR INCLUSION IF REQUIRED:

Sulfate - Urinary	IV
TSH (Pi)	V
Growth Hormone (Pi)	V
Thyroid Bound Globulin (T_3) (Pi)	V

INCLUDE	REFERENCE AREA
PROVIDE FOR INCLUSION IF REQUIRED (Cont'd)	
Parathyroid Hormone (Radio-immune Technique - Serum) (Pi)	V
Parathyroid Hormone - Urinary (Nelson Technique - (Pi)	V
Calcitonin - Serum (Pi)	V
Insulin Assay (Pi)	V
Glucagon Assay (Pi)	V
Serotonin (5 HIAA) - Blood (Pi)	V
Platelet Adhesiveness	VI
Fibrinolytic Activity	VI
Blood Rhoology	VI
Blood Lipids	VI

IMBLMS DATA SHEET

1. GENERAL DESCRIPTION:

The purposes, objectives, capabilities, and status of the IMBLMS are described in the text and in Appendix B. In its final form, as presently envisioned, the IMBLMS will consist of two or three consoles plus peripheral equipment. The peripheral equipment will be made up of such items as the lower body negative pressure device, body mass and small mass measurement devices, exercise ergometer, and vestibular litter chair.

2. SPECIFICATIONS AS PRESENTLY FORESEEN (All numbers are approximate):

Weight - Ascent - 1200 - 1300 lbs.

- Return - 150 - 200 lbs. (per resupply)

Volume - Ascent - 275 - 350 ft^3 (including peripheral equipment)

- Return - 10 ft^3 (per resupply)

Power - Average - ~500W

- Peak - ~1000 W

- Standby - ~50W

- Total - Dependent upon mission

Data - Analog - TV 1500 lines/frame

- Digital - Max rate - 75 to 100 KBS

- Film - For use with AAP developed camera

- Tape - For both analog (including video) and digital data

Thermal (BTU/hr) - Standby - ~100 BTU/hr.

- Operate - ~1000 BTU/hr.

Mode of Operation - Cabin Temperature control of 75° ± 5°F required Nominal zero g, i.e., 1 x 10^{-4} g, required, no attitude requirements.

Role of Man - IMBLMS is the system of laboratory equipment operated by man to evaluate man. Therefore, man is an absolute requirement.

- Crew Time Requirements -

  (a) For performance of approximately 12-15 hrs. man/week estimated requirement.

  (b) Maintenance time: Unknown at present.

- Crew skills -

  Specially trained M.D. mandatory.

  Additional specially trained physiologist desirable.

  IMBLMS maintenance technician essential. This can be a crew member trained in electronic maintenance for other space station equipment as well. He should be thoroughly familiar with the systems aspects of IMBLMS.

Additional Requirements -

- Any orbit minimizing exogenous environmental hazards to the flight crew (e.g., radiation).
- Maximum orbital life time permissible.
- Additional interface requirement details will be provided as the IMBLMS development advances.

Available Background Data -

- EIP's for AAP Medical/Behvaioral experiments
- IMBLMS RFP for Phase B-1.

IMBLMS - INTERFACE REQUIREMENTS AND PERIPHERAL EQUIPMENT

1. The Integrated Medical and Behavioral Laboratory Measurement Systems (IMBLMS) is a highly flexible and sophisticated laboratory system to accommodate the medical and behavioral measurements required for existing experiments as well as those anticipated for the future. Its two basic aims are (a) the accommodation of medical and behavioral investigations in accordance with the full objectives of the program and, (b) provision of maximum flexibility. It is basically a rack and module system which can be assembled into working consoles according to the requirements of the spacecraft and the medical/behavioral experiments program for any particular mission. Hardware modules and submodules for specific experiments can be developed to fit specifications of the IMBLMS and utilized on an "as needed" basis for any particular mission. the flexibility afforded by the modular approach will thus significantly reduce leadtime requirements, enhance inflight maintenance, and enable the relatively inexpensive introduction of updated techniques and equipment. For the Space Station, the IMBLMS will be composed of two or three consoles plus five or six pieces of peripheral equipment hard mounted to the spacecraft. Presently identified peripheral equipment includes the bicycle ergometer, rotating litter chair, lower body negative pressure device, body mass measurement device and the specimen mass measurement device. Descriptions of the peripheral equipment follow.

Body Mass Measurement Device (BMMD)

Weight - 38 lbs Launch (25# BMMD 13# Stowage Box)

Size - 14 cu ft Launch - 28 cu ft Operational
0 Return

Power - 2 watts, 28 VDC

Spacecraft Interface

Mounting brackets are required in the Space Station for operation. These should be braced for maximum regidity. Location and orientation of the BMMD should be in the area of the support console and in the viewing cone of the experimenter.

Environmental Constraints

Thermal (Stored and Operational)		-51 to +70°C
Atmospheric Pressure		25 psia to 1 X 10 mm Hg
Relative Humidity		15 - 100%
Acceleration	Storage	0 - 7g
	Operation	0 - 1g
Vibration (Storage)		20 to 100 cps - linear increase (log by log plot from $0.001g^2$/cps to $0.075g^2$/cps
		100 to 500 cps- constant at $0.075g^2$/cps
		500 to 1000 cps -linear decrease (log by log plot) from $0.075g^2$/cps to $0.015g^2$/cps
		1000 to 2000 cps -constant at $0.015g^2$/cps
Shock		30g

Bicycle Ergometer

Weight - 150# Launch
0 Return

Size - 12 ft^3 Launch
0 Return

Power - 48 watts

Spacecraft Interface

The bicycle ergometer will interface structually with the Space Station. The mounting rails of the Space Station must be strong enough to withstand any torque applied by the astronaut during exercise.

Environmental Constraints - None

Subsystem Support

All power and recording requirements will be obtained from IMBLMS.

General Operational Requirements

There are no spacecraft orientation requirements other than those rqquired to maintain a stable thermal environment.

Specimen Mass Measurement Device (SMMD)

Weight - 14 lbs Launch (3# Stowage Box + 11# SMMD)
0 lbs Return

Size - 0.3 ft^3 Launch
0 ft^3 Return

Power - 2 watts, 28 VDC

Spacecraft Interface

Undetermined at present. May interface with Space Station for storage. May interface with IMBLMS during operation.

Rotating Litter Chair (RLC)

Weight - 265 # Launch (container plus equipment)
10 oz Return (otolith test goggles - OTG)

Size - 11.2 ft^3 Launch 38 ft^3 operational
84 in^3 Return (goggles)

Power - 180 watts average, 400 watts peak

Spacecraft Interface

Provision must be made for structurally mounting the rotating litter chair base to the space station. Adequate support in the form of cross members is essential to provide a stable platform for the RLC. A minimal lighting intensity of 20 ft candles is required.

Subsystem Support

None from the Space Station.

Environmental Constraints - None other

Lower Body Negative Pressure Device (LBNP)

Weight - 33# Launch
0 Return

Size - 5 ft^3 Launch 10.6 ft^3 operational
Return

Power - 28 VDC

Spacecraft Interface

Operational mounting location and provisions must be provided which allow subject free access to open end of the LBNP and enough clearance for comfortable space operation. Location of the LBNP device should be in the area of the supporting console and in the viewing cone of the experimenter.

Environmental Constraints - None

General Operational Requirements

Flight Operational Requirements - None

CONTENTS

MATERIALS PROCESSING AND MANUFACTURING IN SPACE

INTRODUCTION

A multi-step program embracing an interdisciplinary effort in materials science, industrial application, and manufacturing technology, culiminating in the manufacture of valuable products in earth orbit is outlined herein. It is proposed that three facilities be developed over the duration of the program. Utilizing these facilities, materials processing and manufacturing studies would be performed and products manufactured. Each facility would contain a group of experiments and constitute a step in this program. The design of the orbital process facilities and the selection of processes and technologies to be investigated will be supported and refined by an on-going Ground Based Program.

The Ground Based Program Element will consist of: (a) a number of studies to establish and define the physical parameters of manufacturing processes which are affected by zero-gravity (b) a survey of industrial and research organizations to evaluate the areas of investigation which promise the greatest scientific, economic and utilization return (c) a comprehensive ground based test program, utilizing drop towers, ballistic airplane flights and other zero-gravity simulation techniques to define and design the materials, processes, and equipment needed to carry out the Initial Orbital Program.

The Initial Orbital Program Element will utilize the process module which has been designed for the metals melting and brazing experiments approved for the AAP-2 flight. Studies on spherical casting, composite casting, and single crystal growth have been added to complete the experiment group. "Suitcase" experiments will be developed to be carried on the workshop revisit. These experiments will utilize the FPE II Process Facility.

The Second Orbital Program Element will be an extension of earlier studies and will incorporate experiments identified from the Ground Based Program and the Initial Flight Program. The process module for this program will be larger and more sophisticated than the initial flight facility, however, it could still be accommodated within the present Multiple Docking Adapter or Orbital Workshop.

An advanced orbital program element will be a significant extension of previous efforts. The process facility for this element will be part of an experiment module that will also have the capability of performing basic materials research and space physics experiments. This experiment module will dock with the orbiting space station. It will contain process equipment for carrying out materials and process investigations. A primary function of processing in this advanced space station module will be the production of useful products.

Examples of the products and experiment tasks have been identified to the degree presently possible in the data sheets of this proposed plan. These selections are subject to change and a firm selection of products and tasks is dependent on the information derived from the Ground Based Program and data from the preceding program elements.

OBJECTIVE

The objective of this program is to establish the technology and evaluate the manufacture, in space, of products which can be made better in a near zero-gravity environment or cannot be made on earth, meet a real and significant need of science and/or industry, and have a value exceeding the cost of processing and transportation.

EXPERIMENT PROGRAM

Since 1958, NASA has conducted programs to probe and understand space, to develop a safe place for man in this new environment and to use this knowledge to advance science and technology for the benefit of mankind. Manned Space Flight has focused on the mission of placing man on the moon and returning him to earth. One question posed is how to use the advantages of the space environment, the presence of man in space, and the capabilities of experienced people to conduct a meaningful program. During the past few years, NASA has conducted a series of studies to determine those programs which offer the most return within the resources available. Based on the results of these studies, a manned earth orbital program is highly attractive for the contributions which manned orbital laboratories or observatories could make to our knowledge of the earth, the solar system and the universe. In addition, many possibilities exist to utilize the unique conditions of the space environment to investigate the processes which may be used to produce materials of high scientific and economic value. The melting of materials free of the contamination of the crucible, the growing of large single crystals with reduced dislocations, and the uniform blending, alloying and conversion of compacted powders into castings appear probable in a reduced gravity environment. The program outlined herein is composed of four major program elements. Each succeeding element will extend the capability for conducting processes and manufacturing products in space and will contain tasks leading to the operational capability for producing useful, unique products.

PROGRAM

FPE I GROUND BASED PROGRAM ELEMENT

A study to determine the critical physical effects of weightlessness on materials and manufacturing processes will be conducted. Criteria will be developed from this study for use in evaluating the feasibility of performing candidate experiments in earth orbit. Conducted concurrently with the development of processes and equipment used in the initial orbital program, the study and survey are of major consequence in the planning of the tasks and facility design for subsequent efforts. It is the intent of this effort to identify new items which can be manufactured in space; to perform theoretical analyses and predictions of the behavior of materials in space; to delineate the degree to which the manufacture of an item is affected by the space environment; and to analyze each item with respect to application and scientific value.

A subsequent study will determine the economic value of items manufactured in space for earth use.

Since the most important aspect of the space environment related to materials processing or manufacturing appears to be zero-gravity, an expansion of the capability for zero-gravity testing at MSFC is envisioned. Drop tower facilities will be employed where the short periods of zero-gravity obtainable (up to 4 seconds) can be utilized. Preliminary studies in such areas as bubble formation, electromagnetic field positioning of suspended objects, etc., can be performed. It is also anticipated that extensive testing will be performed aboard aircraft flying zero-gravity parabolic trajectories. KC 135 aircraft already employed by MSFC in the performance of human factors analysis can be used in support of this program providing usable zero-gravity test times approaching 30 seconds.

FPE II INITIAL ORBITAL PROGRAM ELEMENT

As an initial step toward achieving the capability of manufacturing useful products in space, an evaluation of several promising processes will be made. This early evaluation can be accomplished in the Orbital Workshop of the Apollo Applications Program by utilizing a flight experiment apparatus already developed.

Experiment M512, initiated in 1966, was originally oriented toward the joining of metals in space, i.e., electron beam welding and exothermal tube joining. The original objectives of the experiment were to observe the effect of reduced gravity on a molten puddle, to measure the amount of spatter, to determine the effect of weightlessness on the weld or brazed metal microstructure, and weld strength.

With the recent emphasis on exploratory evaluation of material processes which eventually may allow the manufacture of useful products in space, the facilities developed for the above experiment have a broader utility. This equipment will be utilized as a materials melting facility, using the electron beam system and the exotherm material as heat sources.

Various candidate material processing techniques in space have been proposed for evaluation in the orbital workshop and of these, several were found to be within the capability of the facility. (See Figure 1). Three additional experimental tasks have been approved for the M-512 experiment on AAP-2- Crystal Growth, Composite Material Forming, and Sphere Forming. The tasks are listed in Figure 2 and described in the Appendix. The FPE II Process Facility will be used for further experimentation related to Experiment M-512 or for additional experiments developed by NASA or industry during the interim between the Initial Orbital Program (AAP-2) and the Second Orbital Program.

FPE III SECOND ORBITAL PROGRAM ELEMENT

The Second Orbital Program Element consists of an improved, enlarged facility and of those tasks resulting from and amplified by the knowledge gained during the initial orbital program. The facility chamber, Figure 3, will be approximately 30" in diameter by 48" in length. It will contain a selection of heat sources, provisions for controlled cooling, instrumentation, and capabilities for material positioning and handling. Final chamber design will be determined based upon the evaluation of initial program results and after detailed studies have been completed. The various considerations affecting chamber design are schematically outlined in Figure 4. Two primary factors to be considered are selection of heat sources and methods of manipulating materials within the chamber. Thirteen candidate heat sources are presently under investigation. The most promising of these appear to be induction, electrical resistance, and electron beam. Six techniques for handling of materials within the chamber are also under study. The most promising appears to be pulsed magnetic fields. Other factors of consideration in chamber design include: (a) the thermodynamics of heat transfer, (b) total power requirements for operation of the chamber and experimental apparatus which is dependent on chamber power, (c) vacuum venting and control systems, (d) gas pressurization and control systems, (e) instrumentation for monitoring chamber operation and collecting experiment data, and (f) packaging constraints imposed by fixed vehicle interfaces.

Studies of facility configuration and function have been initiated. These studies will be supplemented or changed as more definitive requirements become known from industrial surveys and initial program experiments. The tasks to be conducted in the chamber will be extensions of studies performed under the initial program and those identified in the ground based studies (FPE I).

FPE IV '75 SPACE STATION PROGRAM ELEMENT

This effort will develop the space processing and manufacturing portion of an experiment module which will be designed to remotely dock to an earth orbiting space station planned for launch in the mid-to-late 1970's. Experiments in basic materials research and physics may also be performed in this experiments module. This module will contain working room for at least two astronauts, facilities, raw materials, and manufacturing and material processing chambers. The module configuraiton will be designed to contain a large airlock which will permit transfer of personnel, materials, process equipment, etc., between the space environment and the work area of the

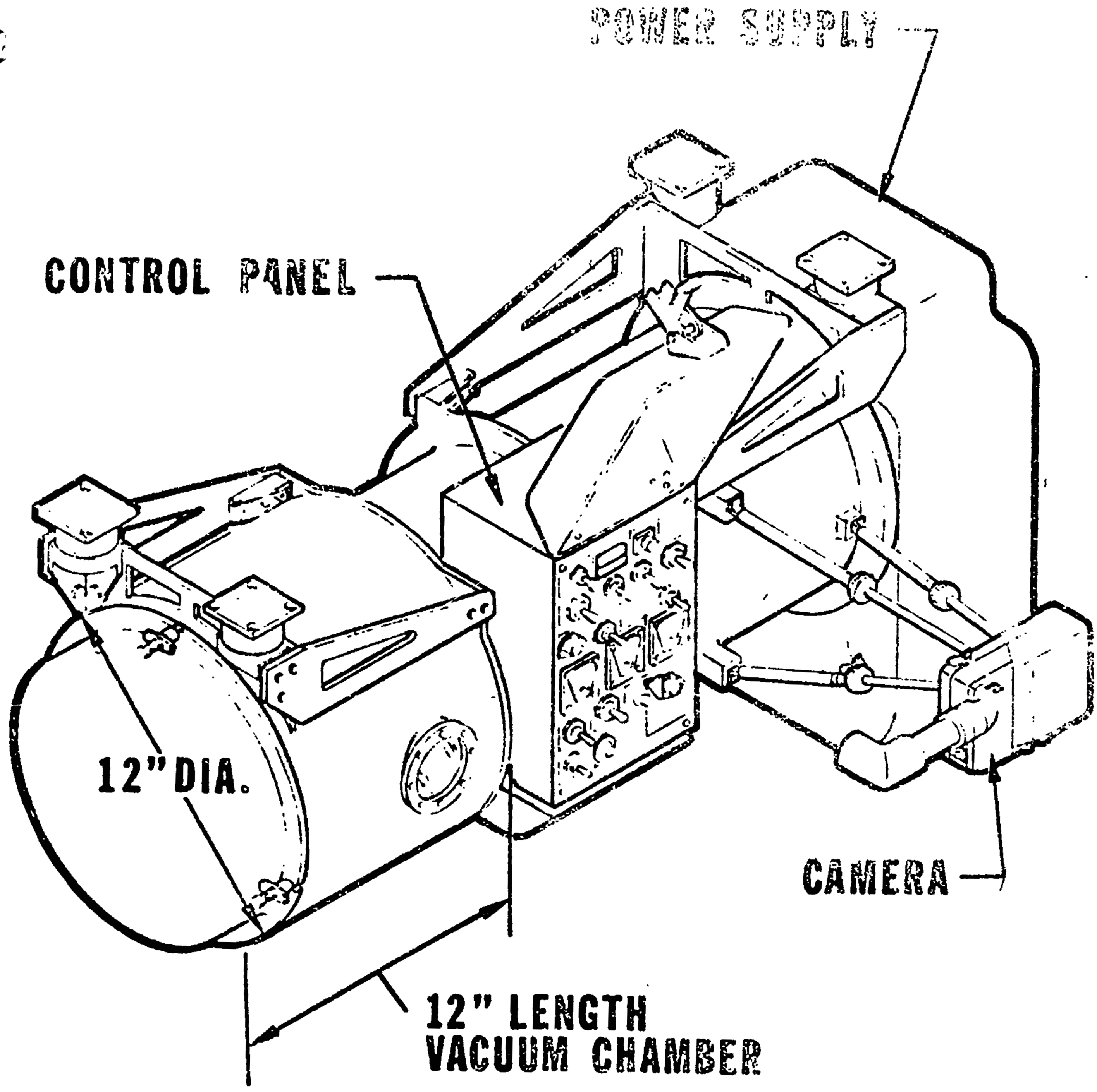


FIGURE 1. FPE II PROCESS FACILITY

SPACE MANUFACTURING
INITIAL ORBITAL PROGRAM
SUPPORTING STUDIES IDENTIFICATION CHART

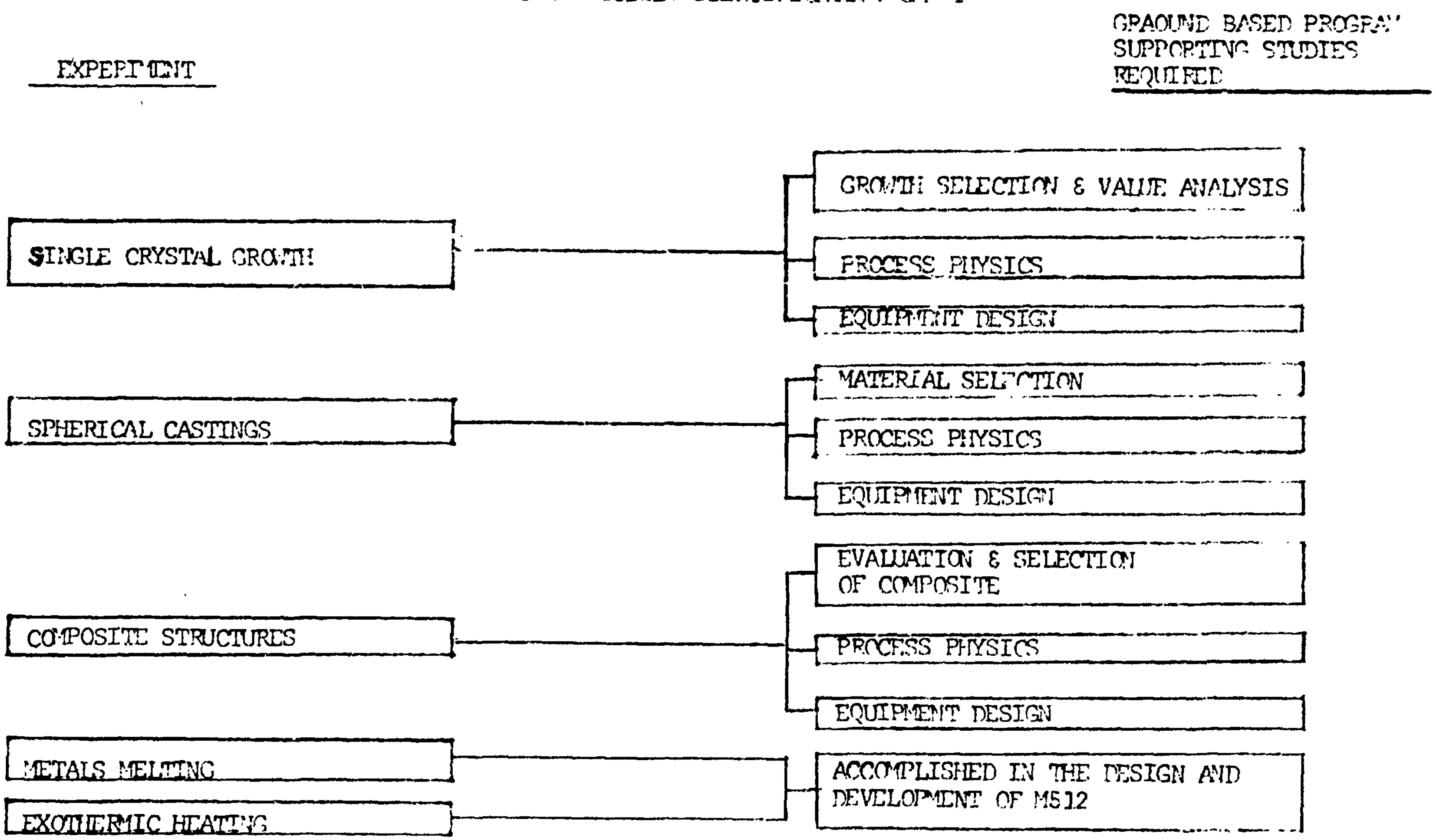
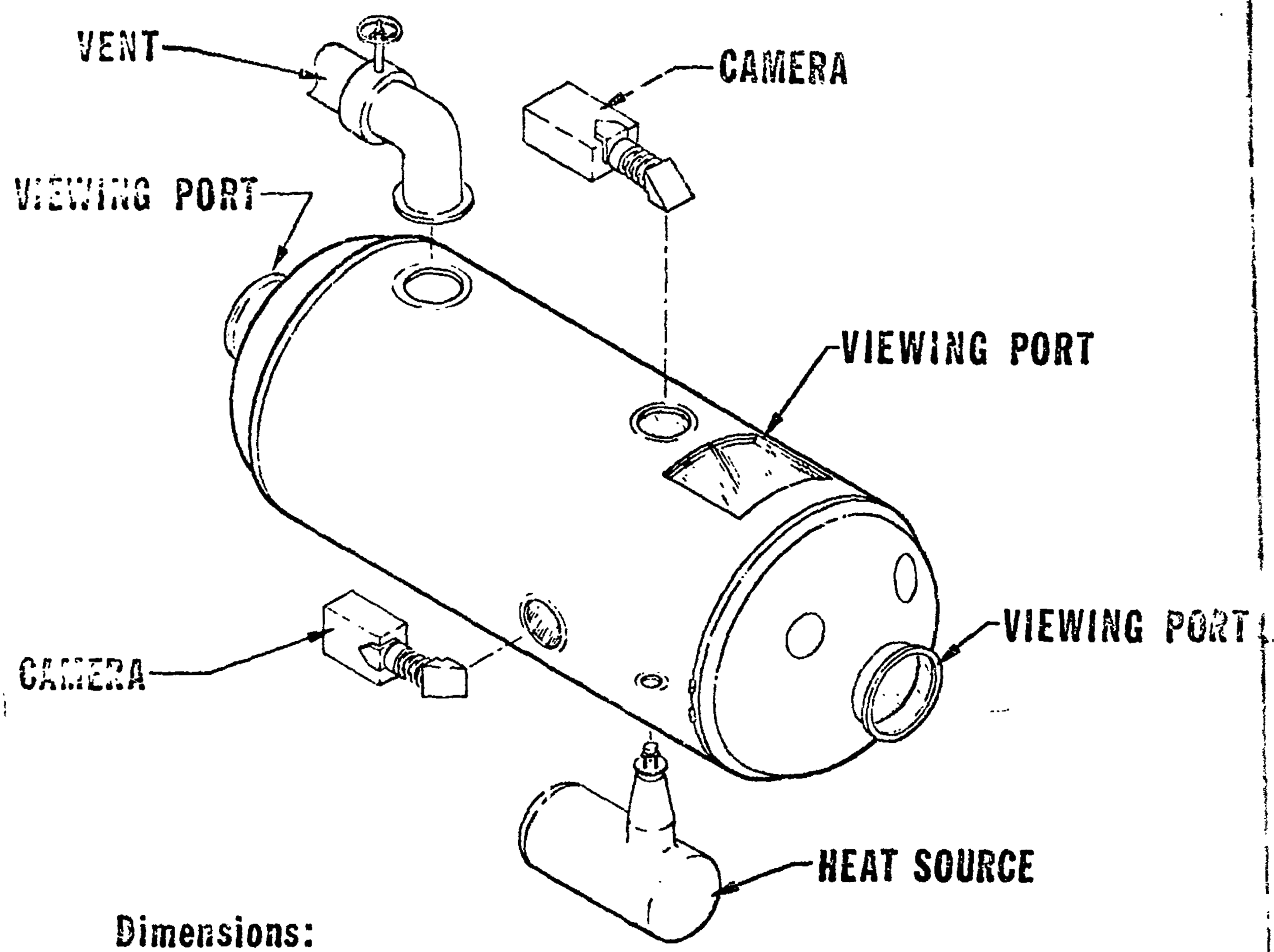


FIGURE 2.

9

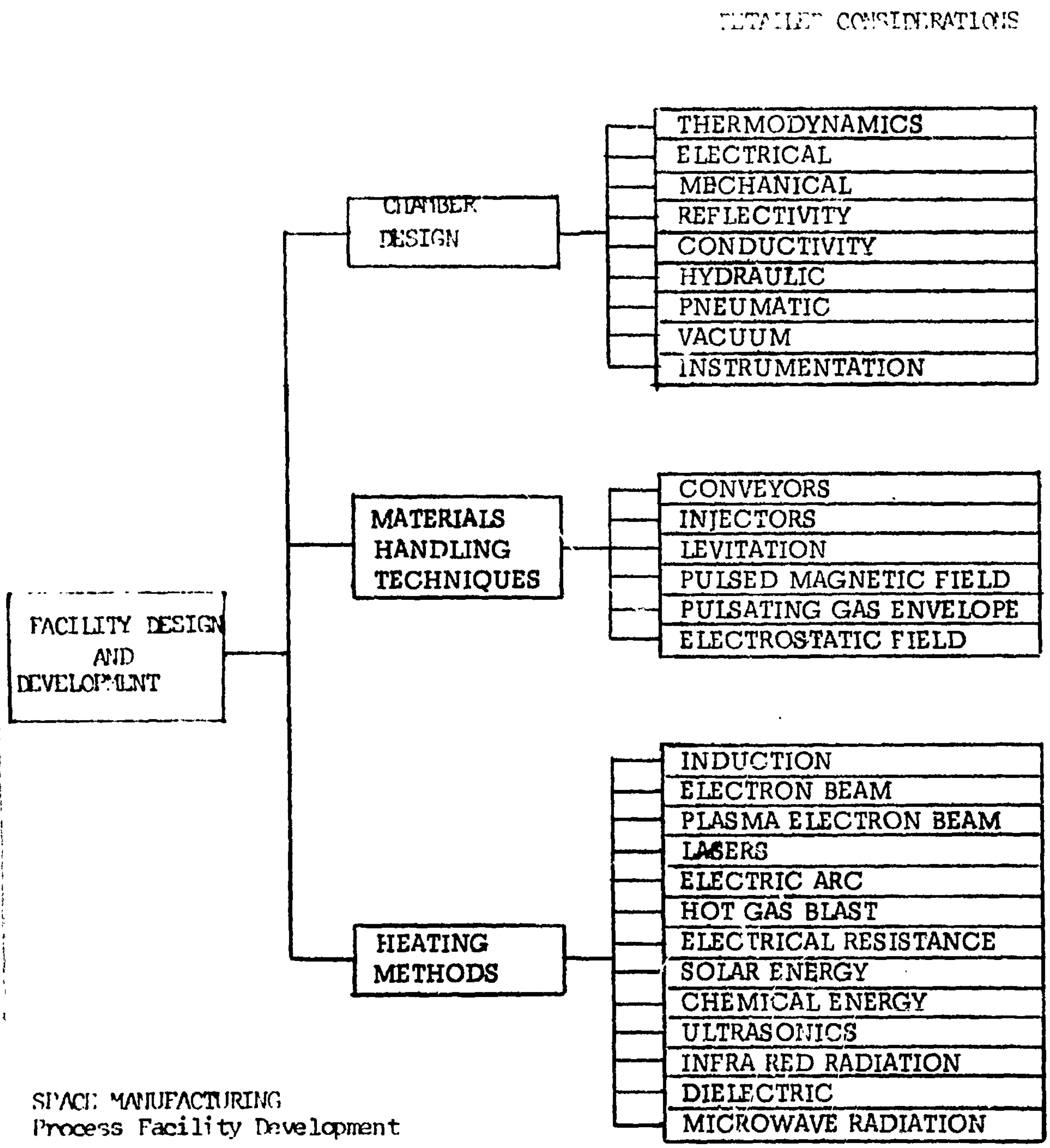
MP6



Dimensions:
diameter – 30 inches
length – 48 inches

FIGURE 3 TPE III PROCESS FACILITY

FACILITY CONSIDERATIONS



SPACE MANUFACTURING
Process Facility Development

FIGURE 4

module. An initial weight estimate of the structure and associated equipment described will be approximately 25,000 pounds. Typical envelope dimensions are 22' (diameter) and 35' (total length). Periods of minimum acceleration can be obtained by free flying the module apart from the primary space station. After module separation and experiment completion, the module will reuse the remote control rendezvous and docking system which was initially required to dock it to the unmanned orbiting space station. This module will provide for a continuing effort on manufacturing process investigations and production of small quantities of specialized items that can best be produced in the unique environment of near zero-gravity. Products produced within the space environment will be returned to earth for use in specialized industrial, medical, or government applications. The experiment module, in addition to the processing equipment, will contain test apparatus, monitoring equipment, closed circuit television (module to earth) so that timely and intelligent adjustment in processes or experiments can be made by the researchers while remaining in earth orbi..

Efficient long term operation of the experiment module and re- d systems dictates the development of a rapid on-site maintenance and pair capability. The experiment module will incorporate a variety of sophisticated test and process equipment which will be expected to function properly under repeated use over the life span of the station. Much of this equipment will be housed in the shirt-sleeve environment of the module, thus facilitating ease of in-space maintenance and repair. This effort will lead to the establishment of a space manufacturing and material processing complex for quantity production of selected components. It is anticipated that industrial participation will increase with each succeeding phase, and it is hoped that industry will assume a major responsibility and role in the programs to follow in the 1980's.

FUNCTIONAL PROGRAM ELEMENT I

GROUND BASED PROGRAM

1. Discipline: Space Manufacturing

2. Program Element: Ground Based Program

3. Requirement:

The low gravity environment of an Earth Orbital Workshop or Space Station provides the opportunity to produce unique products which cannot be produced on earth because of gravity forces. Products have been tentatively identified by NASA and industry which are of value and will satisfy current or future needs. The processes postulated to produce these products require the absence of natural convection and buoyancy forces to form unique materials by mixing and blending materials of different densities, and use surface tension forces to shape liquid materials in a free state. In general, they involve melting, processing in the liquid state, and solidification. Analytical and experimental studies are required to determine the underlying physical principles and the effects of manufacturing in a low gravity environment.

4. Justification:

The results of these studies will be used to support the presently approved flight experiments, to evaluate the feasibility of proposed space manufacturing processes, and to define and develop new flight experiments leading to the manufacture of prototype products in a space station.

5. Component Tasks:

a. Theoretical studies of physical parameters which affect manufacturing processes in a low gravity environment.

b. Industrial survey identifying areas of greatest return.

c. Identification of chemical processes as enhanced by zero-gravity.

d. Effect of zero-gravity on crystal whisker growth.

e. Study of space environmental affects on diffusion in metals.

f. Affects of zero-gravity on solidification.

g. Determination of the degassing methods for a free liquid in zero-gravity

h. Materials processing study concentrating on:

(1) Electronic single crystals grown from a high temperature glass melt.

(2) Levitation melting and zone refining.

(3) High speed centrifuge separation.

i. Analytical and Preliminary Design Studies of processing chamber configuration and controls.

j. Analytical and Preliminary Design Studies of handling and positioning devices.

k. Space Processing Project Study by Carnegie-Mellon University.

6. Description:

This program element will be conducted (in conjunction with FPE II). The results and findings of this program will determine, identify and define the FPE's which follow. Most of the program will be conducted in conjunction with and based upon on-going scientific research.

7. Special Provisions:

The results of this FPE are important in the design, conduct and evaluation of FPE II. These results are required to establish the parameters of FPE III and IV.

TYPE I TASK DATA SHEET

A. THEORETICAL STUDIES OF PHYSICAL PARAMETERS

1. Specific Objective:

Initiate studies to determine the physical parameters of thermal control, fluid dynamics, configuration control by surface tension-viscosity interactions, size-time relationships for suspension of solids or gases in free liquid masses, etc. which affect manufacturing operations in a low gravity environment. These data will be used to (1) establish the theoretical feasibilities and limitations of selected space manufacturing processes, (2) determine new processes, (3) define preliminary experiments, and (4) analytical studies necessary to define flight experiments.

2. General Discription:

A study will be conducted to accomplish the objectives listed above. Based upon the findings of the study, a survey of the materials processing and manufacturing field will be made to determine those aspects which evoke the greatest interest and support and which promise the greatest value in scientific and economic return.

3. Development Schedule:

FY 69 funds will be used to initiate these supporting research studies. FY 70 effort will be used to continue the studies selecting the most promising concepts, to initiate detailed theoretical and experimental studies establishing feasibility, and to prepare manned flight experiment proposals. Future effort will involve definition of flight experiments and techniques for conducting manufacturing operations in space.

4. COST:

FY 69 $95,000
FY 70 $100,000

B. INDUSTRIAL SURVEY TO IDENTIFY AREAS OF GREATEST RETURN

1. Specific Objectives:

The purpose of this task is to assess the potential for using the space environment to prepare unique materials which cannot be prepared on earth. Attention is primarily directed to processes which are clearly affected by gravity and to materials which would have a high value/weight ratio in the earth-bound industrial market to justify the cost of space transportation. The material of interest must have both economic and technical justification, in addition to scientific value.

2. General Description:

A listing will be made of materials and processes meeting the specific objectives mentioned in the preceding paragraph. Attention will be directed toward determining the industrial needs, economic benefit, and technical feasibility of these materials and processes. Based on present knowledge, a prime area of interest will be the growth of electronic single crystals. Flight experiments will be defined which verify the findings of the study. The goal will be to return from space samples of unique materials which are economically and technically valuable to society.

3. Development Schedule:

The task will be initiated during FY 70. Efforts in FY 70 will culminate in the definition of specific orbital experiments which will demonstrate the feasibility of the zero-gravity processes.

4. COST:

FY 70 $100,000

C. IDENTIFICATION OF CHEMICAL PROCESSES

1. Specific Objectives:

This task involves the identification of potential chemical processes. The refining processes involve two immiscible liquids, which, in zero-gravity, become miscible: thereby creating a process for obtaining a highly refined end product. This process will be particularily suited to obtaining high purity drugs for medical application.

2. General Description:

Certain manufacturing processes for chemicals which can be enhanced by zero-gravity may be practical for processing in future space stations. The chemistry of certain materials is such that the refinement process is accomplished by intermingling two immiscible liquids and thereby precipitating out the contaminants in the form of flocculents and crystalline solids, both being capable of removal by a simple filtering process. The intermingling process has been accomplished on earth for certain materials, however, the earth's gravitational effects limit its use. Zero-gravity should provide ideal conditions for obtaining many high purity compounds.

3. Development Schedule:

FY 70 Identify potential processes.
FY 71 Conduct investigation of the processes and materials selected and identify items for verification in space.

FY 72 Establish processes and requirements for flight experimentation.

4. COST:

FY 70	$ 14,000
FY 71	$ 70,000
FY 72	$ 100,000

D. EFFECT OF ZERO-GRAVITY ON CRYSTAL WHISKER GROWTH

1. Specific Objectives:

The objective of this effort is to investigate the effect of gravity on the growth of crystal whiskers with emphasis on developing techniques for growing longer whiskers in orbit under zero-gravity conditions than is possible on earth.

2. General Description:

Manufacturing processes in zero-gravity involving crystal whisker growth cannot be precisely predicted because of a lack of basic knowledge of the gravitational effects. One of the most influential effects resulting form the absence of gravity is the removal of the plastic flow of the longer whiskers. Whisker [illegible] stals have tremendous tensile strengths because they are almost [illegible] Earth bound processes produce whiskers of about 1mm. length [illegible] meter) and it may be possible to extend these to 1 cm length in [illegible] ity.
Si [illegible] crystal whiskers will be grown at different gravity levels, characteristics of their structures will be determined by laboratory examination and the results extended to growth in zero-gravity environment. Three methods of whisker growth may be used; vapor deposition, chemical reaction, and compression growth. Mobile furnaces on rotary mounts, a centrifuge drive, speed control, chemicals glass supplies, and a goniometer will be required.

3. Development Schedule:

These efforts will begin during FY 69 and extend through FY 70, during which feasibility of orbital experiments will be determined.

4. COST:

FY 69	$30,000
FY 70	$40,000

E. STUDY OF SPACE ENVIRONMENTAL EFFECTS ON DIFFUSION IN METALS

1. Specific Objectives:

Preliminary and basic experiments and analyses will be made to improve the understanding of diffusion in metal-melting and freezing processes. Specifically, the effects of gravity forces will be separated from those of molecular forces, thermal effects, and surface energy effects on (a) diffusion of vacancies, interstitial atoms and impurities, (b) concentration and mobility of dislocations, and (c) engineering properties which are dependent on the former processes.

2. General Description:

Melting and freezing experiments and analyses will be made to determine orientation and levitation effects for comparison with space flight effects. Complete characterization of specimens at each step will involve metallographic and solid state parameters such as: topology and grain structure, defect structure and density, crystal structure and orientation, compound segregation size and density, band structure, fermi level, surface absorption, conductivity, magnetic susceptibility, and domain structure. These data will be obtained successively on pure metals starting with aluminum, binary, ternary, and quaternary alloys to provide data for increasingly complex situations.

3. Development Schedule:

During FY 69 and FY 70 experiments will be conducted and the resulting information will be used to guide "Materials Processing in Space" flight experiments so that the comparative data obtained will be useful to the community of basic materials scientists.

4. COST.

FY 69 $50,000

F. EFFECTS OF ZERO-GRAVITY ON SOLIDIFICATION

1. Specific Objectives:

The objective of this effort is to analytically and theoretically investigate the role of gravity on the various mechanisms of solidification.

2. General Description:

The important mechanisms involved in the solidification of semiconductors, super conductors, ferroelectrics and other materials having a high potential for space manufacture will be defined. This effort will be closely related to the various research programs in crystals and other materials.

3. Development Schedule:

The investigations will be initiated in FY 70 and continue through FY 71 with efforts as indicated in the general description above.

4. COST:

FY 70 $25,000
FY 71 20,000

G. DETERMINATION OF DEGASSING METHODS

1. Specific Objectives:

Perform studies to determine the mathematical relations and mechanics of degassing free floating liquid materials in a low gravity field using methods as described in Patent Application by H. Wuenscher dated April 10, 1969. The results of work performed under NASA Grant NsG-542, "On the Shape of a Rotating Liquid Drop in an Electric Field", by Habip, Siekmann, and Chang of the University of Florida, and others on related subjects will be used as a basis for the proposed study.

2. General Description:

Degassing of materials during their liquid phase is a basic requirement of most manufacturing operations to obtain a useful engineering material. Degassing of materials on earth is aided by buoyancy forces which cause entrained gas bubbles to rise to the surface of the melt and escape. This process is further enhanced by melting and degassing in a vacuum. However, in an Orbital Workshop bouyancy forces are not present and the elimination of gas from a molten material becomes a serious problem. One method of degassing a material is by centrifugelizing of the material within a container. Many proposed space manufacturing operations derive their uniqueness from the capability to process material free of a container: therefore, a means of spinning a free floating material to remove entrained gases is required. The establishment of the theoretical feasibilities and limitations of degassing a free liquid mass in a low gravity field is of utmost importance.

3. Development Schedule:

FY69 - Perform the work as stated in the objective and publish results for use in design and development of materials processing equipment for space manufacturing facilities.

4. COST:

FY 69 $20,000

H. MATERIALS PROCESSING STUDY ON - a. ELECTRONIC SINGLE CRYSTALS GROWN FROM A HIGH TEMPERATURE GLASS MELT

b. LEVITATION MELTING & ZONE REFINING

c. HIGH SPEED CENTRIFUGE SEPARATION

1. Specific Objective:

Three operations have been identified that should be enhanced by performance in space.

a. The growth of large single crystals of electronic materials from a glass melt will utilize the reduced gravity environment of space and the techniques that were used to manufacture polycrystalline materials on earth. The objective will be a single-crystal material with reduced grain boundaries and dislocations.

b. Levitation melting, purification, or solidfication processes which would be most likely candidates for economically feasible space processing will be identified and defined.

c. The feasibility and advantages of ultra-centrifuge separation processes in space will be investigated.

d. Feasibility and limitations of using electromagnetic and electrostatic fields to meter, move, position, mix/agitate, heat and shape materials in a low g (10^{-4}) environment will be established. Follow-on studies will be identified and simple laboratory experiments or tests necessary to support the mathematical analysis and assist in determining whether the proposed concept is valid will be performed.

2. General Description:

a. The expanding interest in electronic devices that operate at extremely high frequencies requires the use of a single crystalline material. A large difference in density between the crystals and the melt characterizes a significant class of these materials and improved single crystals may result from their manufacture in the reduced gravity environment of space.

b. Melting and solidfication without a crucible will require positioning of the subject material because all of the external forces cannot be eliminated. Levitation operation by electromagnetic means has been used extensively on earth and will be studied for space application. Other positioning controls and the side-effects of positioning (heating, oscillations) will be considered in this study.

c. An ultra high-speed centrifuge operating in space may be capable of giving better separation of "light"and "heavy" gases, liquids, or solids because the rotor will not need to be supported either mechanically or electromagnetically. Applications for such separation include isotopes, organic biological materials, and chemical analysis.

3. Development Schedule:

FY 69 - Initial efforts to develop background data for specific crystal materials, and investigation of potential ultra-centrifuge application. These efforts will be for a period of nine to twelve months with follow-on consideration dependent on results. Final report on these efforts will be available by the first quarter FY 71.

4. COST:

FY 69 $95,000

I. ANALYTICAL AND DESIGN STUDIES OF PROCESS CHAMBER

1. Specific Objectives:

Effort will continue on the design and fabrication of an experimental chamber. Analysis and preliminary design of heat sources and materials handling devices will receive priority. The most promising heat sources appear to be induction, electrical resistance, and electron beam, and the most promising technique for handling materials appears to be pulsed magnetic fields. Other factors that will be considered are thermal control, total power requirements, vacuum venting and control systems, degassing of materials, instrumentation for monitoring chamber operation and collecting experiment data, and structural design constraints imposed by fixed vehicle interfaces.

2. General Description:

Processes, techniques, and equipment for manufacturing products in the earth orbital environment have not been developed and tested. The major objective of this effort will be to initiate design and supporting research studies for manufacturing process chambers with the necessary heat sources, controlled cooling devices, instrumentation, and materials dosaging, positioning, and handling devices. Results obtained from this effort will be used to design and fabricate the laboratory working model of the next generation space manufacturing facility beyond AAP-2.

3. Development Schedule:

FY 69 - Perform work as stated in the Objective.
FY 70 - Continue work as stated in the Objective.
FY 71 - Complete design and fabrication of the experimental chamber and publish results for use in design of flight units.

4. COST:

FY 69	$ 30,000
FY 70	$150,000

J. ANALYTICAL & DESIGN STUDIES OF HANDLING & POSITIONING DEVICES

1. Specific Objectives:

Initiate studies to determine feasibilities and limitations of the concepts described in NASA Case No. MFS-20410 "A Space Manufacturing Machine", by Hans F. Wuenscher, which uses electromagnetic and electrostatic fields, and to define and evaluate additional concepts. Handling devices are required which work with both electrically conductive and non-conductive materials.

2. General Description:

Unique manufacturing processes which operate in the low gravity environment of orbital space flight involve containerless processing of materials in the liquid state. Theoretical studies supported by laboratory experiments are required to develop design criteria for devices for dosing, positioning, transporting, spinning, and agitating liquid materials. Also, means must be developed for adding liquid, gases, or solids to the melt, for mixing them, and for further processing such as casting, molding, drawing or blowing.

3. Development Schedule:

FY - 69 Perform work as stated in the Objective.
FY - 70 Perform detailed studies, analysis, and preliminary design for concepts selected from FY 69 studies.
FY - 71 Design and fabricate prototype equipment and publish criteria for design of flight-type equipment.

4. COST:

FY 69 - $ 45,000
FY 70 - $ 75,000

K. SPACE PROCESSING STUDY PROJECT BY CARNEGIE-MELLON UNIVERSITY

1. Specific Objectives:

A group of undergraduate engineering students will be assigned a study project devoted to "Manufacturing Possibilities in Outer Space". The project will be conducted on an industrial basis and as a real problem. The project team will be divided into groups assigned to particular tasks with necessary support (phones, drafting, testing, etc.) and experienced supervision provided by the university.

2. General Description:

As a result of this task it is expected that some ingenious ways of using the special conditions of space may result. Additionally a large group of talented young people would be throughly introduced to space technology and manufacturing processes affected by orbital conditions. The students will be required to document their findings in a formal report with presentation, at the end of the study, to industry and government people involved in the area of space manufacturing.

3. Development Schedule:

The study would be conducted during the school year beginning in September 1969.

4. COST:

FY 70 $10,000

FUNCTIONAL PROGRAM ELEMENT II

INITIAL ORBITAL PROGRAM

1. Discipline: Space Manufacturing

2. Program Element: Initial Orbital Program

3. Requirement: Data which is developed by this program element could lead to the following space manufacturing processes:

Free inertia and electrostatic field casting which could produce solid spheres for ball bearings with surface accuracies measured within Angstrom units, hybrid computer components, large optical blanks and high purity nuclear reactor casings.

Adhesion casting by floating layers of metals and non-metals inside or outside a mold to produce multilayer coated isotopes or optical components.

Blow casting by injection of a gas into molten material in a controlled pressurized environment for the purpose of producing ultra-thin membranes for use as filters.

Controlled density casting by dispersion of inert gas inclusions within metals to produce new optimums in strength-to-weight ratio, temperature compatibility and ductility. Examples of new products which could evolve from this process include bulk foam materials for terrestrial expansion, varying-density turbine blades, sonar transducer materials and buoyant stuctures for marine use.

4. Justification: Many scientists and engineers agree that the most significant and useful feature of a low earth orbital space environment for potential space manufacturing operations is weightlessness.

Among the anticipated advantages and potential product improvements that could result from manufacturing in a space environment are the following:

(1) Greater material purity and uniformity. Advances in the purification of magnetic materials on earth have been realized through levitation castings. The possiblity of purifying non-magnetic materials in the zero-gravity of space is now open. The lack of gravity should make possible the production of alloys of much greater unifomity.

(2) Larger and more perfect single crystals. Prime candidates for commercial space manufacturing are very large, dislocation-free, single crystals that can be expected to grow in the zero-gravity environment of space, where the limitations imposed by the Earth's gravity are absent.

(3) Higher Strength-to-weight materials. Lack of a gravitational field, makes possible the control of the distribution of gas bubbles. This might lead to the production of materials having the strength and thermal qualities of metals with the weight of balsa wood. Also, very high strength materials with unique thermal characteristics might result from uniformly mixing ceramic crystals in a metal--a mixture impossible to achieve in the Earth's gravity.

(4) Greater sphericity. Materials in the liquid state outside of gravitational field, rapidly take the form of a perfect sphere. Accordingly, in orbit, it may be possible to cast spherical shapes for industrial use.

5. Component Experiments:

a. Metals Melting
b. Tube Joining
c. Single Crystal Forming
d. Composite Casting
e. Spherical Shape Forming

6. Description:

Prime purpose of the experiments will be to determine the significance of the absence--as a result of the zero-gravity environment--of buoyancy and convection on materials in a liquid state during processing and the properties the materials will exhibit after solidification.

Of equal importance is the knowledge expected to be gained of the role molecular forces play in structuring the materials during solidification in the absence of gravity.

These experiments lead to processes involving:

Blending of materials of different densities in a plastic matrix to produce new materials for use as radiation shielding for aircraft electronic systems at high altitudes or for nuclear and thermal heterogenous shielding materials.

Conversion of compacted powders and compounds into castings which may produce new isotope fuels.

Casting of composite materials by dispersion of solid compounds and fibers in a metal matrix for the manufacture of complex high-strength fittings, high-temperature structures and high-strength brazing alloys.

The experiment chamber planned for use to investigate these processes in zero-gravity will incorporate an electron beam, exotherm reaction, and resistance heating for melting the material samples.

The chamber will be attached to the interior of the Multiple Docking Adapter. The interior of the chamber will be vented to space for some process investigations. The experiment chamber is expected to be about 12 in. in diameter and 30 in. long. It will incorporate a monitoring camera to photograph processing at 250 frames/sec.

FPE II EXPERIMENT DATA SHEET

A. METALS MELTING

1. Specific Objective:

The purpose of this experiment is to study the behavior of molten metal in a reduced gravity.

2. General Description:

Experiments will be performed on various metals and alloys, such as aluminum, stainless steel, and titanium. Samples of metals ranging in thickness from 0.020" to 0.250" will be mounted on a rotating fixture. An electronbeam will pass along the convex side of each 90° segment sample. The power and focus of the beam is such that it will only penetrate to depth of 0.050" in the samples. This enables the electron beam to both weld and cut on the same sample.

Other samples for melting and cutting will have gaps machined into the center of them to compare the effects of melting in zero-gravity when gaps other than ideal are present between the abutting surfaces. The rotation speed, beam current, and focus current are some of the parameters that can be varied to study the effect on the molten metal.

Four segments of each of the three alloys will be returned for analysis. Before and after melting, careful measurements will be made to assist in a full analysis of the samples. These are:

a. Alloy and temper will be carefully studied.
b. Samples will be weighed and measured.
c. X-rays will be made of all solidified metal.
d. Tensile tests will be made to compare mechanical properties.
e. Using appropriate equipment such as the electron microprobe, a statistical analysis of element distribution and segregation will be made.
f. A metallurgical evaluation will be made as to the type of grains, size, and orientation.
g. Chemical analysis of vaporized metals will be made.
h. Study of the formation of the solidified partial spheres during the cutting will be made to compare size, shape, and surface finish.

3. Operational Constraints:

The experiment must be performed in the M-512 metals melting facility.

4. Mode of Operation:

High speed motion pictures will be made of the actual melting and cutting processes. The astronauts will load the experiment package, operate, observe, and monitor the experiment. The cameras, however, will record all pertinent data, especially the behavior of the molten metal in the samples.

5. Crew Support:

One (1) hour of astronaut time, reference mode of operation.

6. Spacecraft Support:

Supplementary electrical power.

7. Development Schedule:

Experiment approved January 1969 under M-512 for AAP-2.
Development - 1969 through January 1970.

8. COST:

FY 69 - $2,000
FY 70 - $3,000

B. EXOTHERMIC BRAZING - TUBE JOINING

1. Specific Objective:

The purpose of this experiment is to develop a stainless steel tube joining technique; to study and evaluate the flow and capillary action of molten braze material; and to demonstrate the feasibility of exothermic reaction in space.

2. General Description:

In this first study of capillary action in space, 1/4" and 3/4" diameter tubes will be joined by a gold-nickel braze alloy. The heat source to perform this braze will consist of a mixture of powders known as exotherm material. The experiment equipment also includes a device to secure the tube assemblies. The astronaut loads and unloads the chamber and depresses the ignition button. Ten specimens will be brazed in space and returned to earth for examination.

3. Operational Constraints:

The experiment must be performed in the M-512 facility.

4. Mode of Operation:

The experiment module will be placed in the melting facility. After the facility has been evacuated, the exotherm material will be ignited. Upon cooling, the package will be replaced in the transit container.

5. Crew Support:

Two (2) hours of astronaut time, reference General Description.

6. Spacecraft Support:

None

7. Development Schedule:

Experiment approved January 1969 under M-512
Development - 1969 through March 1970

8. COST:

FY 69 - $30,000
FY 70 - $ 5,000

C. SINGLE CRYSTAL GROWTH

1. Specific Objective:

The purpose of this experiment is to investigate single crystal fabrication from the liquid in the absence of gravity induced convective flow.

2. General Description:

A crystal of material (probably gallium arsenide) will be grown, either from the metallic solution or by a gradient-freeze method. Gallium arsenide is a material of high potential for many applications in electronics, including microwave, optical, and junction devices. The potential problems of growing gallium arsenide are minimized in either of the above methods. In addition to growing a single crystal of gallium arsenide without the striations caused by thermal convection, considerable scientific information, such as diffusion rates, will be obtained.

3. Operational Constraints:

The experiment can operate successfully in any orbit, however, acceleration imparted to the crystal must be kept below a level of 10^{-4}g. The experiment is confined to the M-512 process facility.

4. Mode of Operation:

The crystal growth test module will be installed in the M-512 process facility. The facility will be evacuated by venting to space and the growth sequence initiated by the astronaut. Observation will be periodic over the 100 hour crystal growth time. Subsequent to growth, the crystal will be removed from the process module and packaged for return to earth.

5. Crew Support:

Ten (10) hours total astronaut time required, reference mode of operation.

6. Spacecraft Support:

Storage volume - .5 cubic feet
Spacecraft power - 3 kilowatt hours

7. Development Schedule:

Experiment approved January 1969 under M-512 for AAP-2 Flight Development 1969 through June 1970

8. COST:

FY 69 - $25,000
FY 70 - $ 5,000

D. COMPOSITE STRUCTURE

1. Specific Objective:

The purpose of this experiment is to determine the uniformity of dispersion of whiskers in a metal matrix, when melted in a zero-gravity environment.

2. General Description:

A composite compact, such as green aluminum/silicon carbide, will be mounted in the cavity of an exotherm heating package. The astronaut will energize the exotherm igniter. The powder will melt causing encapsulation and wetting of the whisker. The material will be returned to earth and compared with similar samples prepared in a gravity field.

3. Operational Constraints:

The experiment is to be performed in the M-512 metals melting facility.

4. Mode of Operation:

The experiment module will be placed in the melting facility. After the facility has been evacuated, the exotherm material will be ignited. Upon cooling, the package will be replaced in the transit container.

5. Crew Support:

One (1) hour of astronaut time, reference mode of operation.

6. Spacecraft Support:

None

7. Development Schedule:

Experiment approved January 1969 under M-512 for AAP-2. Development - 1969 through June 1970.

8. COST:

FY 69 - $30,000
FY 70 - $ 5,000

E. SPHERICAL CASTINGS

1. Specific Objective:

The purpose of this experiment is to melt and solidify a small quantity of metallic material in order to determine the surface finish and properties of the space casting.

2. General Description:

Small quantities of metal will be melted in a vacuum insulated container by exposure to an electron beam. The beam is produced by a generating device in the M-512 process facility. The material will be positioned and retained on the end of a "sting" (slender rod) throughout the melting and cooling cycle.

The total process is estimated at one hour. The semi-spherical space casting attached to the sting will be removed from the chamber and returned to earth for laboratory analysis of properties and surface finish.

3. Operational Constraints:

The experiment can operate in any orbit. It is confined to the M-512 process facility.

4. Mode of Operation:

The equipment for the spherical casting experiment will be installed in the M-512 process facility. The facility will be evacuated by venting to space and the casting sequence initiated. Observation will be continuous. Subsequent to solidification, the casting will be removed from the process module and packaged for return to earth.

5. Crew Support:

One hour total astronaut time.

6. Spacecraft Support:

Storage Volume - .25 cubic feet.
Spacecraft power - None

7. Development Schedule:

Experiment approved January 1969 under M-512 for AAP-2. Flight Development 1969 through June 1970.

8. COST:

FY 69 - $25,000
FY 70 - $ 5,000

FUNCTIONAL PROGRAM ELEMENT II.a

SUITCASE EXPERIMENTS ORBITAL PROGRAM ELEMENT

1. Discipline: Space Manufacturing

2. Program Element: Suitcase Experiments Orbital Program

3. Requirement:

This program is an extension of the initial orbital program to develop additional data leading to development of processes for manufacturing unique products in the zero-gravity environment of orbital flight. Additional experiments are being defined by industry principal investigators which can be performed in the FPE II Process Facility.

4. Justification:

A number of research organizations in industry and in the universities have shown interest in defining experiments at their expense capable of being performed in the FPE II Process Facility.

5. Description:

Development of suitcase experiments will be a joint venture between NASA and the industry/university scientific investigators. Under such arrangements the industry/university scientific investigator will be responsible for defining the materials, the process parameters, the experiment containers, and will assist in the design and development of the apparatus in the performance of ground based tests. NASA will be responsible for design and development of special processing equipment compatible with the FPE II Process Facility, for ground based testing, for documentation to secure approval of the experiment for flight, and for space operations.

6. Development Schedule:

FY 70 - In-house design and development of special processing units compatible with FPE II Process Facility.
FY71 -In-house fabrication of special processing units, and testing.

7. COST:

FY 70 - $50,000
FY 71 - $50,000

FUNCTIONAL PROGRAM ELEMENT III

SECOND ORBITAL PROGRAM

1. Discipline: Space Manufacturing

2. Program Element: Second Orbital Program

3. Requirement:

The objective of this Functional Program Element is to develop the facility in which second generation experiments will be conducted. Experiment results, as well as scientific studies and data from FPE I and FPE II will be used in the facility design and function criteria. It is anticipated that this experiment package will be hard mounted in a space station, such as the proposed dry workshop, and outfitted prior to launch.

4. Justification:

This Program Element must be conducted as a follow-on to previous efforts. The ground based studies conducted in FPE I will produce data that can not be verified in the AAP-2 experiment. This will provide the first opportunity to fly manned experiments to verify the studies and develop the space processing facility as a working module.

5. Description:

Initial efforts of this program element will be directed toward special fabrication equipment, tooling, and components which will be developed in support of the design and fabrication of the experimental chamber. Two primary factors to be considered are (a) the selection of heat sources and (b) mehtods of manipulating materials within the chamber.

At the completion of the two previous program elements those areas having greatest potential for success in (a) improved crystallographic or microscopic properties of materials, (b) new and novel structural materials, and (c) handling and forming, will be selected. The expected increased involvement of university, industry and government should provide completely new processes, some of which are not now foreseen. The program will be sufficiently flexible to include these processes.

The following groups of experiments may be possible:

1. Making solid precision bodies by free, inertia and electrostatic field casting.

2. Making hollow precision bodies as above and development of bubble centering processes.

3. Control of super cooling, leading to homogeneous nucleation during solidification.

The following materials and configuration may be accomplished:

a. Materials

(1) Supersaturated alloys for thermoelectric and superconductive application.

(2) New types of glasses.

(3) Prestress free blanks for lenses.

(4) Single crystals.

(5) High purity metal standards (centrifugal cleaning)

(6) Polymers

b. Configurations

(1) Precision balls for bearings.

(2) Precision hollow balls for bearings.

(3) Optical components.

(4) Density controlled metal configurations with unique structural electrical and thermal properties. (Liquid - gas - solid i.e. 3 state casting).

FUNCTIONAL PROGRAM ELEMENT IV

SPACE PROCESSING & MANUFACTURING IN '75 SPACE STATION

1. Discipline: Space Processing & Manufacturing

2. Program Element: Space Station Module

3. Requirement:

The objective of this Functional Program Element is to provide the facility for experiments in basic materials research and for the development and execution of space manufacturing projects. The technology for exploitation of the reduced gravity environment will result from the preceding Program Elements.

4. Justification:

This module would provide for a continuing effort on manufacturing process investigations and production of small quantities of specialized items that can best be produced in the environment of near zero-gravity. Items produced in the space environment will be returned to earth for use in specialized industrial, medical and government applications.

This effort will lead to the establishment of a space manufacturing and material processing complex for quantity production of selected components. It is anticipated that industrial participation will increase with each succeeding phase, and it is hoped that industry will assume a major responsibility and role in the programs to follow in the 1980's.

5. Physical Description:

The Space Station Module will be separately launched and docked to the space station. The module provides the facility for an environmentally controlled volume inside the basic structure. It consists of (a) a laboratory section equipped for shirt-sleeve operations, (b) a storage area for experiment materials and products with its own docking port for logistic vehicles, and (c) a workshop with provisions for access to open space.

Many of the experiments are very sensitive to small gravitational disturbances such as those that might be caused by crew movements, logistic spacecraft docking operations, etc. For this reason it might be necessary to isolate these experiments from the basic station. Two potential techniques are currently under consideration: (1) periodically detaching the module and operating it in a free flying mode and (2) positioning individual experiment packages outside the module, letting them free fall for the duration of the experiment period and retrieving them.

The experiments module will incorporate a variety of sophisticated test and process equipment such as monitoring equipment and closed circuit television (module to earth) so that timely and intelligent adjustment in processes or experiments can be made by the researchers while remaining in earth orbit.

EXPERIMENT REQUIREMENTS SUMMARY

EXPERIMENT TITLE

TEXT REF. NO. 1.3.1.2

Respiration Control

EXPERIMENT CATEGORY

Pulmonary Function--Ventilatory Mechanics

OBJECTIVE AND SIGNIFICANCE

To determine the effect of weightlessness on the respiration control associated with possible changes in respiratory gases, acid-base balance, and body reflexes.

MEASUREMENTS AND OBSERVATIONS

Respiration rate
Respiratory volumes
Expiratory pO_2 and pCO_2
Breath-holding time
Arterialized venous blood pH, bicarbonate, pO_2, and pCO_2
O_2-Hb saturation

EXPERIMENT DURATION

Spirometry 10 min. daily for mission duration; chemistries 60 min. weekly for mission duration.

SUBJECTS, MATERIALS, AND EQUIPMENT

2 crew members
Spirometer
Expiratory gas analyzer
pH meter
Specific ion electrodes
Blood gas analysis equipment
Oximeter
Timer

SPECIAL REQUIREMENTS/REMARKS

Available techniques need to be refined.

PERSONNEL REQUIRED

2 technicians

REFERENCES

S. P. Vinograd. Medical Aspects of an Orbiting Research Laboratory. Space Medical Advisory Group Study, NASA Report No. SP-86, 1964.

EXPERIMENT DATA SHEET

1. TITLE: Glass Casting

2. OBJECTIVE: Glass with a unique amorphous structure produced by sub-cooling is required for electronic application and for use in the production of structural and optical components. Large perfectly spherical lenses or quantities of electronically active ceramic glass would be of sufficient value to justify production in earth orbit. In several, materials, (metals, semiconductors, and ceramics) sufficient quiescent cooling will allow the mass to cool below its melting point before solidification. Sub-cooling to a greater degree is anticipated under zero gravity since the supercooled liquid would not be in contact with a container or exposed to motion. The resulting "glass" material has mechanical and physical properties significantly different from the conventional form, making the material very useful for electronic application as well as structural or optical use.

3. DESCRIPTION: The molten material would be allowed to cool without contact with either an atmosphere or a container to achieve as much sub-cooling as possible prior to solidification.

The selected material of about 2 kg will be located in a melting and solidfying unit and held in position during heating and released to float during melting. Shutters in the process chamber would be opened to the vacuum of space during melting and solidification.

The shutters and holding system must be located such that maximum radiative cooling can be achieved. This may require cryogenic cooling of the container and other considerations of chamber design such as reflectivity and absorptivity.

EXPERIMENT DATA SHEET

1. TITLE: SPHERICAL CASTINGS

2. OBJECTIVES: Precise spherical castings of minimum mass are required to reduce friction in high speed rotation equipment and for application in the field of metrology.

Much of the machinery that supports modern technology would be impossible without the extremely low friction obtainable from precision ball bearings. Bearings are essential requirements in high speed rotation, such as dentist drills, and in precision instruments, such as gyroscopes. However, the dynamic loading on solid ball bearings, which are currently used, causes the races to wear out too quickly. The use of the hollow ball bearings with their decreased mass would extend the service life by six to eight times, and would be especially desirable for use in certain high speed aircraft engines. This would be of great practical benefit to the air lines and to the Air Force. Another application would be in large radar units, where hollow ball bearings would flex and provide greater compliance with the changing diameter of the unprotected outer race. To date no satisfactory method has been developed for making hollow bearings on earth to meet the requirements of perfect balancing at 12,000 RPM.

The possibility of positioning a molten metal mass in space without the use of a mold, combined with the proper cooling rates should allow us to cast nearly perfect spheres having uniform properties and surfaces. The equilibrium shape of a liquid mass, influenced by no external forces is a sphere. Lack of spherecity will be caused by: (1) Non uniform heating, cooling or freezing, which leads to internal stress (2) Any anisotrophy

in material characteristics; (3) Contact with a surface before solidification; (4) Oscillations in the melt due to deviations from zero-g; and (5) Phenomena not predicted by present information.
Hollow spheres could be formed by balancing vapor pressure of a metallic core and the surface tension of the liquid matrix.

The purpose is to demonstrate the feasibility of producing both solid and hollow spherical metal castings in earth orbit and to determine the precision to which such castings can be made.

3. DESCRIPTION: The research area consists of the melting of metals by means of a heat source to be slected and subsequent solidification of the mass in free space. Positioning of the mass will be accomplished by electromagnetic field, or other means. The experiments will be conducted and monitored by man.

Small quantities of metal will be melted in a vacuum insulated container by a heat source which will be selected installed in a metals melting chamber. The material will be positioned and controlled throughout the melting and cooling cycle by means of electromagnetic fields. The hollow sphere would be formed utilizing the vapor pressure of a lower melting point metal located at the center of a compressed powder mass which is the base material of the casting. For example, bismuth would be prepared by plating with cobalt. This sphere would be placed nearly at center in a 80 titanium carbide, 20 cobalt power mixture and compressed to form a "green" compact. After emplacement in the spacecraft experimental chamber, the body would be heated to the melting point of cobalt. At this temperature the cobalt plating would dissolve and allow the bismuth, now near its boiling point, to vaporize as terperature is increased and form a cavity by virtue of the vapor pressure exerted. The quantity of bismuth will be predetermined to sufficiently balance against the surface tension of the liquid cobalt with respect to the cavity required.

Upon partial cooling of the body, the bismuth would condense on the inner cavity wall as a liquid after the cobalt has solidified. Upon continued cooling, the bismuth will freeze on the inner wall and the structure will remain as a sound symmetrical spherical object.

EXPERIMENT DATA SHEET

1. TITLE: SINGLE CRYSTALS

2. OBJECTIVE: Single crystals of superior purity with respect to dislocations, uniform distribution of elements and size, to those produced under earth gravity, are required in the field of communication, radar sensors, lasers, and electronic circuitry. Many future developments in electronics can be expected from the improvements and better technical understanding of solid state material. Solid state physics is largely related to the understanding of crystalline material.

The growth of large crystal from a variety of materials would greatly reduce the cost of crystal components. Large crystals would constitute "stock" from which many components could be made and would preclude the expense of repeated, meticulous crystal growing. Some crystal have quite unique properties which are extremely valuable, particularly on a value per unit volume or weight basis. Single crystal selling for several thousand dollars per pound are quite common. Such crystal often are the heart of very complex measuring, counting, sensing, or controlling instrumentation. A relatively small percent of improvement in the performance of the tiny single crystal can mean the success or failure of the entire system, such as a new atomic energy conversion system or the control circuitry of an antiballistic missile.

Many of the desirable properties (size or quality) of single crystals are not obtained in present manufacturing techniques. A space environment of low gravity, high vacuum, and high radiant energy may have considerable advantages for single crystal manufacturing. Zero gravity enhances the potential of new crystals from three general groupings:

a. Crystals solidifying from liquids in which there are no satisfactory containers. Often these liquids have very high melting points (2500°C+) and/or are chemically reactive, dissolving or attacking all known containers. Containers also are known to produce stains and dislocations in many commonly used crystal growing techniques.

b. Crystals solidifying from liquids in which density variations are significant. If these is a mass density differential within the liquid from which the crystal is forming, gravity will become important. Density variations related to thermal gradients have been cited by several investigators to produce convection currents in the liquid melt. These movements produce defects in the crystal being grown.

c. Single crystal that are limited in size because of the gravitational field effects.

The purpose is to grow a large single crystal to measure the effects of density variations in the solidified crystal and to demonstrate the practicality of producing a variety of crystal in earth orbit.

3. DESCRIPTION: The experimental area consists of the refinement and growth of large crystalline materials in a vacuum insulated container which will be heated by filament elements operated from a 28v power supply. The experiment will be conducted and monitored by an astronaut.

The material will be heated in a vacuum insulated container to just below its melting point over a period of two hours prior to zone melting. Matched filament elements operating from 28v will supply the heat. Temperature gradients within the speciment will be kept low.

The insulation will be arranged such that the primary heat flow will be unidirectional.

Applications of electrical power to the zoned heating elements would be sequenced to maintain a small increment of molten material which travels the length of the crystal. The total growth process is estimated at 100 hours. The crystal will be returned to earth for laboratory analysis and comparison to crystals grown under gravity.

EXPERIMENT DATA SHEET

1. TITLE: Composite Structure

2. OBJECTIVE: High strength composites with properties tailored to specific applications are needed in the aerospace industry to improve the performance characteristics of structural components and upgrade the oeverall efficiency of flight vehicle.

To meet these requirements, scientists are developing new materials that combine strength and stiffness with lightness and creep resistence at elevated temperature. Directional properties of fiber reinforced composites are produced when the fiber orientation and density are controlled. Such composites can be constructed on earth; however, optimum distribution and resultant properties are degraded due to process induced defects. For example, metal matrix composites are commonly produced by diffusion bonding thin layers of matrix material, between which oriented fiber are dispersed. Bonding is accomplished by heating the assembly and subjecting it to sufficient pressure to bring the layers of matrix material into intimate molecular contact. The process, however, upsets optimum fiber distribution, damages the fibers and matrix material. In space, oriented fibers would remain in prescribed positions during melting and solidification of a matrix, because of the lack of convection currents and pressure associated with diffusion bonding.

The purpose of these experiments is to study the consistency of fiber orientation during the melting and solidification of metal and organic matrixes in reduced gravity environment.

3. DESCRIPTION: The program elements consist of manufacturing metal and organic matrix, filament reinforced composites by forming or casting the liquid matrix material around precisely oriented fibers.

Prealigned fibers in powder matrix compacts, such as boron/aluminum and boron/epoxy, will be melted in a "space furnace". The specimens will be metallurgically analyzed to measure any change in fiber alignment.

EXPERIMENT DATA SHEET

1. TITLE: Variable Density Castings

2. OBJECTIVES: The lack of buoyant forces in the zero-g environment predicts the stability of gas bubbles in liquids. This suggests the fabrication of foamed materials with a controlled density. Materials with the density of cork and the strength and heat resistance of steel should have many applications. While it is possible to make these materials here on earth, the quality and uniformity required would be extremely difficult.

3. DESCRIPTION: A means for melting metallic materials and of introducing gases into the melt is required. Precise measurement and controlled bubble size would produce materials of desired density and strength. Uniform dispersion would be maintained in zero-g during the cooling and solidification process.

CONTENTS

SUMMARY

MSF ENGINEERING AND OPERATIONS

1. Goals and Objectives

To develop operational capability to utilize Manned Space Systems and Subsystems for the performance of space operational acitivities.

Objectives.

a. Aid in the definition of operational requirements for manned occupancy, and develop techniques to effectively provide living facilities to keep the astronaut crew at their most effective level of activity.

b. Evaluate and develop techniques of maintenance and repair to ensure that a space system may be maintained in a state of adequate operating capability and that sufficient data is available for the design of future space systems.

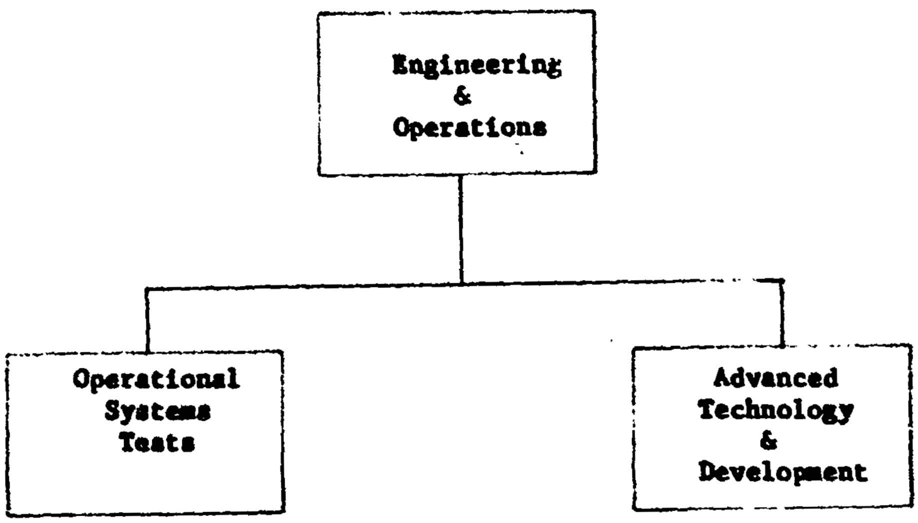
c. Aid in developing capability for the monitoring and evaluation of the operational performance of space systems.

d. Evaluate and develop techniques for in space logistics and resupply operations.

e. Develop operational capability to evaluate and perform assembly and deployment activities in space.

2. Experiment Program

The experiment program for this area is still under study. At the present time general opinion has led to the definition of two fundamental approaches to an experiment program as follows:



Applies to Operational Systems

Applies to design of Advanced Operational Systems

Because of the high cost of manned and unmanned space systems, it is necessary that NASA take advantage of every avenue available to obtain data that can be used to better design future space systems and reduce the cost of the space program. The classical approach in obtaining data in an area of uncertainty is to design an experiment which can provide the data. This is costly but still the best way to obtain needed data in the space program. The Engineering/Operational Program is directed at obtaining data in an organized manner using operational systems and techniques and is meant to supplement controlled experimental data but not replace it.

The Engineering/Operational Program will insure that data relative to the effectiveness of man and hardware in the performance of operational functions is obtained in an organized manner. This will permit analytical studies and correlations of the data to satisfy specific knowledge requirements as defined in the Functional Program Element write ups below. The proposed Functional Program Elements (FPE's) for this area are summarized in the following pages.

Experiments in some of these proposed FPE's will probably be deleted as the program evolves. Others will be added. A third group probably overlays in other disciplines such as "Aerospace Medicine" and "Advanced Technology." This fact notwithstanding, these descriptive write ups are included in advance of the final experiment program to indicate the direction the experiment program may take.

FUNCTIONAL PROGRAM ELEMENT I

1. DISCIPLINE: MSF Engineering and Operations

2. PROGRAM ELEMENT: MSC Flight Operations Package

3. REQUIREMENT:

   a. Develop advanced rendezvous and docking techniques.

   b. Evaluate procedures and equipment for attitude control and statin keeping maneuvers.

   c. Develop flexible methods of flight plan maintenance for long-duration missions.

   d. Evaluate methods for control of unmanned vehicles launched from a manned space station.

4. JUSTIFICATION:

a. By the mid-1970's, the U. S. manned space program will have included between 20 and 30 rendezvous maneuvers, and 10 to 15 dockings of one spacecraft to another. This experience will have created a "first generation" operational capability, more or less specifically oriented toward methods of transferring personnel between two small, fully supplied vehicles. Early space station operations will necessarily be based on the same techniques. However, the EOSL flights will be the first to include repeated, large scale transfers of consumables. They will also include the first rendezvous operations involving a large manned space station with considerable maneuvering margins and the capacity for sophisticated flight control facilities.

It is probable that the "nose-in" docking method adopted for Gemini and Apollo will not be the most convenient for space station logistic operations, if only because it means that cargo access must be through the crew compartment. Moreover, when the target vehicle is manned and capable of controlling the terminal stages of rendezvous it will no longer be necessary for the crew of the approaching vehicle to have a "dead-ahead" view of the docking adapter. It should be possible for resupply vehicles to dock at a number of specialized stations to transfer fuel, unload different kinds of solid cargo, pick up return cargo, and transfer personnel. These capabilities would be highly useful in space station operations, and the early EOSL flights should include development of rendezvous and docking techniques in which the approaching vehicle maneuvers in the various required ways under control from the target vehicle.

b. The station-keeping, momentum management, and attitude control maneuvers of the EOSL will interact quite strongly with experiment activities on the mission, since the latter will cover a wide range of disciplines. These interactions are likely to increase in sensitivity as space station operations evolve toward more ambitious experiment payload functions from constraints imposed by attitude control drift rates and other nominal parameters of the spacecraft maneuvering systems. It will therefore be desirable to experiment during the EOSL missions with specialized maneuvering techniques adapted to possible special payload requirements.

c. It is highly unlikely that a manned mission that lasts for a year or more and has experimental activities as its primary function will be able to adhere for very long to a flight plan which has been prescribed in advance. It is also virtually certain that a number of significant uncertainties will exist about the most effective ways to maintain the different parts of the flight plan (crew timeliness, consumable management, maintenance, etc.), and that at least some of these uncertainties will have been generated by experiences in the AAP program. The EOSL mission should provide for trials of various alternate methods of flight plan maintenance over significant periods of time, so as to provide the data needed for development of optimized techniques to use in the future.

d. A number of experiment proposals involve the use of unmanned subsatellites flying at varying distances from a manned space station, and it is also likely that the information management needs of advanced space station operations will require the use of unmanned data return capsules. It will be more logical and convenient to control both types of vehicle from the space station rather than from the ground, and the EOSL program should include a schedule of activities to reduce the control of such vehicles to operational practice.

EXPERIMENT DATA SHEET

LASER COMMUNICATIONS

1. Title:

The title of this experiment is "Laser Communications."

2. Objective:

The objective of this experiment is to develop an optical communications system for possible application in deep space where data transmission rates and bandwidth per unit power must be optimized.

3. Significance:

Man's curiosity insures that the moon will only be a stepping stone in the conquest of knowledge concerning our solar system. **Most certainly once this mission has been completed, systems for** taking us to one of the nearby planets must come off the drawing board and into the design stage. The NASA proposed Space Station provides an excellent test bed for the development of future spacecraft systems including advanced communications systems such as the LASER.

Current studies show that optical systems are promising for the realization of high information rate deep space communications systems. The great potential of optical frequencies for transmitting high data rates at planetary distances resides primarily in the very tight optical beam or high antenna gain. Radio-frequency (RF) communications systems have been developed to a very high advanced technology with littl future improvements visualized for these systems for increasing the data rates. We are approaching practical limits on RF transmitter, rece. .r, and antenna design for space application. On the other hand, optical systems have room for improvement in terms of improved efficiency, antenna size, better detectors and other factors. Optical communications systems can theoretically provide information rates of megabits per second at planetary distances. Just as improtant, these systems enjoy a clearcut advantage of spectrum bandwidth and range as future mission requirements are expanded. Optical systems, however, are not without problems as discussed below.

4. Experiment Approach:

It is not the intent of this proposal to specify a design for a Space Station LASER system or a specific experiment proposal. Rather, it is the intent to point out the unique advantage of the Space Station as a test platform for LASER experimentation. It is perhaps premature to speculate on the type of optical system which will find application to a planetary mission. However, one is tempted to speculate anyway; it appears likely that for missions to the nearby planets and beyond an optical communication system will be provided with its receiver located on a space platform above the Earth's atmosphere (or perhaps on the moon) to avoid the major problem of earth cloud cover and atmospheric disturbances. Communications with various points on the Earth would be maintained by conventional RF means.

This experiment could be performed in two parts:

a. Part one would utilize a LASER transmitter/receiver located on the surface of the moon. Specific objectives of this configuration would be to investigate:

(1) The problems involved in the pointing, acquisition, and tracking of the narrow beam (fractions of an arc second) by both the transmitter system and receiver telescope.

(2) The effects of long distance propagation delay on the pointing of the LASER. Under certain geometric conditions a narrow beam LASER cannot communicate in real time angle with a deep space vehicle. The LASER would have to be aimed ahead or behind the vehicle to insure far-field intersection of the spacecraft to effect optimum communications.

(3) Radiation effects of space on the LASER system.

(4) Technology development - LASER and modulator efficiency improvement.

(5) Maintenance of diffraction-limited optics.

b. Part two of the experiment would utilize the Space Station transmitter/receiver for communications with an earth-based station. The prime objective here would be to investigate the effects of the Earth's atmosphere on LASER communications.

EXPERIMENT DATA SHEET

MAGNETIC TORQUING FOR ATTITUDE CONTROL

1. T'tle:

   The title of this experiment is "Magnetic Torquing for Attitude Control."

2. Objective:

   The objective of this experiment is to prove the feasibility of using magnetic torquing for attitude stabilization and control of a Space Station.

3. Significance:

   An attitude control system employing magnetic torquing shows promise of providing major costs and weight savings over conventional attitude control systems employing reaction control engines (RCS) or control moment gyros (CMG). A number of small automated satellites are now successfully using magnetic torquers for attitude control but manned application of this technique has been largely overlooked. In general there appears to be only two significant disadvantages with the magnetic torquing system. First, the system has less "authority" than an RCS or CMG, thereby requiring more time to effect a major attitude change. Second, momentum change can only be provided in directions perpendicular to the Earth's magnetic field and attitude change may require waiting until the direction of the Earth's field has changed.

   As indicated in the reference listed below high field strength electromagnets of FE/CO alloy permendur can be fabricated which can provide reaction torques with the Earth's field of up to one newton-meter for each 310 pounds of magnet core material. The electrical power required to magnetize a core of this size is quite small-probably substantially less than 100 watts. Based on computed gravity-gradient torques for the AAP Saturn 1 Workshop assembly, a 2 newton-meter unit would be adequate for AAP Workshop attitude control. A control unit designed for operation in the proposed Space Station would not be substantially larger than a two newton-meter unit.

4. Reference:
Owen K. Garriott, Memorandum to KA/Robert K. Thompson, subject: "Magnetic Torquing for Attitude Control," October 17, 1968.

5. Approach:
The magnetic torquer should be flown as an experiment but could be designed for operational use for Space Station stabilization if proven feasible.

This system would provide torques on the Space Station through interaction of onboard electromagnets with the Earth's field. These electromagnets would consist of a ferromagnetic core **magnetized** as appropriate by coils wound around it.

The design of the onboard torquers would of necessity be an integral part of the attitude control system for the Space Station. A thorough study should be made to determine the optimum configuration for these modules in view of the gravity gradient torques, aerodynamic torques and moments of insertia expected for the basic Space Station and Space Station assemblies.

A simple magnetometer would be a necessary part of the system for sensing the Earth's field. Three orthogenal coils wound around the same core would permit the magnetic dipole to be oriented in any desired direction. Control electronics for the magnet exciting coils would be needed as well as computer software (either ground-generated or onboard generated) for maintaining and controlling vehicle attitude.

EXPERIMENT DATA SHEET

Operational Experiment Proposal

1. Title:

The title of this experiment is "Onboard Tracking System".

2. Objective:

The objective of this experiment is to establish the feasibility of an onboard tracking system used in conjunction with ground-based transponders.

3. Significance:

The interrogation of ground-based multi-located transponders from on-board an orbiting Space Station can provide navigational data and relieve the need for complex ground radar sites and relatively inaccurate satellite tracking systems, e.g. Transit or the proposed Data Relay Satellite System. Such a system can be used to augment or back up on-board guidance and navigational systems in establishing Space Station position and course. The ground-based transponders and antenna systems could conceivably be designed for unattended operation for long periods of time further reducing operational tracking costs of the Space Station.

4. Related Studies:

The NASA Marshall Space Flight Center has sponsored the development of an onboard tracking system entitled AROD (Airborne Range and Orbital Determination). Specific references are listed below:

a. ITT Federal Labs., Astrionics Center: "AROD Vehicle Tracking Receiver." NAS 8-5483; April 1964.

b. Space Craft, Inc., "AROD Transponder Theory of Operation." NAS 8-5480; June 1964.

5. Experiment Approach:

a. Theory

The onboard tracking system as proposed here is a vehicle guidance system based on trilateration with measurements of range and range rate to three or more fixed ground stations of known location. In this system the central station is located on the Space Station (see Figure 1). It would contain a standard frequency generator, transmitter/receiver, demodulators, computer, and other auxiliary equipment to operate the system (see Figure 2). Each ground station would require only a transponder which receives the signal transmitted from the Space Station and sends back a coherent version of the received signal.

This system would provide for simultaneous reception from up to four transponders, although only three signals need be received to completely determine the Space Station position and velocity. This system would therefore contain four channels.

The determination of the range to each ground station transponder is made by measuring the time delay between transmission of a signal from the vehicle to the ground station and reception of a signal returned from the ground station to the vehicle. In order to provide accuracy in this measurement, the phase delay of a high frequency sine wave modulated on the carrier is measured. Because this measurement can be ambiguous if the vehicle is at a greater range than one wave length of the modulating signal additional lower frequency modulating frequencies are required. These frequencies are called sidetones and this ranging technique is commonly known as "sidetone ranging". The AROD system concept developed by MSFC uses modulation sidetones of 2.342 MHZ, 73.1875KHZ, 2.287KHZ, and 71.47HZ in order to provide range measurement accuracies of ± one meter at distances of over 4000 kilometers (2200 nautical miles). The RF carriers of this proposed experiment could share the 2.2KMHZ frequency band now used by the Apollo unified S-band system. The RF signal from the Space Station would be received by the ground-based transponders and coherently displaced in frequency for retransmission to the Space Station. Each of the ground transponders would require a different frequency displacement to provide the four receiving channels.

In addition to the range measurements, the onboard tracking system can measure radial velocity of the Space Station by means of the Doppler shift on the returned carriers. Each carrier has on it a double Doppler (2-way) resultant from the round trip made by the signal, since the transponder does not remove the Doppler from the signal received from the Space Station.

As shown in Figure 2, the range and range rate information would be fed into an onboard computer for determining the Space Station position and velocity. The onboard computer would contain each ground station position coordinates and if desired could compute acquisition times for upcoming MSFN or transponder ground station passes.

b. Proposed Ground Stations

The selection of the transponder ground stations used in conjunction with an operational onboard tracking system should be undertaken with a view toward optimizing tracking accuracy while maintaining a reasonable tracking interval for earth orbital missions. However, for experiment purposes, only a minimal-type ground system need be implemented. It is recommended that three ground sites be selected in the United States as the experimental ground stations.

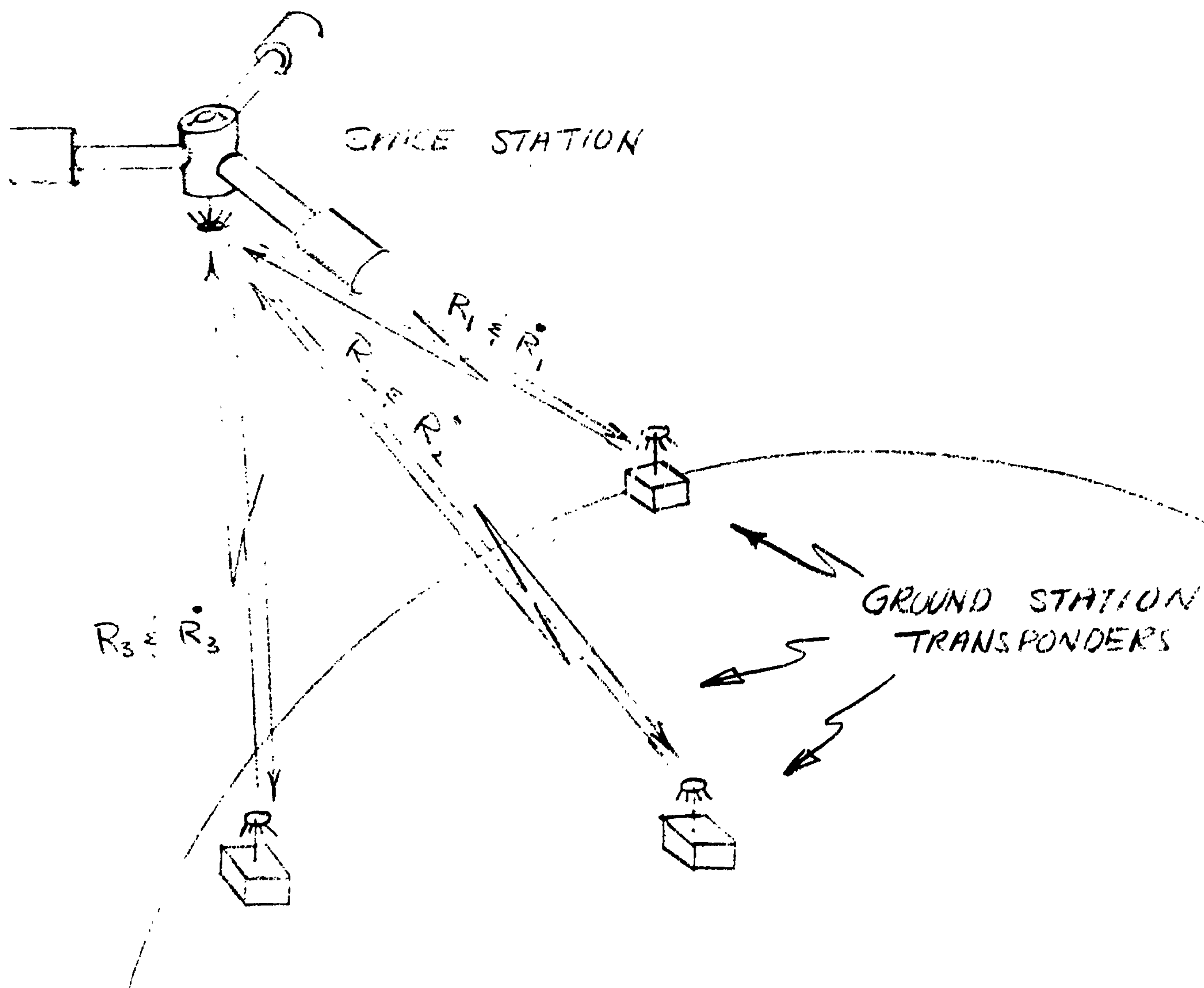


FIGURE 1 ONBOARD TRACKING SYSTEM CONCEPT

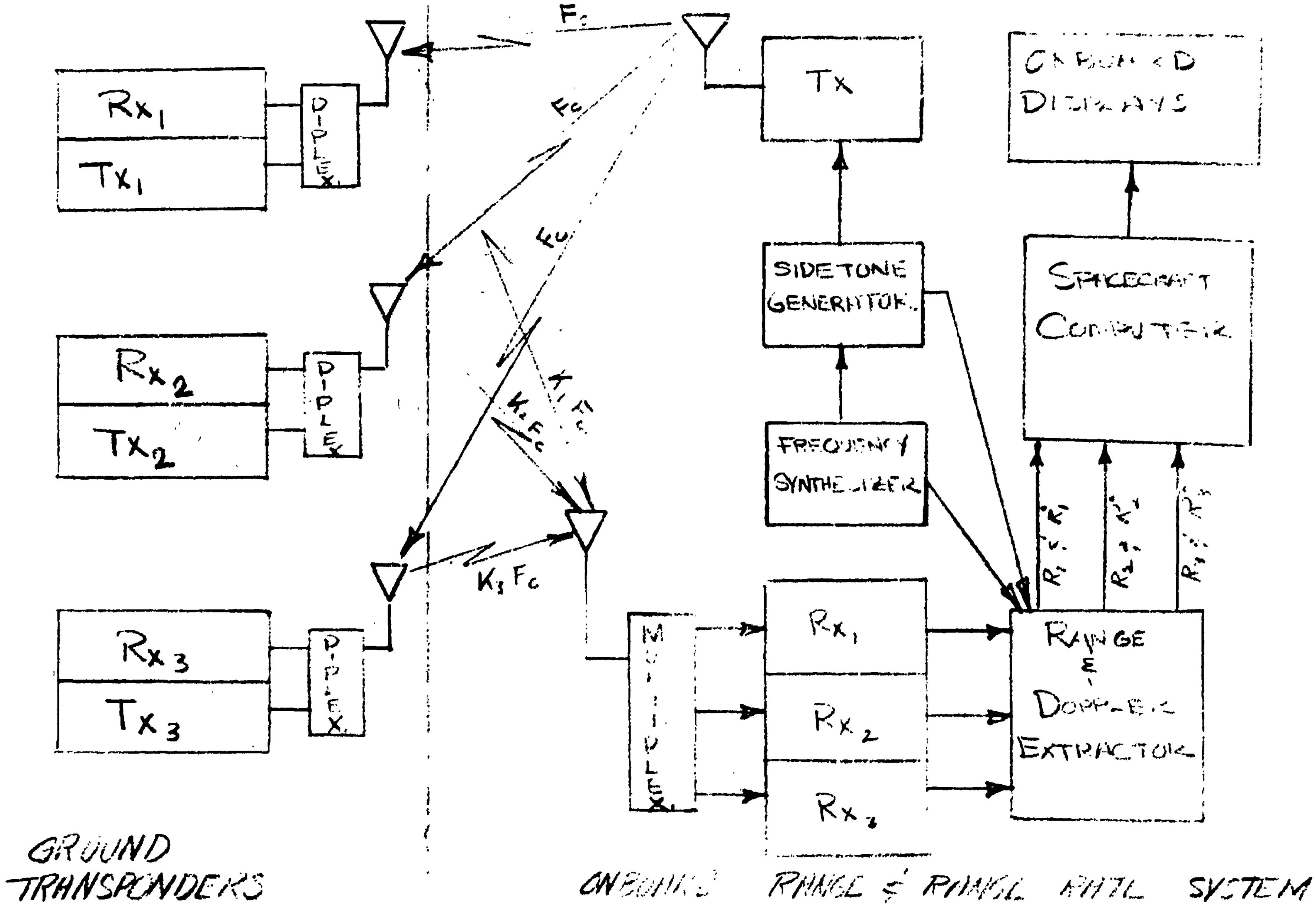


FIGURE 2 [illegible] TRACKING SYSTEM DIAGRAM

EXPERIMENT DATA SHEET

Operational Experiment Proposal

1. Title:

The title of this experiment is "Telefactor Space Operations".

2. Objective:

The purpose of this experiment is to develop the capability of using a telefactor manipulator to do tasks in the space environment.

3. Si[illegible]ficance:

The development of remote control master-slave manipulators for space operations will enable the crew of a space vehicle or the ground controllers to do EVA tasks from an area not exposed to the space environment. A general purpose telefactor device can be designed to do tasks which an EVA crewman would normally be required to do.

The development of remote control manipulators will lead to a completely mobile telefactor which can be used to do all types of work in space--assembly, equipment deployment and repair, equipment operation, and experiments performance. The telefactor can be scaled larger or smaller than a human. A large, stronger-than-human telefactor could be used for assembly of space station modules.

The telefactor could be developed as a vehicle with its own propulsion system and controlled remotely by an operator from the safety of the space vehicle or the ground via a command link. Eventually, development could lead to a telefactor with the capability of doing all the tasks that a human can perform in the space environment with the advantage of being stronger, comparatively indestructible, and scaled and designed to perform tasks which a human could not do or only with great difficulty perform.

Further development may lead to a telefactor to operate on the surface of the moon to explore, examine, work, and do research in that hostile environment. The operator can control the remote manipulation from the safety of a lunar base or shelter, a spacecraft, and from the earth itself although time delay over the latter's distance may become a problem.

4. Disciplinary Relationship:

Remote handling tools and manipulation have been developed for use in nuclear research and operations. Various manipulators have been developed by the Argonne National Laboratories. The Argonne National Laboratories have developed master-slave manipulators with force feedback so that the operator can "feel" the objects grasped. A headborne television system has been developed by Philco wherein all head movements of the operator control a remoted TV camera. A small TV receiver mounted on the observer's helmet provides the observer with a visual display of the remoted camera's view. William E. Bradley, Institute of Defense Analysis (IDA) has published a paper on "Telefactor Control of Space Operations" from which the information of this proposal is based.

5. Experiment Approach:

The experiment will consist of a telefactor mechanism which will be tested and operated in the extra-vehicular environment. The telefactor need not be a fully mobile general purpose remote control manipulator. The purpose of this experiment is to test the feasibility of using such a device to aid crew members or ground controllers in doing those tasks which otherwise would have to be done by an EVA astronaut.

The telefactor should be mounted external to the spacecraft as shown in Figure 1. The device would approximate geometrically a human from the waist up. A TV camera is mounted on the top of the device with two manipulator arms below this. The TV camera, arm manipulators, and waist servo-mechanism are controlled by an operator in a control harness inside the spacecraft or by ground controllers if continuous real time coverage is available. The harness is geometrically similar to the telefactor.

The telefactor must be placed within manipulator arm range of the airlock so as to be able to pull out and replace equipment. The telefactor will deploy experiments placed into the airlock by the crew. The telefactor can deploy sensor experiments especially those requiring pointing. The slave servo-mechanism itself can replace experiment mountings in some cases by holding and pointing instruments at targets of interest. For the purposes of this telefactor experiment, a number of other experiments will be deployed by the telefactor and then retrieved and placed into the airlock after which the telefactor (or the crew) will seal the outer airlock door allowing the crew to recover the experiment.

The manipulator will be tested with various types of grips. Examination will be made if a universal grip (similar to a hand with fingers) vs. special grips designed to do specific jobs. Repair and assembly tasks will also be performed. Various degrees of strength augmentation can be evaluated. The dexterity of the manipulator will be evaluated.

A crew member will be required to operate the control harness of the telefactor. It may also require a ground controller if the capability of ground control is included as a part of the experiment.

6. Telefactor Principles (from Telefactor Control of Space Operations by W. E. Bradley, IDA)

   1. The operator is remoted from the slave manipulating apparatus.
   2. The operator moves many mechanical degrees of freedom continuously and simultaneously, but without conscious attention to each.
   3. There must be kinematic similarity between the control harness and the telefactor itself at the remote location. They must be geometrically similar.
   4. The telefactor will permit force reflection.
   5. There must be a headborne television system.

7. Requirements:

   1. Electrical Power

      Electrical power is required to operate the joints of the master-slave manipulator, the TV system, and telemetry of position and force feedback to the operator. The largest power drain will be that due to the TV system. The operator harness will require power to transmit commands to the telefactor.

   2. Command

      Command signals are required to be generated from control harness to the telefactor slave. This can be a hardline when the operator is an onboard crew member. If the operator is a ground controller RF commands must be transmitted to the space vehicle.

3. Air-ground Communications

This is required only in the case of a ground controller operating the telefactor. Commands must be transmitted to the space vehicle and telefactor. The telefactor must transmit a TV image, force feedback data, position data, and some manipulator system data.

4 Spacecraft Interface

The telefactor should be mounted near an airlock. Ideally, the telefactor should be mobile but as this experiment is to test the feasibility of such devices in space operations, it is mounted permanently to the space vehicle. Mounting the salve servo-mechanism near the airlock will enable the telefactor to support operations normally requiring EVA.

The telefactor requires electrical power and a command link with the space vehicle. It is not known whether or not cooling will be required for the manipulator motors.

5. Environment

The telefactor is to operate in the space environment. The control harness is to operate in the space vehicle atmospheric environment or in a normal room environment.

7. Reference:

The data in this experiment proposal was obtained from a paper published in Astronautics and Aeronautics, May 1967, by William E. Bradley "Telefactor Control of Space Operations".

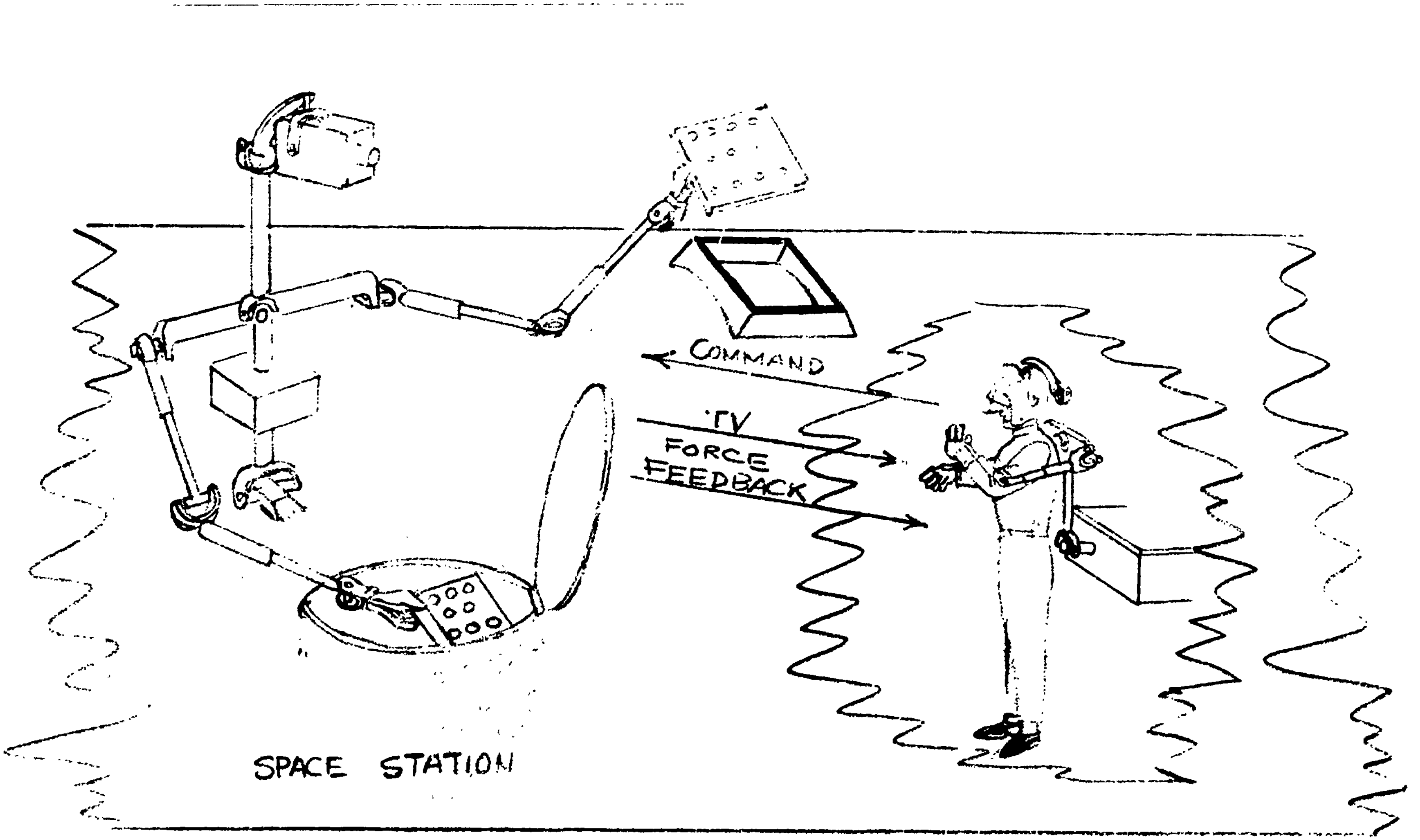


FIGURE 1 TELEFACTOR CONTROL SYSTEM

EXPERIMENT DATA SHEET

SPACE STATION WIRELESS POWER TRANSMISSION

1. Title:
   The title of this experiment is "Space Station Wireless Power Transmission."

2. Objective:
   The objective of this experiment is to demonstrate the feasibility of using microwave or LASER energy for wireless transfer of power from the Space Station to an unmanned substation.

3. Significance:
   The objectives of the currently proposed Space Station have been the subject of considerable review and planning. To assist in the fulfillment of these objectives unmanned substations have been proposed for use in performing various experiments. The "untethered" substation approach will most likely be used. This concept requires the use of a source of electrical power which must either be self contained on the substation or, as discussed in this proposal, transmitted from the Space Station to the substation. As proposed here, electrical power from a nuclear power generator on the Space Station would be converted to microwave or LASER energy, as shown in Figure 1. This energy would be transmitted to the substation and through suitable conversion would satisfy all substation electrical power requirements.

   Recent studies referenced below have been made to determine the feasibility of wireless power transmission, and were based on the present state of research and development in microwave power generation, transmission and reception. In one recent study (reference 1 below), a small helicopter was operated aloft, deriving its electrical power from microwave energy beamed from a ground-based generator with an overall efficiency of 18 percent. A beam-riding system is under development for this system which will attempt to use the microwave beam to control the distant helicopter as well as provide its electrical power.

The present availability and performance of microwave components point to the desirability of developing an experimental system for use on the Space Station. The practicality of wireless power transmission systems could then be explored.

Practical microwave power transmission would require better efficiency than is presently available for radar and communication systems. Reference 2 below recommends an idea for improving efficiency through forming a converging beam in an **ellipsoidal** transmission envelope. Reference 2 also explores the conversion of received microwave energy to D.C. power. It appears that semiconductor diodes are the most promising from the standpoints of efficiency and weight.

In addition to the microwave power transmitting system, a LASER system should be seriously considered for experimental use on the Space Station. Although the technology of high-power transmission by LASERS is in two early of a stage for conjecture on its practicality, the LASER does offer clearcut advantages over microwave. The transmitting **aperture** for a LASER beam is very small compared to a microwave antenna **aperture** and this same advantage applies to the receiving end of the system. In addition a much narrower beam can be transmitted, even for long distances.

References:

1. Brown, W. C.: Transmitting Power Without Wires, Science Journal, July 1966, pp. 51-56.

2. Robinson, William J., Jr.: The Feasibility of Wireless Power Transmission for an Orbiting Astronomical Station, NASA TM X-53701, February 15, 1968.

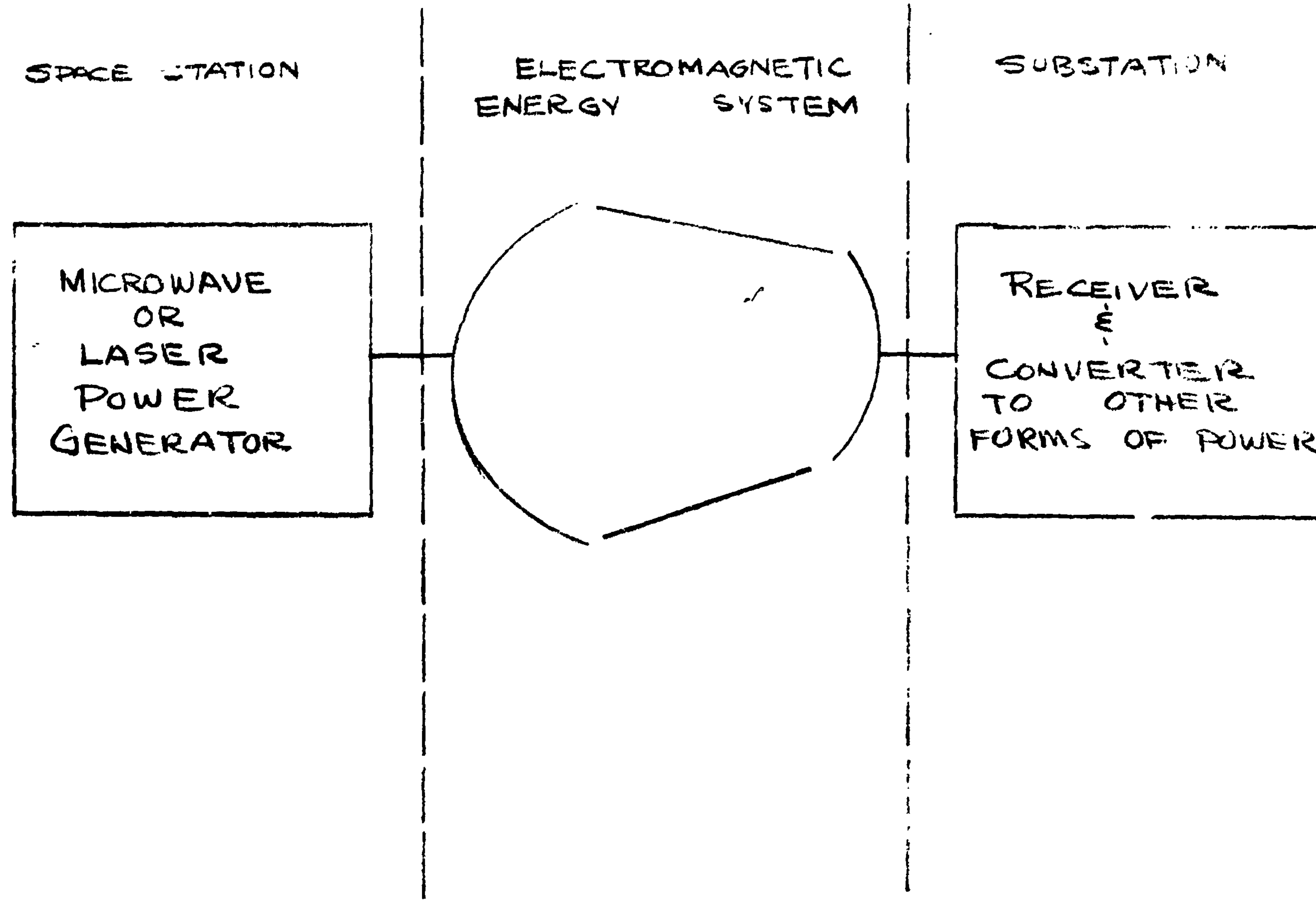


FIGURE 1 WIRELESS POWER TRANSMISSION SYSTEM