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CANDIDATE EXPERIMENTS

FOR

MANNED ORBITING LABORATORY

VOL I

REVIEW ON 31 Dec 1999

1 APRIL 1964

MANNED ORBITING LABORATORY
EXPERIMENTS WORKING GROUP

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Manned Orbiting Laboratory
Experiments Working Group

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FOREWORD

The selection of specific experiments is a critical item in achieving the Manned Orbiting Laboratory (MOL) objectives. The objective of the MOL experiments program is to establish a qualitative and quantitative measure of man's usefulness in space for performing military tasks.

This report, presented in two volumes, contains those experiments submitted to the MOL Experiments Working Group which survived preliminary screening, as well as those written by the Group during the evaluation procedure. The experiments in the report were written by personnel of the Air Force, the Navy, and the Aerospace Corporation. In addition, Army requirements were considered during the evaluation and selection process. The experiments are in three groups: Primary; Secondary; and Contributory, Deferred, and Marginal. The 12 Primary and the 18 Secondary experiments are in Volume I. The remaining experiments, numbered 31 to 176, are in Volume II (Part 1 and Part 2).

The Primary experiments are the best of those considered which directly assess the role of man qualitatively and quantitatively in performing military space tasks. They have been tentatively selected for inclusion in the MOL Program. The Secondary experiments are the best of those considered for advancing technology applicable to future military space missions or those which will gather scientific data of national importance. The Secondary experiments will be performed as crew and vehicle capabilities permit after the requirements of the primary experiments have been satisfied. The three types of experiments in the third class are: (1) Contributory - used or considered in writing or revising the Primary, Secondary, or Deferred experiments; (2) Deferred - considered fairly good, but not as appropriate to MOL as the selected experiments; and (3) Marginal - those which marginally passed the preliminary screening but which, upon further analysis, were not considered appropriate for MOL.

The classifications of all the experiments must be considered tentative. It is expected that with further study, additions, deletions, and modifications will be made to the list of selected experiments. In addition to possible changes in the list, the experiments themselves must be analyzed further to define equipment, test procedures, simulation techniques, and evaluation procedures before they, as a group, can serve as an adequate input to the MOL design.

ACKNOWLEDGEMENT

This report is the result of the efforts of many members of the DOD, the Aerospace Corporation, ICS (ITT) Corporation, and The Mitre Corporation, who participated either as panel members on the MOL Experiments Working Group, as consultants to the Panels, or as sponsors of experiments.

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1. INTRODUCTION

The primary purpose of reproducing this collection of MOL experiments is to insure the availability of the experiment data to technical personnel for further detailed analysis. The experiments included in this report are generally identical to the ones submitted to the MOL Experiments Working Group. Very little editing and retyping was accomplished, since improvement in technical content would be negligible.

2. EXPERIMENT SELECTION PROCEDURE

The selection of the experiments in this report has been the result of across-the-board DOD participation. Requirements submitted by the Army, Navy, and Air Force, in support of their respective missions have been analyzed by a composite Experiments Working Group. The Experiments Working Group was formed under the direction and guidance of the Air Force Space Systems Division to accomplish the task of determining the preliminary experiments package. This group was organized into four functional panels: observation, mission analysis, bioastronautics, and general scientific.

The functional panels gathered proposed experiments from various contributors from within the DOD and industry. These experiments were analyzed to determine feasibility, applicability to the MOL program objectives, and compatibility with the selection criteria. Of the 405 input experiments, 164 were recommended by the panels for further consideration. In order to define a meaningful set of experiments which would provide an assessment of man's ability in military space tasks, it was necessary to analyze each military space mission and determine how man could be used to enhance the mission capability.

The experiments recommended by the panels were categorized into technical areas and reviewed by committees comprised of technical experts in the particular specialities as follows: optics, IR/UV, radar, communications, ELINT, maintenance/assembly/and deployment, physical sciences, extra vehicular, bioastronautics, and applied mechanics. These committees analyzed the experiments to determine common objectives and common equipment which might satisfy more than one experiment objective. As the result of elimination and combination, the technical committees identified 59 experiments. These 59 experiments were then further examined by an integration board to determine compatibility with the preliminary vehicle concepts. A resulting package of 50 experiments was reviewed by SSD/Aerospace from which 30 experiments were selected and classified as Primary and Secondary experiments.

3. CRITERIA FOR SELECTION OF EXPERIMENTS

The following criteria was used to evaluate the experiments presented in this report.

a. The MOL is a space laboratory, not an operational vehicle.

b. The experiments should be focused upon the role of man rather than specific equipment.

c. The proposed experiments should consider the entire spectrum of possible military applications.

d. Photography of reconnaissance quality will not be used to record or verify experiments.

e. Maximum use should be made of ground simulations, aircraft tests, and existing space programs for testing.

f. Experiments selected for MOL should be those that cannot be achieved in any other way, or which constitute a proof test of experiments primarily conducted in ground simulations or aircraft tests.

g. The cost of the experimental program should be minimum, making use of existing equipment, and provide a comprehensive and meaningful test effort.

h. Where new or modified test equipment are required, the equipments must be technically feasible of attainment with minimum technical risk and readily available within the MOL program schedule.

i. Experiments which contribute to the development of military technologies and scientific experiments which are of national importance may be considered as secondary experiments, particularly if they provide an assessment of man's utility.

INDEX FOR VOLUME II

Following is a subject index for the experiments in Volume II, numbers 31 through 176. In the index, the experiments are referred to by number only. The Table of Contents, which appears in both volumes, may be consulted for experiment titles. It may be noted that experiment number is on the top of each page of each experiment.

ACQUISITION AND TRACKING OF GROUND TARGETS

I. TEST OBJECTIVE

The objectives of the experiment are to evaluate man's performance in acquiring pre-assigned targets and precisely tracking them to an accuracy compatible with the requirements for precise IMC determination under various conditions of target type and lighting. Additionally, since the pre-assigned target acquisition function would most probably be accomplished by providing the astronaut with some reference photo (of modest resolution) of the target area, this experiment will evaluate the astronaut's proficiency in accomplishing the acquisition as a function of the quality (resolution) of the reference photo, again under various conditions of target type and lighting.

II. DESCRIPTION OF EXPERIMENT

A. Experimental Equipment

The equipments required for this experiment include a direct viewing pointing and tracking telescope, a tracking servo system, a general purpose computer, and a coupled camera. The functions and general characteristics of each of these equipments are described in the following subsections.

1. Direct Viewing Pointing and Tracking Telescope

A pointing and tracking telescope, similar in nature to an optical bombsight, is required. Additionally, since wider fields-of-view at less magnification are desirable during the acquisition phase, and narrow fields-of-view with higher magnification are desirable during the tracking phase, the optical configuration should be capable of being zoomed over a range from approximately 6 x to 100 x. An optical element to provide scanning in both azimuth and elevation is required, as are a set of manually controlled crosshairs.

2. Tracking Servo System

The function of this system is to provide for adjustments in the slewing rate of the scanning element during the tracking mode to insure that the target does not leave the field-of-view of the pointing and tracking telescope because of differences in the nominal slewing rate (based on predicted LOS angular rate) and the actually required slewing rates. Two possible techniques for achieving these adjustments can be considered: a direct servo feedback to the scanning element based on motions with respect to the center of the field-of-view, of the manually controlled crosshairs which are moved by the astronaut to keep them on the target, or continuous recomputation of the line-of-sight angular rates by the general purpose computer with signal being provided to the scanning element drive to make adjustments in the slewing rate.

3. General Purpose Computer

This computer may be utilized in conjunction with the tracking servo system, as discussed above, and is utilized in the computation of the expected line-of-sight angular rate at the instant a high resolution photo would have been taken. In accomplishing the latter, inputs are provided from the tracking system, based on motions of the scanning element and manually controlled crosshairs, and from the vehicle guidance and navigation system with respect to angular motions of the vehicle.

4. Coupled Camera

The purposes of this item are to verify that the astronaut has acquired the proper target and to permit evaluation of the man's performance in accomplishing the tracking function. During the tracking run, periodic photos will be taken, with the manually controlled crosshairs superimposed on the image, to determine the operator's proficiency in keeping the crosshairs on the target. Analysis of these photos will enable determination of the accuracy to which the required IMC would have been determined. On-board film processing equipment may permit analysis of the test results and thereby limit communication/data retrieval requirements.

B. Test Procedures

Pre-selected targets, which could include military airfields, operational missile sites, missile flight test development centers (e.g., AMR), naval bases, and specially prepared target sites, would be acquired and tracked by the astronaut. To evaluate his proficiency in target acquisition, the reference photos of the various targets would be intentionally varied in quality. Repeated tests would be made to evaluate the astronaut's proficiency under varying conditions of lighting, and the target areas would be so selected as to provide various background and color conditions.

The orbital altitude of the spacecraft for these tests is not especially critical and could be anywhere within the range from approximately 100 to 175 n. mi. Orbit inclinations of approximately 40° may be required to insure that a sufficient number of target sites are available within the Z. I. There are no presently identifiable requirements for sun synchronous orbits, in fact, non-synchronous orbits may be desirable to permit repeated acquisition and tracking of the same target under various lighting (times of day) conditions.

A typical experiment scenario might be as follows:

(a) The astronaut aligns the vehicle in yaw by pointing the PTS at the ground underneath him. A grid is superimposed in the field-of-view and a zero azimuth angle is set on the scanning element. The grid line will be parallel to the vehicle longitudinal axis, and yaw alignment errors will be indicated by target points drifting across the grid lines instead of parallel to them.

(b) Based on knowledge of orbit ephemeris astronaut would at appropriate time scan the land area within which he expects to find the target using his direct viewing pointing and tracking scope at low magnification.

(c) The astronaut attempts to match some segment of that land area with the reference photo of the target area.

(d) Upon doing so, the astronaut centers the particular target in the field-of-view of the telescope, increases the magnification of the telescope, and initiates the tracking mode (the astronaut may have to wait for accomplishment of a roll maneuver between the time he positions the target in the center of the field-of-view and the time the tracking run is initiated).

(e) During the tracking run, the astronaut attempts to keep the crosshairs of the pointing and tracking telescope positioned on the target.

C. Evaluation Procedures

The preferred approach is the utilization of the coupled camera to take periodic frame photographs during the tracking run, as discussed earlier.

III. IMPORTANCE OF TEST (RATIONALE)

Future reconnaissance missions may require the capability to obtain very high resolution photographs, for example, for technical intelligence purposes. Very high resolution photographs can, in theory, be obtained if a sufficiently large optical system is provided, and if precise image motion compensation can be accomplished. A potentially promising technique for the precise IMC determination involves the utilization by an astronaut of a direct viewing pointing and tracking telescope. With this, the astronaut would acquire the target of interest (probably pre-assigned), and then precisely track it for a period of approximately half a minute prior to the taking of the very high resolution photo. The tracking information (i.e., the changing line-of-sight angles with respect to the spacecraft axes) would be provided to an IMC computer which, with additional angular references and vehicle angular rate data provided by the spacecraft navigation and guidance subsystem, would then precisely compute the expected line-of-sight angular rate at the time the photo is to be taken. The computer would then provide signals to the film drive servo of a very high resolution optical system to accomplish the IMC. Through such techniques it is expected that IMC can be accomplished to an accuracy significantly better than 0.2%, perhaps as good as 0.01%, though it is obvious from the above scenario that the precision attainable is quite dependent on the performance of the human operators.

IV. VEHICLE REQUIREMENTS DATA

A. Power

Power requirements are imposed by the tracking servo system, the general purpose computer, the coupled camera, and the film processing equipment. Power levels are not expected to be high, most likely on the order of 200 watts.

B. Stabilization

In an operational mission, the primary requirement for stabilization arises from the necessity of having the target pass through the field-of-view for the reconnaissance sensor. For this MOL experiment, however, stabilization requirements are not critical, and angular positioning of the spacecraft to several degrees with residual angular rates of 0.1 degree/sec. would be quite sufficient.

C. Weight (Preliminary Estimates)

Pointing and tracking telescope (including tracking servo and coupled camera)		400 #
General purpose computer		50 #
Film processing equipment		75 #
	Total	525 #

D. Volume (Preliminary Estimates)

Pointing and tracking telescope - clear volume approximately 18" diameter by 6 feet in length

General purpose computer - 1.5 cu. ft.

Film processing equipment - 1.0 cu. ft.

E. Aperture Requirements

A viewing aperture of approximately 12 inches in diameter will be required. This should be a direct opening to the space environment.

F. Clear Field-of-View

With the optical axis of the telescope in the vertical direction, a clear field-of-view downward, $\pm 60^{\circ}$ in elevation from the local vertical, and forward, $\pm 90^{\circ}$ in azimuth with respect to the orbital velocity vector, is required.

G. Miscellaneous

If on-board processing and analysis of the coupled camera photos is anticipated, then a suitable working table with proper lighting will be required. Additionally, typical photo interpretation equipment, (e.g., microscopes with mensuration, etc.) must be provided.

V. SIMULATION PROGRAM

A. Pre-Phase I

Prior to the initiation of Phase I, it is recommended that a study relative to the detailed definition of the experimental IMC subsystem be conducted (see Section VI-A). However, realization of the objectives of such a study and the associated design effort, are dependent on the knowledge of certain human performance factors. Therefore, a separate concurrently running study is also recommended during which certain elemental simulations will be performed. Among these are those which will provide data on:

(a) Proper magnification, fields-of-view, and scan rates for target detection/acquisition

(b) Preferred manual techniques for target re-acquisition after discontinuation of automatic scan mode

(c) Preferred magnifications for precise tracking

(d) Desirable design approaches and techniques for precise tracking.

B. Phase I and Subsequent

During the developmental phase of the MOL program the various portions of the experiment would be simulated to insure a high probability of success for the MOL experimental mission, to verify the experimental concept, and to evolve design refinements for the experimental equipment. Initial simulations of the acquisition portion of the experiment might be accomplished in ground-based facilities, though later simulations should be performed using aircraft to obtain more realistic conditions of target characteristics, background, color, and lighting. Simulations of the tracking function can, however, best be accomplished in ground facilities as aircraft cannot provide a suitable stabilization environment.

VI. EXPERIMENT DEFINITION

A. Pre-Phase I Studies

While the concept of manned tracking for precise IMC determination has been explored in sufficient depth to establish general validity, it is particularly important to conduct a study relative to the detailed definition of the experimental IMC subsystem, including the direct viewing pointing and tracking telescope, the tracking servo, the coupled camera, and the general purpose computer. This study will include consideration of:

(a) Pointing and tracking scope optical configuration

(b) Coupled camera and film processing equipment design

(c) Tracking servo system analyses and design

(d) IMC computational requirements and associated computer specifications

(e) Vehicle interfaces

(f) Functions of man with respect to set-up, operation, and maintenance of the IMC sub system.

B. Phase I and Subsequent

The aforementioned study will have defined the experimental IMC subsystem in sufficient depth to permit awarding of Phase I development contracts concurrently with the MOL vehicle developments. Conducting these developments simultaneously will insure proper coordination of all interfaces.

VII. FUNDING

A. Pre-Phase I

1. IMC Subsystem Study - 1 contractor for 3 months - $200,000 total.

2. Tracking, Scanning, and Data Interpretation Study - 1 contractor for 3 months - $100,000 total.

B. Phase I and Subsequent

Funding for this experiment is expected to be in the 10 to 25 million dollar range, these figures including the development and fabrication of the experimental equipments.

VIII. PARTICIPATING AGENCIES

Sponsor: AFSSD/Aerospace

Experiment No. P-2

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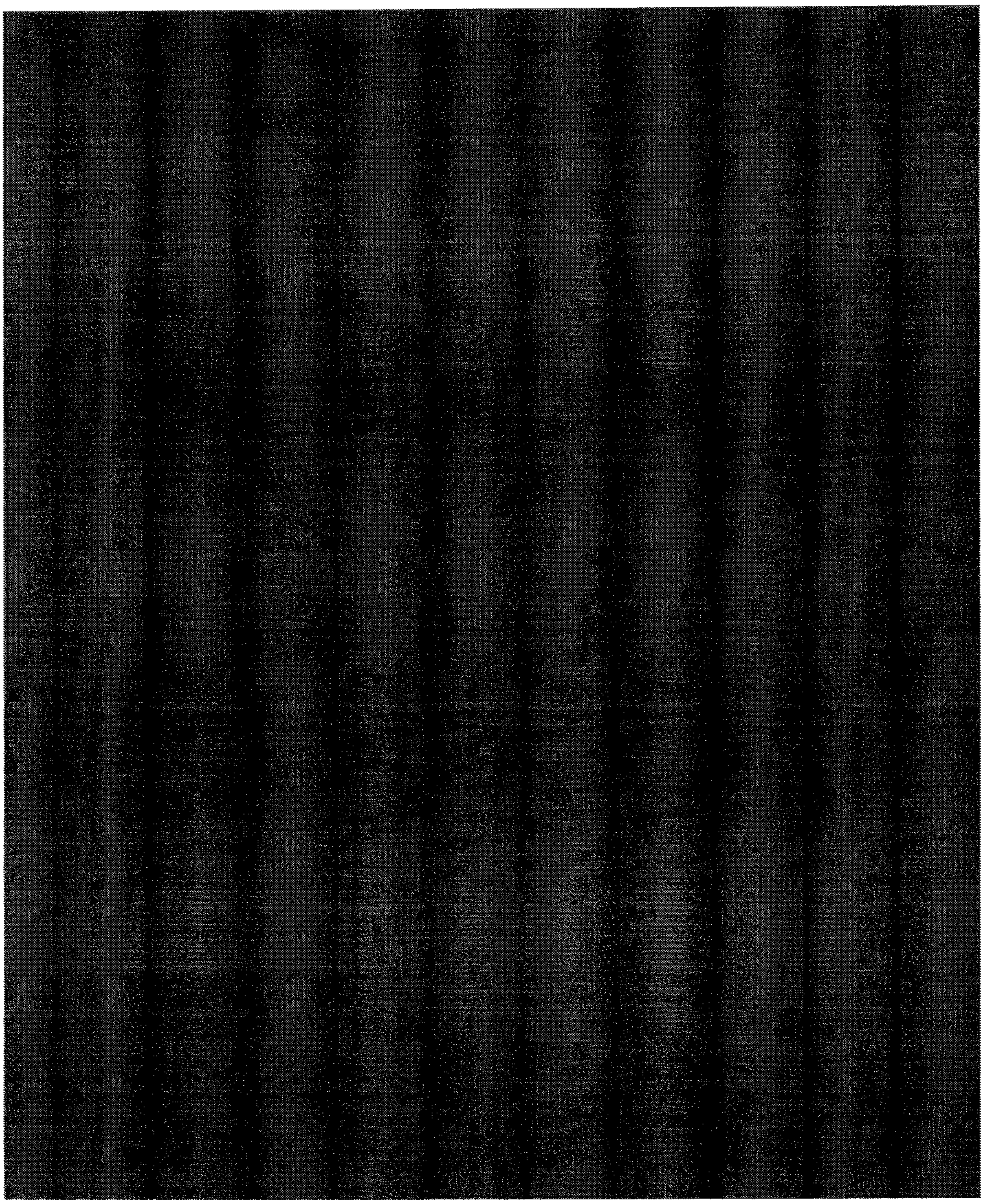
Exp No. P-2



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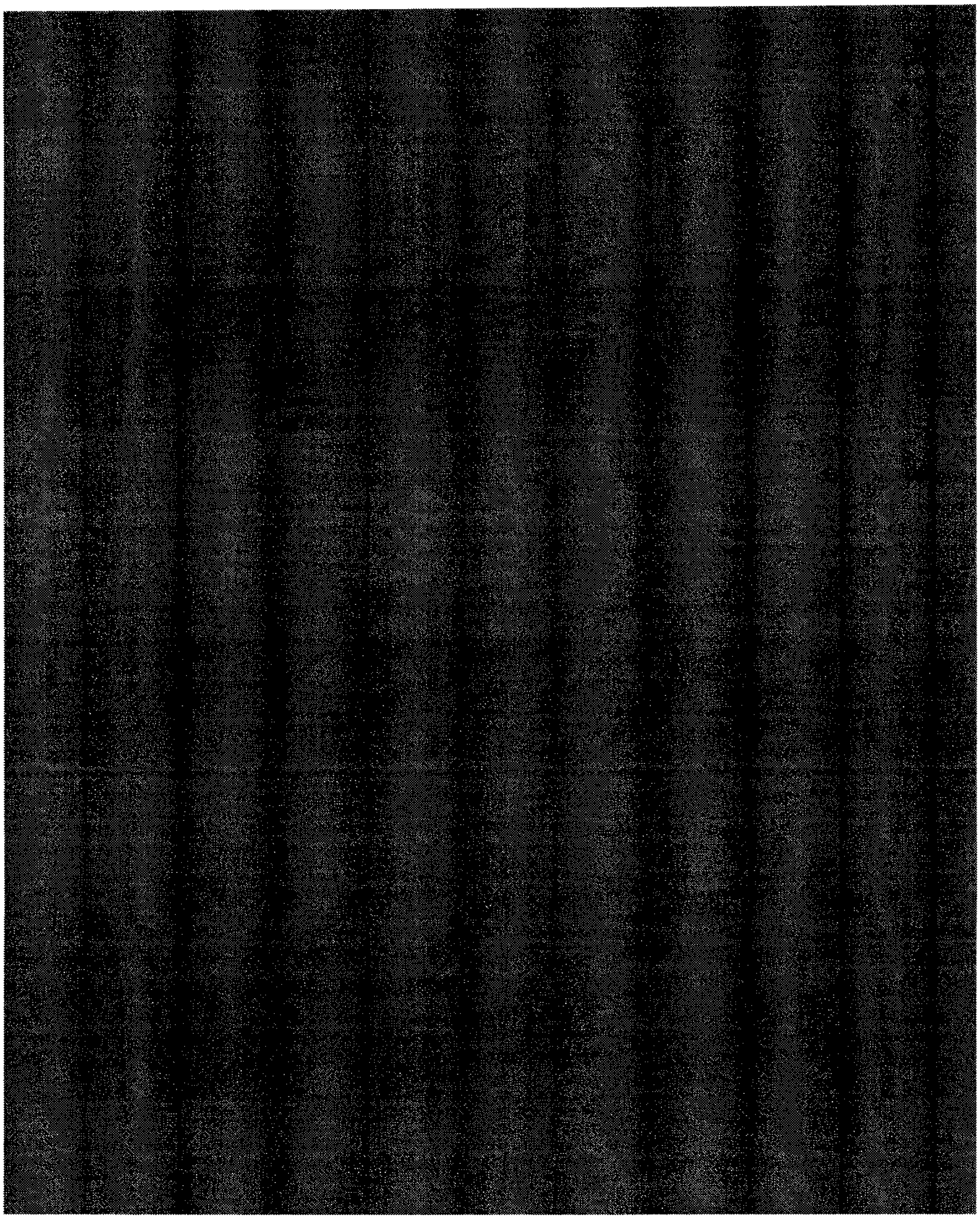

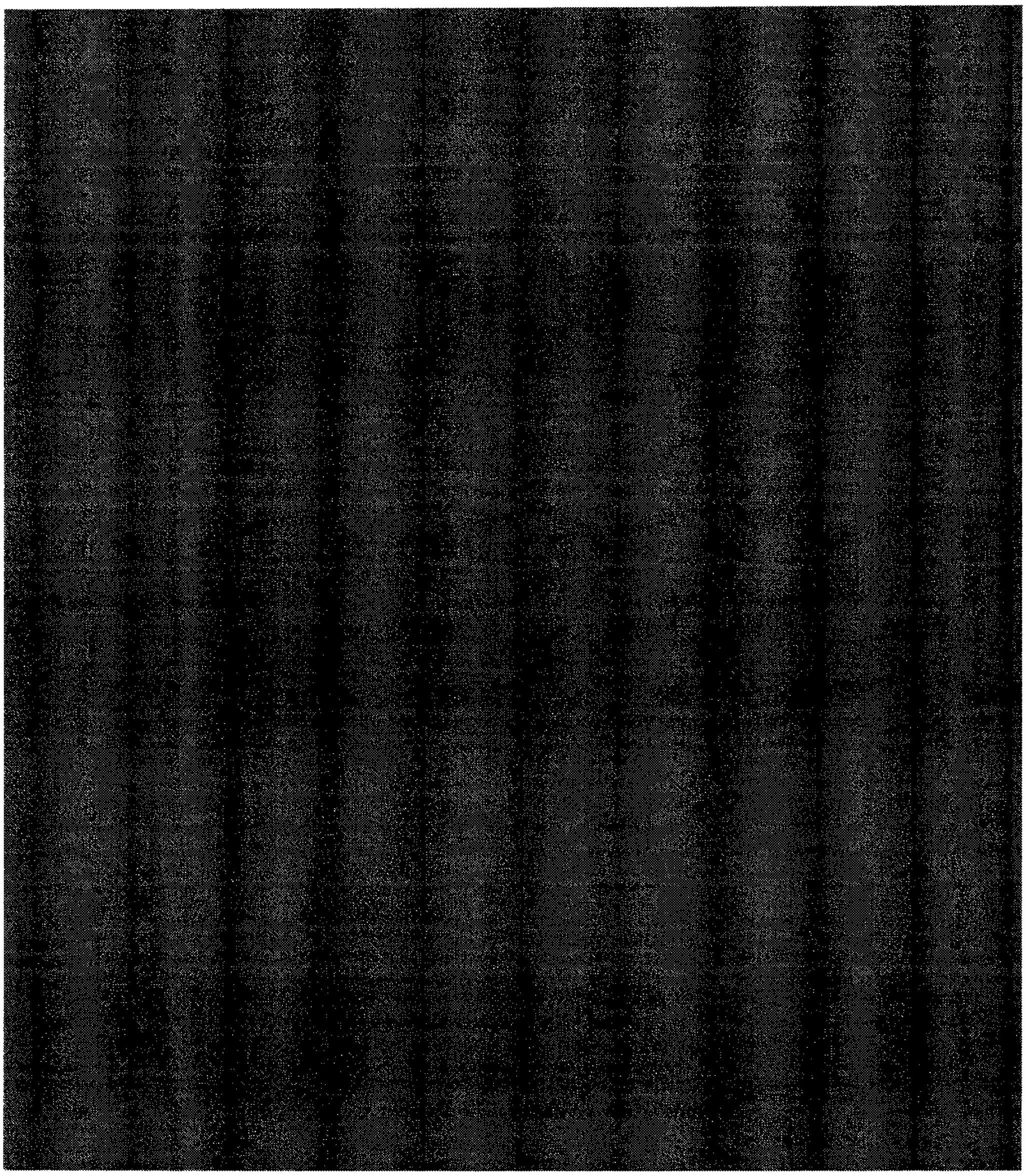

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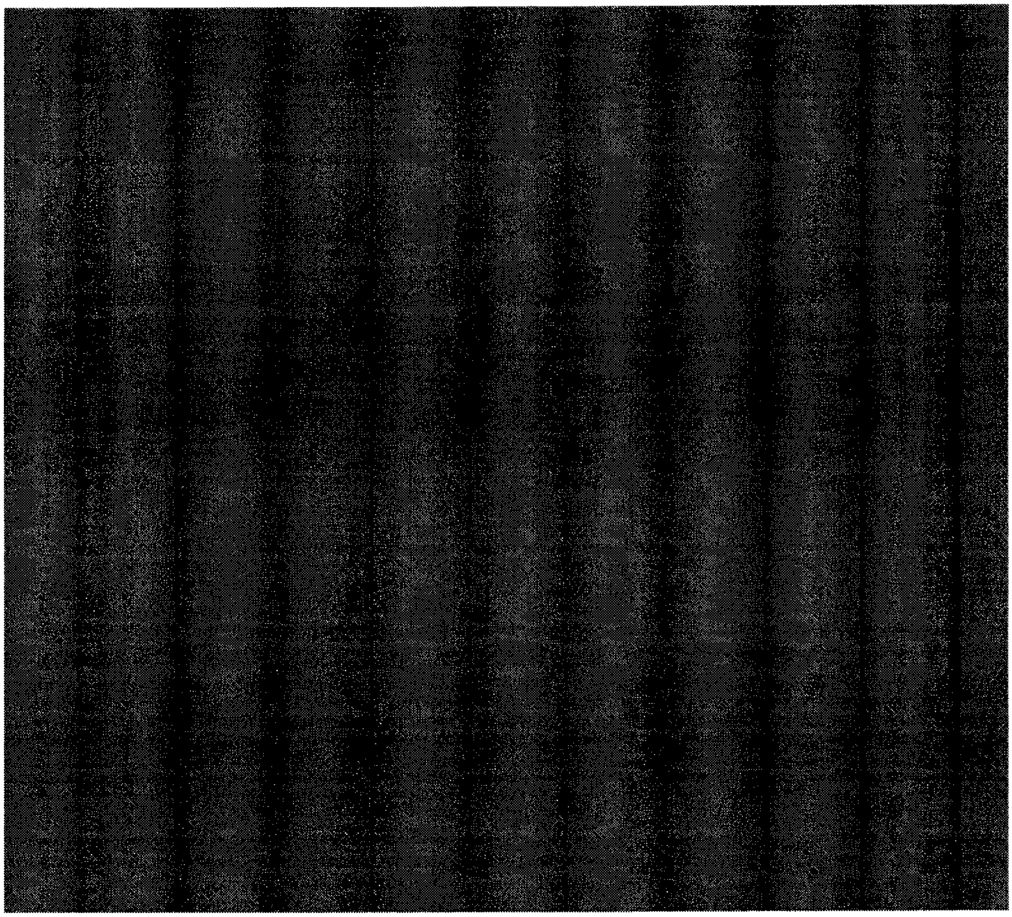

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DIRECT VIEWING FOR GROUND AND SEA TARGETS

I. TEST OBJECTIVES

The first objective of this experiment is to evaluate the astronaut's proficiency in detecting ground targets of opportunity under varying conditions of target type, lighting, and background, and to define preferred scanning techniques thus optimizing the percentage of the land area which may effectively be examined during a given orbital pass.

The second objective of the experiment is to determine the detectability of ships and surfaced submarine targets under varying conditions of target size, color, contrast, sea state, sun angle and atmospheric transmission.

The third objective of the experiment is to evaluate quantitatively man's ability to perform ship classification, and possibly actual identification, from orbit using varying degress of optical magnification. The end result of this part of the experiment would be the determination of probability of correct classification versus time duration of observation for various classes of ships, light levels, sea states, levels of atmospheric contrast transmittance, and levels of resolution.

It will be a specific objective of the MOL program to extend the knowledge gained in the Mercury and Gemini programs relative to manned visual observations of surface targets from near-earth satellites. In contrast to those programs, the MOL will contain optical equipment capable of presenting the astronaut with a magnified view of the ground and ocean surface, and thus will permit studies of detection probability of targets of smaller size and lower contrast than those visible to the naked eye.

II. DESCRIPTION OF EXPERIMENT

A. Experimental Equipment

The equipments required for this experiment include a direct viewing pointing and tracking telescope, a coupled camera, and a general purpose computer. These equipments are essentially the same as those already described in Experiment P-1, except that provision may have to be made for automatic scanning operation of the direct viewing system. The astronaut will also utilize equipment for direct voice recording when scanning with the unaided eye.

The telescope will be fitted with filters, both chromatic and polarizing, in order to minimize contrast attenuation for the ship and submarine experiments. In addition, the telescope will contain a reticle designed to provide two orthogonal pairs of "crosshairs" which are brought together to provide direct indication of ship length and beam width. This measurement together with the observer's impression of general class of ship, recorded verbally or digitally, comprise the basic data required on the spacecraft.

B. Test Procedures

On selected orbital passes, the astronaut would either operate the direct viewing system in an automatic or manual scanning mode or scan with the unaided eye and attempt to detect certain types of ground targets of opportunity (see Section D following). The orbital passes would be so selected as to provide various conditions of lighting. Repeated tests with the direct viewing system would be made at various magnifications and scanning rates to determine the percentage of targets detected. In certain cases, the astronaut would carry out those procedures necessary to obtaining a frame photograph of the detected target to obtain a time index of his performance, though the photograph so obtained would not be of reconnaissance quality. The astronaut would note by means of direct voice recording any features of interest observed while scanning with the unaided eye. Orbit requirements for the experiment are the same as those discussed in Experiment P-1

Simulation, aircraft flight tests and Gemini experience will be required to rigorously define the ship detection experimental test procedures. In general, however, the procedure will involve placing target vessels in otherwise deserted ocean areas which lie near or under the MOL orbital path during local daylight hours. The astronaut will be given pointing instructions (or approximate target geo-coordinates, depending on computer-servo implementation) and will be required to perform a visual search of the prescribed area of the ocean surface during the fly-by. Parameters to be measured include detection capability as a function of target ship size, contrast (color) speed (wake) line-of-sight angle, sea state, atmospheric condition (contrast transmittance) magnification, filtering, etc. Additional tests will include search for targets of opportunity in densely populated shipping areas, observation of Kepplerian wakes from cooperative submarines, and recording of results with the coupled camera and/or such other means as are appropriate to both the operational and scientific aspects of the detection tests.

The targets for the ship classification and identification experiment should include as many classes of ships as possible, both naval and merchant. The naval ships should include surfaced submarines, destroyers, landing ships and carriers. The merchant ships should include tankers, dry cargo ships, passenger ships (esp. troopships), and trawlers. The naval ships would be deployed in selected ocean areas having low probability of cloud cover. A limited number of merchant vessels should be provided for a controlled experiment, augmented by experiments on normal ocean traffic using low flying aircraft (or other means) to provide identification simultaneously with spacecraft overflight. Low inclination orbits are acceptable; regions off the southern coasts of the U.S., Mexico and near Hawaii will provide suitable conditions. Atmospheric conditions in the test areas would be monitored.

A scenario could be envisioned as follows:

(a) Following the detection experiment, the astronaut selects a target, slews the scope to put the target into the field-of-view at low magnification.

(b) The scope is zoomed as rapidly as possible (without losing the target) to a specified magnification.

(c) The measuring "crosshairs" are adjusted to just touch the extremities of the target, and these measurements are recorded automatically.

(d) The astronaut spends a specified time examining the target and records his impression of ship class, of the heading of the ship, and any uniquely identifying featues he can discern.

C. Evaluation Procedure

The particular evaluation procedures to be utilized in connection with the ground target experiment are based upon certain assumptions relative to the scanning methodology to be employed. While it would be desirable if complete coverage of the land area being traversed could be achieved through rapid, automatic scanning with the direct viewing system, practical considerations of minimum allowable dwell times on a particular land area to permit the astronaut to detect targets within it may require that only a limited number of selected areas be examined on any overflight. For example, areas in and around known cities, military installations, or railroads could be examined, while rural areas of those geographical in which there is a small probability of detecting anything of potential interest would be neglected. Targets of opportunity would generally be defined as items or activities which are relatively impermanent in nature (e.g., new aircraft types or airfields, mobile systems, moving railroad trains, etc.).

Therefore, in conducting the experiment with the direct viewing scope, the astronaut would be instructed to look for the aforementioned type targets of opportunity within pre-selected areas. Within any given target area, the presence of a number of such targets could be varied orbit-to-orbit or day-to-day, to provide a reasonable measure of the astronaut's target detection capabilities. Where targets do exist and the astronaut would have been motivated to take a photograph, he would voice record what he observes, this data being correlated with knowledge of the make-up of the target area at the time of the particular orbital pass.

In the case of scanning with the unaided eye, somewhat larger areas of terrain can be covered; however, because of the poorer resolution, the features of interest are necessarily of fairly large dimensions. Important features or activities which could be detected include construction of new roads, preparation for new airfields or missile sites, etc.

In conducting the experiment with the unaided eye the astronaut would be instructed to scan a pre-selected area and describe by means of direct voice recording, all features of interest observed within the area. This data could then be correlated with the known make-up of the area at the time of the orbital pass.

Among the experiment parameters to be varied are the dimensions of the land areas to be scanned, the lighting (time of day) conditions, the magnifications of the telescope, and the types of targets to be detected.

The experiment evaluation for ship detection will largely rest on the comparison of astronaut sighting reports, including geo-referenced location coordinate data available from the computer output, with actual target ship presence and location. In the general case, each ship detection experiment will be coupled with a ship-identification experiment which will verify the detection and ensure against false sighting reports. The principal evaluation procedure will involve scaling of MOL-astronaut results in ship detection against prior simulation and aircraft testing results for verification and correlation of results.

Evaluation in the case of the ship classification and detection experiment would be performed by direct comparison of the observations, measurements, and interpretation thereof, with the (known) ship targets. In addition, pictures should be taken with a coupled camera to provide a permanent record.

III. IMPORTANCE OF TEST (RATIONALE)

The general reconnaissance mapping of large land areas for purposes of detecting long-term developments and deployment of known weapon types can best be accomplished by panoramic cameras. However, a valuable adjunct in this mission may be the astronaut's ability to detect targets of opportunity of potential interest and perhaps take frame photographs with resolutions somewhat better than could be provided by the panoramic cameras. To accomplish this, the astronaut could utilize a pointing and tracking telescope in an automatic or manual scanning mode. Upon detection of a target, the astronaut would over-ride the automatic scan mode, re-acquire the target, place and retain it in the center of the field-of-view, increase the magnification of the system, and obtain a frame photograph with a coupled camera. In addition, the astronaut would perhaps provide important information by scanning larger areas of the terrain with the unaided eye and noting (by voice recording) any features or activities of interest. The operational utility of such a capability is, of course, dependent on the types of targets which can be detected under various conditions of lighting and background, and the percentage of the land area which can be effectively scanned during a given orbital pass.

The primary military significance of the planned ship detection experiments is the acquisition of data regarding the optical detectability of surface ship targets and consequent determination of optimum means for achieving an operational capability for this mission from space. As a result of several decades of experience and many years of study and experimentation, the U.S. Navy has begun to acquire a systematic body of knowledge about the detection of surface ships and surface phenomena from aircraft, and many studies have been performed to translate this knowledge and experience to space platform observation altitudes. It is known, for instance, that the ocean's surface viewed from space has a widely variable contrast (luminence) depending on atmospheric conditions, sea state, sun angle, elevation angle and viewing spectral wavelength. In the optical spectrum, the probability of detection of ship targets in open ocean by unaided visual search in real-time from a low-altitude satellite (such as MOL) is estimated to be relatively low under average conditions. Assuming "clear" skies (no obvious cloud cover), some pointing or locating information (such as elint, radar, IR, pronounced wakes in calm seas, or intelligence data from ground sources), would appear to be required if the probability of visual detection were to approach unity. The aforementioned estimates of visual detectability are, however, somewhat subjective and a carefully planned program of experimental investigation could indicate better than the estimated capabilities, particularly if only localized areas of the oceans were to be examined. The MOL experiment on ship detection will concentrate on the determination of man's abilities as a sensor when aided by optical devices of varying characteristics. The astronaut's functions will include visual observations of both open ocean areas and pre-designated "salted" areas for surface ship targets using the pointing and tracking telescope installed for other experiments. Because of the widely variable magnification and spectral response of this instrument, a variety of search and detection techniques may be employed, and measurements of detection probability for each may be made.

In addition to the detection and surveillance of surface shipping, the MOL experiments will involve search for, and investigation of, such other surface phenomena as may be observed from orbital altitudes with the available optical equipment. These could include, but are not limited to, smoke detection, submarine detection by Keplerian Wave and "clinker" effect, sea state detection, oil-slick detection (significant in sea-rescue efforts) etc.

A vital factor in determining the value of ocean surveillance is the degree to which ships can be identified. If the name of the ship or some other unique feature can be seen, then it is quite clear that the surveillance problem is reduced to one of moving markers on a plotting board. At the other extreme, if only position of the ship is known, then a very complex system is required; the ships must be scanned and located very frequently if ambiguity is to be eliminated, and a large-scale computer is required to correlate this massive flow of data with other sources which give ship identifications, ports of origin and destination, cargo, etc. One means of approaching a direct, unique identification is through the use of an optical system which provides man with sufficient ground resolution to be able to classify the ship within a small group of possible candidates. This would still require some data processing, but it would be very small compared to the location-only approach. Ground resolutions of the order of 5 to 10 feet appear to be appropriate to the classification problem. Man's function is to perform real-time pattern recognition, yielding an indication as to which targets should be followed up by aircraft or sea-based forces, as well as data for updating large scale surveillance systems.

IV. VEHICLE REQUIREMENTS DATA

Reference is made to the corresponding discussion under Experiment P-1. No significant differences in spacecraft requirements from those discussed therein are presently identifiable with the exception that a viewing post for direct scanning of the terrain with the unaided eye will be required.

V. SIMULATION PROGRAM

A. Pre-Phase I

The pre-phase I simulation study described in Experiment P-1 will also provide data applicable to the design of the direct viewing telescope for use in this experiment.

B. Phase I and Subsequent

During the development phase of the MOL program scanning with the direct viewing system (pointing and tracking telescope) will be simulated in aircraft. A proper selection of aircraft altitude and velocity will enable exact simulation to be made of the apparent ground motion beneath the satellite. The magnification and field-of-view of the aircraft simulation equipment can also be selected to reproduce the satellite condition. Flights will also be made over pre-selected areas of the oceans in which a variety of ships have been positioned, these flights being made under varying conditions of lighting, atmospheric transmission, etc. Identification of specific surface ship targets will be included in the simulation procedures.

VI. EXPERIMENT DEFINITION

A. Pre-Phase I Studies

Reference is made to the corresponding section in experiment P-1.

B. Phase I and Subsequent

Reference is made to the corresponding section in experiment P-1.

VII. FUNDING

A. Pre-Phase I

No additional funding is required over that stipulated for experiment P-1.

B. Phase I and Subsequent

An incremental cost of from 1 to 10 million dollars, over that associated with experiment P-1 is associated with this experiment. This increase is for the cost of aircraft operations and ship deployments for the simulation program and the development and fabrication of a "scaled" telescope system for the aircraft simulations.

VIII. PARTICIPATING AGENCIES

Sponsor. AFSSD/Aerospace

ELECTROMAGNETIC SIGNAL DETECTION

I. Objective:

This experiment will validate man's capability for making semi-analytical decisions and control adjustments to optimize the orbital collection of intercept data from advanced electromagnetic emitters.

Automatic collection systems operate at high-speed, have high-intercept probability, and are excellent for generating location or deployment of emitters in dense or dangerous environments. Automatic systems have certain inherent limitations, including: quantizing, with limited logic and possible loss of intelligence, of intercept parameters to conserve data storage in long missions; need for frequent readout or recovery for wide-band analog data; sensitivity loss to reduce false alarms; and tendencies to "lock-up" program logic on strong or saturating signal conditions.

Semi-automatic manned systems, although inherently limited by man's slow time constants and requiring visual/aural displays, have certain potential advantages: optimum adjustment of collection system controls; lower false alarm threshold; recognition of anomolous signal characteristics; conservation of wide-band recording media; real-time adaptive redirection of mission objectives, plus over-ride of logic routines; evaluation of faulty equipment, maintenance, adjustment and calibration.

The application of these capabilities to increasing advanced emitter intercept quality, for maximal content extraction per intercept, is the basis of this experiment.

A natural consequence of this experiment will be the factual base for development of new or improved program logic usable in future automatic system development. Each sophisticated emission intercept and its dissection, analysis and interpretation are individual laboratory-like experiments, using flexible instrumentation to encompass many probabilities; manned guidance for this electronic capability is initially essential, prior to sufficient understanding necessary to logic system development.

II. Description of the Experiment:

a. Experimental Equipment:

The on-board equipment will be representative portions of militarily useful intercept systems designs, with sufficient frequency difference to introduce diversity of operating decisions and actions. Since the MOL time period considered is a major segment of normal advanced development cycles, it is anticipated that extension to space compatible designs from present development programs is quite feasible.

Capability will exist, over the selected frequency ranges, for fixed and steerable antennas, automatic and semi-automatic receivers, signal-sorting and processing equipment for operator alerting to exotic signal conditions, measurement and display console and record-playback storage equipment. Suggested frequency regimes are 400-900 mc/s and a choice of C-band or S-band. (Actual coverage should be studied relative to development trends in emitter design and use, circa 1970).

Sensitivity of reception equipment must be that capable of operating to the horizon, at orbital altitudes of approximately 150 n. m., against radiators of 10kw - 100kw average power, whose effective minor lobe power may be -20 to -30 db relative to the main lobe. Bandwidths must be commensurate to the spectra of frequency agaility systems anticipated in the 1968-1970 time period.

Antenna structures must provide general coverage patterns, consistent with orbit pattern chosen, for acquisition and high intercept probability in favored directions. Possible inclusion is considered of steerable (electronically phased or mechanical) structures to prolong time of intercept or improve location fixing. Specific studies (see below) are indicated on this problem.

The complexity and inclusion of the automatic (environment scanning) reception and processing equipment will be a function of the breadth of the mission objective, in the operational context, required of the console operator. Simulation experiments (see below) must provide guidelines for this decision. One may hypothesize that more limited objectives and highly pre-instructed operators will allow reduction of signal sorting equipment.

Measurement and display console equipment, and associated recording playback capability, will be somewhat independent of frequencies of reception. Included in this equipment should be: frequency activity monitoring display, frequency resolution display (associated with selectable bandwidth choices of the semi-automatic receivers), slow and fast time base modulation envelope displays and such alpha-numeric readouts as are essential to operator alerting. Recording capability must include wideband (4-6 mc/s) analog video tape, multi-track digital and narrow band aural recording for control status, low-frequency signal modulation and comment. Frame-by frame photo recording may also be desirable for post-real-time, partial analysis or ground examination.

Additional supporting equipment needed in the performance of the experiment are ground and sea based emitters as sources of specific known signals. Since emphasis of this effort is on sophisticated emitters, such targets must include frequency agility, long pulse internal coding, and other intentioned parameter modulations or complex scan modes. Use of vessel-based emitters under U. S. Navy or USAF control (i. e., missile launch cruisers and tracking vessels such as ARIS) can provide fairly sophisticated targets in light density environments.

Ancillary equipment such as data readout and/or recovery systems are not dealt with here, as it is presumed they will be a necessary subsystem to the general performance of the overall program. Extended requirements imposed by this experiment must be injected as a result of more specific definition of the program and separate study.

b. Test Procedure:

Certain assumptions are necessary to development of procedures for the experiment. Orbit inclination must be chosen to give some continuous over-flight of ZI territory, or other areas well controlled, accessible and in good communication to the MOL Flight Control. The ability to establish known signal environments, under control, is dependent on such choice. Inclination of greater than 30° is essential. Cooperation of cognizant commands, agencies and other responsible organizations must be secured early and well exercised, so that a "ground truth" condition is established during orbital flight.

The extension of simulation program results to orbital test requires some calibration of the initial performance capability of the operator as a frame of reference to subsequent performance. It will therefore be necessary to utilize targets representative of those employed in aircraft simulation tests, thus providing continuity in evaluation.

The basic matrix of tests includes the cross products of:

1. light versus dense signal environments.
2. simple versus highly complex signal parameters.
3. self versus machine-aided alerting, and
4. maximum versus minimum precognition or instruction.

Additional subcategories of investigation should provide tests of signal anomoly recognition, "non-intentioned" radiation events, activity level significant changes and adjustment and calibration maintenance. These must be "programmed-in" under ground control to provide realism and objective data taking.

On each available orbit (assuming competition from other test programs) including day and night crossings of the test points, the console operator will be offered successively more difficult problems in terms of the above mentioned matrix of choices. The development of this test sequence is a major item of preliminary study.

Specific control actions to be taken by the console manipulator include:

1. Center frequency tuning adjustment to center signal in pass-band.
2. Choose optimum bandwidth of S/N improvement.
3. Set gain controls for dynamic range control in recording most important sections of strong signals or extracting weak ones.
4. Adjust synchronizing controls of displays to maximize or minimize effects of interleaved clutter signals.
5. Employ time gating or frequency exclusion gating for removing clutter.
6. Select appropriate detector outputs for display, particularly with the réference to clarifying signal coding.
7. Select appropriate recording medium and length of recording.
8. After a pass, play back recordings, as desired, for evaluation of next pass procedure, or improvement of approach.
9. Respond to direction for or programmed adjustment and calibration.
10. Monitor and report "events" in "activity level", unusual noise level, etc.
11. Alerting of other sensors.

c. Evaluation procedures:

Evaluation of test results will be in part a function of the data reporting system available. A combination of "hot-flash" verbal reporting, video signal readout, tape and/or photo recovery, while in flight, will exercise and grade the operator on his accuracy, quality of intercept, and ability to compress data. Specific scoring elements should include:

Recognition and recording of significant signal parameter modulations.
Recognition and recording of emitter radiation patterns.
Recognition of aperiodic, "non-instructed" activity level events.
Speed of acquisition and processing time per test intercept.
Response to "system degradation" or "failure" modes of operation.

Due consideration must be given to equipment performance factors and propagation effects in comparing ground based reference data to orbital reports. Study on calibrating requirements will assist objective evaluation of the man's performance. For example, measurement of the performance degradation of the operator with time must be accomplished by resubmitting a standard test intercept periodically during the course of orbital flight.

III. Vehicle Requirements Data

Major Equipment	Wt/lbs	Vol/cu. ft.	Power/watts
Antennas	75	1.5	50
Receivers	100	1.5	200
Display Console	200	3	300
Recorders	125	2	200
	500	8	750

Vehicle stabilization of $\pm 1^{\circ}$ is required. Apertures may be required for control cables and possible mechanisms for erection and/or extension of antenna arrays.

IV. Simulation Program

a. Prephase I.

The geometry of the satellite-in-orbit electromagnetic intercept experiment provides, at 125-175 n. m. altitudes, approximately 0-16 minutes from horizon point forward pickup to horizon point rearward loss. On the nadir track, the maximum time is available; at the edges of the circle of horizon coverage the time becomes zero.

Assuming all other factors equal and favorable, the fundamental questions behind this proposed experiment simulation are:

What tasks can the operator perform in the time available? or,

What is the minimum time necessary for operator intercept processing under varying conditions of signal and physical environment complexity?

Recent tests of new airborne systems with capability analogous to that described above have shown results which border on the feasibility limits. However, these results are not a directly usable data point as the intent of the test program was equipment shakedown and evaluation. No great emphasis was placed on operating speed. Improvement factors possible have been estimated at from 2 to 4:1, thus providing fair justification for additional consideration, as this would provide 1-2 minutes per intercept processing on selected targets.

Therefore it is recommended that an immediate simulation program be instituted using this aircraft intercept system, or its essential equal, to determine the operator's reaction and processing speeds against typical emitters of interest. (A preliminary study for implementing this action is suggested below). Use of ZI complexes such as the Eglin Field area, New York-New Jersey area, Southern California area and others will provide ample test targets in reasonably known environments.

It is believed that such simulation using real signal environment, while more difficult to control than chamber or mock-up simulators, will provide authentic results capable of translation to the next step of development and test. In this method, radio frequency reception controls become "live" as compared to video playback systems in chambers or static test consoles.

b. Phase I

During Phase I and subsequent times, it is presumed that composite simulation of a MOL in entirety with all controls will be studied and built. This experiment and its equipment should be included, assuming fruitful results from Prephase I simulation and studies. Input signals for this simulation could be derived from tapes of the aircraft tests and comparative results analyzed.

V. Experiment Definition

a. Prephase I Studies

(1) Simulation in aircraft:

For the aircraft simulation tests, wherein a first calibration of the operator's response and control action timing is achieved, an initial prephase I study encompassing at least the following items is suggested:

(a) Determination of approproate aircraft availability.
(b) Assessment of control and display functions analogous to a potential MOL console.
(c) Determination of suitable flight test areas providing proper emitter targets.
(d) Lay-out of a test matrix embodying the possible cross-products of the test difficulties in (II, b) above.
(e) Decision on type of operator selected for testing.
(f) Plan for test flights and ground coordination.
(g) Plan for test and evaluation procedures capable of being extended to future simulations in other modes.

(2) Optimum orbit and antenna patterns for MOL intercept experiment

This study should explore the orbital inclination, altitude and repetition pattern most suitable to conduct of this experiment. Ground range availability, including sea borne targets, and emitter choices consistent with simulation testing are included. Relation to high inclination orbits is a topic to be evaluated. Antenna patterns should be explored for highest acquisition probability, spatial clutter filtering, location fixing and gain.

(3) Study of space borne display systems for rapid recognition of signal modulation variations.

The console for the MOL operator will be limited in size and weight. It is of great importance to be able to present, to the operator, displays emphasizing departures from simple non-varying signal modulations. Consolidation of display and/or correlative displays should be studied for possible improved presentation systems.

(4) Study of recording, storage, readout and recovery of selected intercept data in MOL experiments.

This study is directed to analysis of the quantity of data to be taken and its digestion and manipulation in the testing of the operator's activities. Attention is directed to recording and storage time necessary, bandwidths, status and monitoring recording. This study is inter-related with the general problem of on-orbit test reporting and would provide inputs to that effort.

b. Phase I Studies

At this time it is considered vital to establish a firm base upon which to plan Phase I effort by conduct of the studies and aircraft simulations described above. If results are sufficiently encouraging from these efforts, Phase I preliminary design studies leading to firm specifications would include:

(1) Advanced simulation studies relating to combined payloads in MOL chamber mockups and using normal mission time clocking.

(2) Study for adaptation or redevelopment of intercept equipment designs suitable for inclusion in the MOL.

(3) Study of specific antenna designs providing general coverage and steerability in the chosen experimental frequency ranges.

(4) Study of orbital experiment test plan and ground range selections.

VI. Funding

a. Prephase I Studies

(1) Aircraft simulation program study	$50K
(2) Optimum orbit and antenna patterns for MOL intercept experiment	25K
(3) Study of space borne display systems for rapid recognition of signal modulation variations	50K
(4) Study of recording, storage, readout and recovery of selected intercept data	50K
(5) Simulation program direction (not including operating costs)	50K
	$225K

b. **Phase I Studies**

Estimated rough costs **$500K**

VII. PARTICIPATING AGENCIES

Sponsor: AFSSD/Aerospace

Experiment No. P-5

IN-SPACE MAINTENANCE
(PART 1)

INTRODUCTION.

This experiment is in two parts. Part 1 discusses maintenance of electronic equipment required in experiment P-4. Part 2, discusses the maintenance of the MOL vehicle, subsystems, and equipment of other experiments.

I. OBJECTIVE.

The objective of this test is to verify, to evaluate and to establish the capability of an astronaut operator to perform the maintenance function of complex military electronic signal detection equipment in a spaceborne environment. Although the experiment was directed towards electronic signal detection sensors, it is also believed to be applicable to communication radar, IR and guidance sensors.

II. EXPERIMENT DESCRIPTION.

The on orbit experiment will be performed in conjunction with the equipments required in Experiment P-4. The additional equipments to support this experiment are the Fault Generating Programmer Unit, appropriate tools, maintenance manual, support self-test set and/ or an external portable test set. Replacement spares, as optimized in kind and quantity by previous study, will also be required.

The proposed procedure is to cause programmed failures through the use of the Fault Generating Programmer Unit. The initiation of the faults may be done through internal preset timers or by direct control from the ground Command and Control Facility. The types of failures would include:

Failures that cause significant degradation of performance.

Failures that are catastrophic, causing complete breakdown of operation.

Through the operation of the external and/ or internal test sets, the astronaut will localize the fault; then the maintenance function proven by the ground simulation program may be applied. (It is assumed that the design of the sensor is configured upon a fail safe concept.)

The maintenance function selected may be one of the following, based upon the design of the primary equipment:

1. The equipment may contain built-in, inherent redundancy such that a common failure does not produce a catastrophic failure. In actual practice a failure of a component may occur without the astronaut operator being aware of the failure. Operation of the device would continue to be normal. The ability to locate such failures will be dependent upon the degree of complexity of the test sets.

2. The equipment may contain redundant components which are available by the action of automatic fault sensing and automatic switch over.

3. The equipment may contain redundant components which are available by the action of automatic fault sensing and manual switch over.

4. The sensor may contain redundant components which are available by the action of the manual fault sensing and manual switch over.

5. The Manual Maintenance Functions are defined as:

   a. Removal and direct replacement of a modular unit. Examples are receiver IF amplifier, video channel, logic chain. These are usually mounted as a self-contained unit on a plastic plug-in board or a plug-in capsule.

   b. Direct replacement of major component parts. Examples: replacement of a cooling blower motor, gyroscope, power supply, etc.; the component may be part of a base frame or structure member.

   c. Disassembly of a complex component and replacement of the defective part and/ or parts. Example: replacement of an electron tube, transistor, etc., from an assembled unit; removal of the beam unit of a TWT or similar replacement may be required.

   d. Repair of the actual defective component, if practical. Example: repair of mechanical damage, securing of parts to structure, etc.

   e. Adjustment of controls to initial state. Examples: adjustment of gain controls to overcome loss of circuit gain, or to correct the effects due to loosening,etc.

   f. Alignment of electrical circuits and mechanical assemblies.

The evaluation of the astronaut operator will be based upon:

1. The time required to recognize the existence of a system malfunction.

2. The time required to perform the test function of localizing the specific area of failure.

3. The time required and quality of the system characteristics after direct replacement of a defective module, part, etc. The evaluation is based on the assumption that absolute minimum down time is essential, and further, that some loss of system performance is tolerable. In other words, some operation is preferable to none.

4. The time required and quality of the system characteristics after performance of the proper kind of maintenance function(other than in 3). The evaluation, in this case, assumes that sufficient time exists before the next required operational period. In such circumstances, ground to space instructions may be considered practical.

5. Where possible, the quality of the repair will be evaluated from the study of photographs.

It is recognized that during the mission of the experiment, non-programmed natural failures will occur. In such cases the astronaut is expected to perform the maintenance functions required to return the device to proper operating condition, and such action will provide additional data on the validity of the maintenance concepts.

The method of confirmation of return to proper operating condition may be determined from:

1. By detailed observations taken by the associate astronaut.

2. By the print-out or manual recording of the check-out data given by the external and/or self-test sets.

The experiment will be covered photographically with proper time references. From the pictures, comparison may be made with similar data taken during the ground and/or aircraft simulation program. Additional data on the basic time and motion behavior may be determined.

III. IMPORTANCE OF THE EXPERIMENT.

Upon completion of the experiment, it should be possible to determine the specific kinds of maintenance functions the astronaut operator can perform. Also and maybe more important it should be possible to determine those kinds of maintenance functions that an astronaut operator cannot or should not perform.

In those cases where the maintenance function was found to be unsatisfactory, then the implications upon the design to overcome the deficiency must be determined.

From the results of the experiment it should be possible to further optimize a design philosophy such that it is compatible with the capability of the average astronaut operator to perform maintenance in the spaceborne environment.

IV. VEHICLE REQUIREMENTS.

The estimated physical and electrical characteristics of the equipment required for the experiment are listed:

	Weight (lb)	Volume (ft^3)	Power (w)
Fault Generating Programmer Unit	20	2.5	100
Malfunction Detection Panel	30	5.0	100
Portable External Test Set	7	0.2	50
Tool Kit, Maintenance Manual	5	*	---
Cameras and Lights	20	1.0	200
	82	8.7	450

V. PARTICIPATING AGENCIES.

Sponsor: (PART 1) AFSSD/Aerospace
(PART 2) RDT (Aero Propulsion Lab)

* Stored in console space.

Experiment No. P-5

INSPACE MAINTENANCE

PART 2

I. TEST OBJECTIVE.

The principal objective of this experiment is to provide a demonstrated capability of orbital maintenance. This orbital maintenance capability will result in future reduction in weight of space systems by reducing or eliminating the number of redundant systems required to complete a mission.

Finally, this experiment is a necessity before undertaking longer and deeper space missions where the probability of component failure is high and mission success will depend on man's ability to effect on the spot repairs.

II. IMPORTANCE OF THE TEST.

This maintenance kit will be available for all MOL missions and will provide a significant increase in safety to the crew. This proposed space maintenance experiment is important to verify maintenance techniques that have been established through R & D contractural and inhouse efforts. Previous manned space missions undertaken by NASA have established the requirement for orbital maintenance capability. That is, these flights have had a number of failures which required the astronaut to correct the malfunction or to take alternate or redundant approaches.

These experiments must be conducted on the MOL because this vehicle will be the only manned vehicle in orbit for a thirty (30) day mission. These space maintenance techniques require the utilization of man in the repair cycle. There are no adequate facilities on the earth which could simulate zero g and a vacuum simultaneously for prolonged periods of time, which would be required for conducting these experiments.

The use of a KC-135 or C-130 will not provide sufficient time under "0"g conditions to properly assess the tools techniques perceivable. Likewise, air-bearing simulators cannot simulate the true conditions of "0"g's: therefore, MOL is the only known method of carrying out various sustained manual operations which can provide a thorough insight into the problems as they are actually encountered in sustained space operation. Without question, the man/machine relation can be thoroughly demonstrated to asses man's ability and utility while functioning in the role of maintenance and repair. Little is known as to what effect the total space environment will have on man and tools and techniques to be used for space maintenance.

This experiment will definitely assess and demonstrate man's ability in maintaining his vehicle in the hostile environment of space. All of the proposed experiment relies on the inclusion of man's ability to do maintenance tasks.

III. DESCRIPTION OF THE EXPERIMENT.

This experiment will include maintenance tasks to be conducted both inside the MOL and inside unpressurized module. These tasks will incorporate the zero reaction power tool, minimum reaction manual tools, space qualified adhesive system, instant attachment systems, electrical conducting rapid setting plastic cements, insulating (electrical) rapid setting cements, and welding techniques (thermite, contact,) and electronic transistorized fault detection device. The astronaut will conduct tests on the interior of MOL, utilizing the above mentioned techniques. These techniques, in addition to being used experimentally, can be integrated into actual emergency repairs to the basic MOL mission.

The astronaut will enter unpressurized module and perform various maintenance tasks such as replacing components, performing structural repairs, applying and repairing coatings for control of emissivity/absorptivity, checkout new materials for maintenance (rapid setting plastics, etc.), checkout thermite type welding and pressure welding techniques, checkout utilization of zero reaction space power tool, verify astronaut attachment techniques, and checkout small hand held fault detection device (for electronic devices).

Problems: The most significant problem anticipated for the performance of these experiments is the development of a truly flexible extravehicular space suit. Many unforeseen problems are expected but primarily in learning to use the tools in space when working against a time deadline. These problems, however, should not be of such critical nature to affect crew safety on vehicle operation. As in the other military missions, the receiving and evaluation of data on the ground must be part of the test so that decisions can either be made or simulated on earth and transmitted back to the satellite as an expedited command.

It should be recognized that the available payload space and crew time available in MOL would dictate the degree of complexity permitted for these tests. The actual test could vary from one minute of time to one hour and could require little or a lot of expended man and machine energy.

a. Configuration of Test Items.

The experiment would be contained in a 5.0 cu. ft. tool box, total weight of 100 lbs., preferably located in pressurized area of MOL. The location preferred would make available repair kit to astronauts for emergency repairs to interior of MOL. Key items in tool box are; zero reaction power tool, welding device, astronauts attachment device, rapid setting cements, emissivity coatings, and fault detection device. See Attachment 1.

b. Test Support Equipment Required.

The experiments will require use of several maintenance task panels. These panels would have bolt patterns, simulated micro-meteorite holes, damage electrical cables, and a pressure vessel with a blow-out plug.

c. Test Procedure.

This experiment will demonstrate the extent of man's ability to perform representative maintenance tasks inside the vehicle. It will also define problems that have not been anticipated during the performance of a maintenance mission in an actual space environment.

Internal Maintenance and Repair - Bench tests will be conducted to demonstrate the man/machine relation of selected mechanical and electrical maintenance and repair tasks. The crews will rotate the tasks and a still photo, movie, and note record will be made as to the outcome of the individual efforts. The work will initially be carried out in a shirt-sleeve environment throughout a range of temperatures and pressures gradually working up to a full suit operation in the laboratory working in a space vacuum environment. The tasks will be conducted at various times of the 24-hour period to evaluate the physiological as well as the psychological, performance of the crews. After the routine operations of the tool use and specific techniques are identified, the crew will vary the tasks to attempt to function against time in simulating various emergencies that might occur in the MOL. Areas of test would involve: leak detection; gas diffusion; simulating meteorological etching and fatiguing of coatings, glass, metals; fabrication and assembly by riveting, adhesives, welding, cutting of structural and antennae material with constant and differential temperatures. Emergency electrical repairs will be simulated, such as cable repairs, detection, and replacement of electronic components. Most of the unpressurized tests will be conducted in the unpressurized compartment of the MOL.

External Maintenance and Repair - Within safety limitations, the crew members will conduct extravehicular inspections and conduct tests on their own vehicle in an area which is not critical to the mission. The process will be much the same, as described above, and will repeat work in those areas that are considered of a nature requiring vehicle repairs and simple construction tasks while tethered, as well as operating with an Astronaut Maneuvering Unit.

d. Category of Experiments.

These experiments fall in category B as defined by the format.

e. Cost.

(1) See Attachment 4

f. Schedule.

(1) Hardware and software available for test - Early 1966 or late 1965.

(2) Hardware and software flight readiness date - Early 1967.

IV. PARTICIPATING GOVERNMENT AGENCIES.

Sponsor: (Part 1) AFFSSD/Aerospace
(Part 2) RDT-Aero Propulsion Lab.

Test Equipment Acquisition: Air Force Aero Propulsion Laboratory APFT, WPAFB, Ohio

V. ADDITIONAL REQUIREMENTS.

a. Special Security.

Unclassified

b. Manning Description Summary.

The maintenance and repair tasks will be rotated between the two astronauts. They will require ground and aircraft training in the use of the tools with and without equipments for functioning in free-space.

c. Logistics.

	CY 64	CY 65	CY 66	TOTAL
(1) Manpower (Man Years)	B	B		
(a) Hardware Dvlpmt	1	1	-	2
(b) Installation	-	1	1	2
(c) Operation	-	-	1	1
(d) Additional Support	-	-	1	1
TOTAL				6 Man Years

d. Facilities.

Sponsor can use existing facilities located at WPAFB without any modification being required. Man will be using space qualified equipment. All of the facilities required to conduct the experiments, prior to the flight, are available at WPAFB and no new facilities are required. These items will be man rated.

An air-bearing table capable of supporting a 500# weight will be available at WPAFB and can be used to conduct portions of the experiment. Following the air-bearing tests, the "0"g KC-135 should be used with minor modifications to incorporate the test tools, tether and task items. Low-pressure work in an AMU is desirable. A 24 foot diameter 10^{-9} mm Hg vacuum chamber is available for vacuum testing.

e. Simulation and Training.

(1) Astronaut: The astronaut that will perform these experiments would perform the required maintenance test on a six degree of freedom simulator in a pressurized suit prior to the flight. The extent of the training would depend on the astronaut's confidence that he could perform these same tests in a space environment. For these tests the astronaut can be trained as a technician. Zero g flight tests will be utilized to train astronauts.

(2) Ground Personnel: Not required

(3) Equipment: Simulators, G degree freedom platform, zero "g" aircraft, and vacuum chamber

VI. GENERAL.

a. Communications and Data Handling Requirement

See Attachment 6

b. Development Characteristics

See Attachment 7

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED - Zero reaction power tool, instant attachment device (device to anchor astronaut to a work site), hand tools, materials repair kit (consisting of rapid setting plastic and organic cements), thermite welding technique, and a transistorized fault detection device for locating electronic malfunctions. For simplicity, all of the above items are assumed to be in one kit or tool box.

2. WEIGHT - 100 lbs. (Materials Wt. 15 lbs, attachment device and adhesive pads 20 lbs, zero reaction power tool and support equipment 20 lbs, thermite welding technique and support equipment 15 lbs.)

3. VOLUME - Stored 5.0 cu. ft. In use 5.0 cu. ft.

4. POWER

   a. Continuous - No continuous power required, periodic recharging of hand held power tool battery will be required; however, this can be done on a small trickle charge basis.

5. SPARES - Extra batteries for power tool

   a. Volume - .05 cu. ft.

   b. Quantity - 1 battery

   c. Weight - 2 lbs

6. TOOLS - Since this experiment has tools as its primary equipment, listed under Item 1 of Attachment 1, this section is not applicable.

7. HEAT OUTPUT - Negligible

8. STABILITY - This experiment requires no special stabilization and it will not impart to basic MOL.

9. VIBRATION LIMITS - The items or equipment to be utilized in this experiment do not have any critical vibration limits. The tool case will be lined with a plastic foam to absorb vibration and shock.

10. SHOCK LIMITS - Not critical, especially with plastic foam tool box liner.

11. HAZARDS - Power tool will present little or no hazard. The welding technique may involve some hazard but nothing that cannot be overcome with proper safety procedure. Chemical reactions from rapid setting plastics will not be toxic in quantities given off. In fact, rapid setting non-toxic plastics would be utilized.

12. TEMPERATURE LIMITATIONS - $\pm 150^{\circ}F$

13. TYPE AND RANGE OF MEASUREMENT - Since this experiment will evaluate various maintenance techniques to be utilized by man, the optimum measurement technique would be the astronaut's comments or evaluations plus a stop motion picture coverage of the test. Stop motion camera could be mounted on astronaut's helmet to record every 10-20 seconds a photograph of what the astronaut views.

14. SPECIAL ENVIRONMENTAL REQUIREMENTS - None except an extravehicular space suit. Prefer MOL atmosphere not to be pure oxygen.

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS - No special orientation required.

16. EQUIPMENT OPERATING CYCLE - The operating equipment is battery charger for hand power tool.

17. EQUIPMENT LOCATION REQUIREMENTS - Prefer to be stored in actual pressurized cabin, but this is not an absolute necessity.

18. SPECIAL MOUNTING REQUIREMENTS - The only mounting requirements would be a bracket or tie down to hold tool box.

19. PRESSURE VESSELS - Small pressure vessel of nitrogen prefered for experiment on sealing a punctured pressure vessel.

20. ELECTRO MAGNETIC INTERFERENCE - Only possible interference would be from portable hand held power tools; however, the tool will be shielded against transmission of interference signals.

21. MAINTENANCE REQUIREMENTS

a. Ground - None

b. Space - Only periodic recharging of hand held power tool battery.

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA

   a. Tape - Record astronauts comments

   b. Film - 16 or 8 mm stop motion camera film

   c. Other - Experiment notebook kept by astronaut and strain gages.

2. HANDLING

3. PACKAGING - N/A

4. CALIBRATION - Strain gages

5. JIGS AND FIXTURES - Three (3) each maintenance test panels for conducting extravehicular repair tasks in unpressurized module of MOL.

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION - None anticipated.

7. SENSORS - Strain gages

8. TRAINERS/SIMULATORS - Six (6) degree freedom simulator, 24 ft. dia. 10-9 mm Hg vacuum chamber, 30 sec. zero g flights, etc. are available in-house under auspices of APFT sponsoring organization.

9. INSTRUMENTATION - Strain gages

10. RELATED SUPPORT EQUIPMENT

    a. Targets - None required

    b. Ground Stations - None required

    c. Tracking - None required

    d. Handling Equipment - None

11. AGE - None required

12. ENVIRONMENTAL TEST EQUIPMENT - None required

13. FACILITIES - None required beyond what is now available to APFT.

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS

   a. Altitude - Below Van Allen Belts

   b. Inclination - Any

   c. Epoch - Any

   d. Ellipticity - Any

2. PLANE CHANGE - None

3. ALTITUDE CHANGE - None

4. TIME ON ORBIT - Would like to conduct portions of experiments in both daylight and also dark portion of orbit.

5. TEST DURATION - Eight (8) maintenance tests will be conducted in pressurized module of MOL. These tests would last about 30 minutes each. Four (4) extravehicular missions to be conducted in unpressurized module duration 35 to 40 minutes each. Later astronaut wearing an AMU will possibly inspect MOL and try to repair micro-meteorite bumper.

6. TOTAL NUMBER OF TESTS - Eight (8) pressurized cabin tests. Four (4) non-pressurized compartment test and possibly one extravehicular test with AMU.

7. TEST FREQUENCY - As often as necessary to ascertain effectiveness.

8. INTERVAL BETWEEN TESTS - As necessary to adapt to the environment.

9. CREW TASK LOADS - Man hours

   a. Internal pressurized tests - 4 to 5 manhours

   b. Non-pressurized compartment test - 3 manhours

   c. Extravehicular test - At discretion of astronaut

All test times include donning space suit, AMU and servicing of AMU/ or tools.

10. CREW TASK FREQUENCY - One astronaut will be required to devote his full attention and effort to the experiment, with possible exception in pressurized compartment test. Other astronaut would periodically observe experimenter in non-pressurized and extravehicluar tests. Astronauts would rotate after completion of each experiment.

11. FIELD OF VIEW REQUIREMENTS - Angle of view afforded by space helmet would be adequate. Direct observation is prefered.

12. GROUND CONTROL LIAISON DURATION - Not required

13. GROUND CONTROL LIAISON FREQUENCY - Not required

14. EXTERNAL TEST ITEMS:

a. Launched from Station - None required

b. Launched from Resupply - None required

c. Launched from Ground - None required

15. QUALIFICATION TESTS

a. Ground - Mandatory vacuum qualification tests, shake, rattle, roll test, temperature limitation testing, and reliability qualification testing.

b. Atmosphere - Mandatory zero g flight testing on KC-135 aircraft.

16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT

a. Pressurized test - (1) Test and use a zero reaction power tool for replacing components inside the MOL. (2) Test method for use of hand tools in performing a maintenance task inside the MOL. (3) Test and evaluate the application of rapid setting adhesive system and other techniques for repairing electrical connections (e.g. insulators, conductors) and also evaluate application of adhesive system for performing maintenance task inside the vehicle. Finally, a pressure vessel of nitrogen will have a leak initiated in it. The astronaut will try and effect a repair with his tool kit.

b. Unpressurized Test Inside Vehicle - (1) Perform a maintenance task utilizing the zero reaction power tool and hand tools, including the checkout of using a fast setting adhesive attachment system in the performance of the maintenance task. (2) Evaluate the application of rapid setting materials for the performance of maintenance task such as: repairing electrical malfunctions, patching hole in a structure. (3) Evaluate thermite welding techniques. (4) Sealing a leaking or punctured pressure vessel.

c. Extravehicular test - The astronaut will don the AMU, exit the vehicle and maneuver to a preplanned work site. He will conduct an overall inspection of the MOL, and attempt to effect repairs on the vehicle, such as patching outer shell of micro-meteorite bumper.

17. HANDLING PROCEDURES - AMU will be utilized where possible.

FUNDING SUMMARY

BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing		$250K	$300K	$200K	$200K		$950K
Integration & Installation of MOL					25K		25K
AGE		0	0	0	0	0	0
Simulators/Trainers		0	0	0	0	0	0
MOL Flight Data Reduction		0	0	0	0	40K	40K
Equipment Rework After MOL Flight Experiment		0	0	0	0	100K	100K
Other		0	0	0.	0	0	0
TOTAL		$250K	$300K	$200K	$225K	$140K	$1115K

Hitch Line Number: 62405336

MANNING DESCRIPTION

1. ASTRONAUTS

a. Number required - One astronaut will be required to perform the experiments.

(1) Man's function

(a) As part of test - Man will actually be part of the test. He will be required to go outside his pressurized environment and perform the described maintenance test and analyze the results. Man will conduct and execute specified maintenance task in the pressurized portion of MOL.

(b) As technician conducting test - The astronaut will be required to utilize his technical judgment during experiments. He will be required to assess to effectiveness of his tools and repair materials.

b. Crew skill requirements - The skill of the average astronaut will be enough to perform these experiments with knowledge of the specific operational techniques to be used.

c. Manpower Profile - Astronauts should be familiar with system maintenance requirements. The tests will consume about 8 hours out of the entire 30 day mission.

d. Critical Functions - The critical function throughout these experiments is demonstrating the effectiveness of using the maintenance techniques specified to perform a maintenance task in the unpressurized compartment of MOL.

e. Work Positions - Work positions will be inside the pressurized vehicle, inside the unpressurized vehicle, and possible extravehicular at astronaut's discretion. He will work both tethered and untethered.

f. Time Controlled Tasks - Each task will be time controlled. The astronaut will be required to be outside the pressurized portions of the vehicle for forty (40) minutes, maximum. He should function under simulated emergency "time" conditions.

g. Human Performance Measures - Time measurements are required for man in a pressure suit in a hostile environment to perform a required maintenance task.

h. Physiological and Psychological Measures - Both of these factors will be considered in this experiment.

i. Selection Factors - Astronaut should have normal dexterity.

j. Training Requirements - Training relative to the procedures and techniques required in the performance of the maintenance task will be required. Simulator-air-bearing as well as "0"g aircraft tests are mandatory for familiarization with the tools and techniques.

2. GROUND PERSONNEL - Not required

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE - N/A

2. FUNCTIONS TO BE MEASURED - N/A

3. TYPE OF ANALYSIS REQUIRED - Two (2) way voice communication and astronauts evaluation of the performed operation.

4. PICTORIAL DATA REQUIRED - Stop Motion camera to take pictures every 20 seconds.

5. REAL TIME MONITORING REQUIREMENT - N/A

6. DATA EDITING OR COMPRESSION - Stop motion film and notes by astronaut will be returned to earth.

7. READ-OUT TIME - N/A

8. REQUIREMENTS FOR PERMANENT DATA RECORDS - Film and notes.

9. MANUAL AND/OR AUTOMATIC CONTROL - N/A

10. SIMULTANEITY - N/A

11. GROUND COMMANDS REQUIRED - N/A

12. COMMUNICATIONS AND DATA HANDLING - Not mandatory - photos and movie record will be returned with the crew. If space permits imaging photos from a hand held TV camera would provide the ground with early visual observations of the test as a supplement to any terse verbal summary of the activities.

Exp. No. P-5 Atch. #7

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME - Through CY 65 to early part of CY 66.

2. FINAL DEFINITIVE TEST DESIGN TIME - Through CY 66 to early part of CY 67.

3. NUMBER OF GROUND OR FLIGHT TEST REQUIRED - Tests will be required on a six degree of freedom simulator throughout CY 67, on the ground.

4. TYPE OF DEVELOPMENT TEST ITEMS

   a. Vacuum Chamber - Power tool, adhesives, welding.

   b. Shaker - N/A

   c. Thermal - Power tool, adhesives

   d. Acoustic - N/A

   e. Simulators - (Six degrees of freedom) all test items, typical MOL flight simulators.

   f. Aircraft - Flying Keplerian Trajectory all test.

5. SUPPORT EQUIPMENT DEVELOPMENT TIME - Available

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

   a. Ground Test - 5 repair kits

   b. Atmospheric Test - 3 repair kits

   c. Space Test - 8 complete repair kits to be made available for all MOL missions for added crew safety.

7. DATE AVAILABLE FOR TESTS - Early CY 67

8. CURRENT DEVELOPMENT STATUS

   a. Proposed only - N/A

b. Project or program is approved and test item is under study, breadboard stage, etc. - Program is approved and test items are under study and some have reached the breadboard stage.

c. Funds expended to date - $160K

Experiment No. P-6

EXTRAVEHICULAR ACTIVITY

I. TEST OBJECTIVE

The objective of the experiment is to determine what functions man can effectively perform while outside a spacecraft, and the tool and equipment requirements. The experiment results will determine the tools and equipment which are necessary and effective for man to perform and operate in an extravehicular environment.

II. IMPORTANCE OF TEST

There are many tasks in long term space operation which might be more easily accomplished if man can be used in extravehicular operation. These operations include assembly, maintenance, rescue, logistics, and crew transfer. Feasibility of the concept has already been established in tests on the ground and in aircraft. The limitations of these tests to date have missing one or several of the following: zero "G", long time, orbital mechanics effects, space environment, and attitude reference requirements. The Astronaut tasks to be performed inside the spacecraft will require a large free volume in which the motion of the astronaut will be free of obstructions.

III. DESCRIPTION OF THE EXPERIMENT

Each astronaut will perform various tasks such as replacement, connecting and patching; using such tools as zerts and spunfits; while inside the spacecraft in a shirtsleeve environment and in a pressure suit with various levels of suit pressure, different tie-down techniques, and with and without the maneuvering unit attached. The other astronaut will observe and take pictures during the experiment. Performing this part of the experiment inside the spacecraft is safer and provides better monitoring capability without compromising objectives.

At the conclusion of the above tests, one astronaut will enter an airlock with the integrated environmental control/maneuvering unit, attach a tetherline, and egress to space. The environmental control/maneuvering unit consists of a self contained environmental control subsystem for operation with the astronaut suit and a propulsion system for linear and angular control and stabilization. Locomotion tasks will be performed on the exterior of the spacecraft using various means such as hand holds, foot holds and magnets. The astronaut then tests the maneuvering unit first tethered and then untethered. The other astronaut monitors and observes the experiment.

During all phases of the experiment information about the astronaut and system performance will be recorded.

A. Configuration of Test Items

The extravehicular experiment consists of four different categories: (1) Performance of astronaut tasks using various hand tools and tie-down methods on simulated spacecraft equipment, that require replacement, connecting, erection or patching familiar to primary experiment No. P-5: (2) Locomotion on spacecraft surface; (3) Locomotion away from spacecraft with the aid of a maneuvering propulsion unit; and (4) Measurement of astronaut performance and physiology, and suit integration.

Category 1:

A storage box for various tools and tie-down equipment is required. The experiment is performed at a panel containing tasks such as nuts, bolts, screws, tubes with various types of connections, etc. with enough free space in front of the panel to show motion of astronaut during attachment to the surface, performance of tasks and detachment. Performance of this part of the experiment inside the spacecraft can be done with more safety and more easily monitor without compromising the experiment.

Category 2:

A test area on the exterior of the spacecraft is required which contains various types of locomotion aids for both hands and feet such as bars, adhesive pads, and magnets. The area should be long enough to allow the astronaut to transverse at least eight feet. Inherent in this part of the experiment is the provision of an air lock, tetherline and individual environmental control system (part of the combined environmental control/maneuvering unit).

Category 3:

A combined environmental control/maneuvering unit will be stored in the air lock. The unit is to be attached to the astronauts back with the control device attached to the front of the astronaut in a position for hand control in a pressurized suit. A tetherline is also required for this part of the experiment.

Category 4:

Provision will be made for the recording and storage of the astronaut performance and physiological information obtained during the parts of this experiment. Integration of the environmental control/maneuvering unit, the tetherline, tie-down equipment and physiological measurement with the astronaut suit is required.

B. Test Results

The purpose of this experiment is to test the equipment and procedures which are required by man to perform extravehicular operations. The test sequence is such that the experiment is to be performed in a safe a manner as possible, with a build up and evaluation of successive steps before proceeding further. The astronaut is an integral part of the experiment therefore the astronaut's opinion will be used to a large extent in carrying on the experiment. The information obtained in the performance of this experiment will provide knowledge of the procedures, tools, environmental control and maneuvering requirements for man's extravehicular activity.

IV. SIMULATION

Simulation work should be done preceding and concurrently with the flight program in order to determine what simulations best represent actual conditions, and what can be used for more refined studies of the requirements for actual performance of extravehicular activity missions which might be required. The procedures, tools and tie-down methods for the experiment astronaut tasks will be chosen after an extensive simulation program using air bearing platforms is accomplished. The maneuvering unit selected after Pre-phase I studies will be simulated and tested aboard the zero "G" aircraft before it is used in space. Simulation of the back unit donning and switchover from the spacecraft environmental control system techniques will be accomplished using the space suit configured for the MOL.

ATTACHMENT 1

DESIGN CHARACTERISTICS OF TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED

2. WEIGHT 275 lbs

3. VOLUME

   a. Back unit 8 cu ft (3.2 x 2.5 x 1)

   b. Storage Box 1 cu ft

   c. Panel 1 cu ft

   d. Recording 2 cu ft

4. POWER REQUIRED FROM MOL

   a. Communication 25 watts

   b. Telemetry Receiver 25 watts

   c. Light 50 watts

   d. Recorder 50 watts

   e. Total watts 150

5. SPARES - To be determined

6. TOOLS - To be determined (Battery, propellant, environmental control system (ECS) service and adjustment).

7. HEAT OUTPUT - To be determined.

8. STABILITY - No special MOL requirements - AMU to be determined.

9. VIBRATION LIMIT - To be determined (T-IIIC launch).

10. SHOCK LIMITS - To be determined (T-IIIC launch).

11. HAZARDS - To be determined

12. TEMPERATURE LIMITATIONS - To be determined (pad to space environment).

13. TYPE AND RANGE OF MEASUREMENTS
    a. Subsystem operation and status
    b. Control characteristics
    c. Physiological measurements and photographic coverage

14. SPECIAL ENVIRONMENT REQUIREMENTS - To be determined (In space at MOL altitudes)

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS - To be determined

16. EQUIPMENT OPERATING - To be determined

17. EQUIPMENT LOCATION REQUIREMENTS
    a. Task panel and tools in MOL laboratory
    b. Maneuvering unit in air lock
    c. Surface locomotion aids in view of pointing and tracking scope

18. SPECIAL MOUNTING REQUIREMENTS
    a. View port between air lock and MOL laboratory.
    b. Mounts for cameras (top ℄ and side near task panel)
    c. Storage area for environmental/maneuvering unit accessible from air lock and to space.

19. PRESSURE VESSELS - Air lock 198 cu ft (4 x 5 xia. MOL)

20. ELECTRO MAGNETIC INTERFERENCE - To be determined

21. MAINTENANCE REQUIREMENTS
    a. Ground - To be determined
    b. Space - To be determined (Provide reuse capability).

ATTACHMENT 2

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA

   a. Tape Recording of physiological measurements

   b. Film Photographic coverage of astronaut during experiment

2. HANDLING - To be determined

3. CALIBRATION - None

4. JIGS AND FIXTURES - To be determined (autopilot and nozzle alignment)

5. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION - None

6. SENSORS - None

7. TRAINERS/SIMULATORS - The MOL and AMU provided for astronaut training will be required.

8. INSTRUMENTATION - Display of physiological and system status information.

9. RELATED SUPPORT EQUIPMENT

   a. Handling equipment - To be determined (for AMU)

10. AGE

   a. Required for checkout of AMU and data subsystems

11. ENVIRONMENTAL TEST EQUIPMENT

   a. Test equipment as normally used to perform environmental tests on space equipment (tests limited to environmental extremes as necessary to determine functional effects).

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ATTACHMENT 3

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS (desired)
   a. Altitude 150 - 250 naut mi.
   b. Inclination - less than 36°, that normally planned for MOL
   c. Epoch - No special requirement
   d. Ellipticity - Near zero
2. PLANE CHANGE - None
3. ALTITUDE CHANGE - None
4. TIME ON ORBIT - 30 days
5. TEST DURATION - 3 hours
6. TOTAL NUMBER OF TESTS - 3
7. TEST FREQUENCY
8. INTERVAL BETWEEN TESTS - 10 day interval
9. CREW TASK LOADS - man hours: 1 hour tasks, 1/2 hour donning, 1/2 hour surface locomotion, 1/2 hour maneuvering.
10. CREW TASK FREQUENCY - Each of the items under 9 may be done separately with each crew member taking a turn.
11. FIELD OF VIEW REQUIREMENTS - Extravehicular astronaut should be in view of other astronaut either through port or using pointing and tracking scope.
12. GROUND CONTROL LIAISON DURATION - None

13. GROUND CONTROL LIAISON FREQUENCY - None

14. EXTERNAL TEST ITEMS - Tetherline and locomotion aids

15. QUALIFICATION TESTS (other than space)

    a. Ground - Functional and environmental performance of AMU

    b. Atmosphere - AMU in KC-135

16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT

    a. Set-up for astronaut tasks

    b. Perform tasks (one astronaut performing while other is photographing and observing.

    c. Enter air lock

    d. Perform donning tests

    e. Connect up environmental/maneuvering unit

    f. Depressurize air lock

    g. Go extravehicular

    h. Performance of surface locomotion tests

    i. Perform maneuvering tests

    j. Return to pressurized volume

17. HANDLING PROCEDURES - Normal procedures for transporting and stowing AMU. Special precautions with AMU propellant may be required.

ATTACHMENT 4

MANNING DESCRIPTION

1. ASTRONAUTS: Two astronauts are required to perform the experiments. While one is performing the actual experiment the other is photographing and observing. Each astronaut will also take a turn at performing experiment. The astronaut experiment roles are:

   a. Perform work tasks.

   b. Don environmental control/maneuvering unit.

   c. Locomote on exterior surface.

   d. Perform maneuvers free of spacecraft.

   Normal motor and perceptual skill levels are required for the execution of the orbital experiments. The astronaut should be average height, weight, and physique and capable of withstanding the high "G" launching environments and the weightlessness of space. He should be able to carry out his normal functions under temporary environmental extremes within human limitations and with the aid of normal life-support systems. There are no anticipated critical functions involved in the experiments. The astronauts will be required to stand and move about when performing the functions of (a) and (b) above and will be able to sit when performing (c), and (d) functions described above. Their tasks will be predetermined and scheduled according to instructions both on-board and on the ground and during pre-flight training. It is suggested they they possess scientific training in the fields of optics, radar and dynamics. During and following MOL launch no human performance measures are required, but some measure of physiological and psychological factors should be made for the following:

(1) Errors and erratic behavior

(2) Fatigue

(3) Visibility and vision

(4) Dexterity

(5) Motion sickness

Normal selection during astronaut training program will suffice. Specific training with a simulator in which normal MOL and RMU controls and procedures must be learned are a requisite prior to final selection and flight.

2. GROUND PERSONNEL

There are no unique requirements for the training of ground personnel. Persons normally employed at ground stations during space flights will provide adequate manning for the experiments. The number of men required will be contingent upon the number of ground stations employed.

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ATTACHMENT 5

COMMUNICATIONS AND DATA HANDLING

1. DATA HANDLING: ON-BOARD

   a. Functions to be measured - sensor and physiological data and human performance

      (1) Data rate/frequency response - to be determined
      Volume of Data
      Accuracy required

      (2) Form of data - output of transducer with time correlation

      (3) On-board processing - human judgement

      (4) Communication requirements (to ground) - analog/digital - raw/real time for extravehicular activity when over stations otherwise nearest dump point.

   b. Requirements for Processing and Analysis To be determined

   c. Permanent Data Records (for fly-down with recovery capsule)

      (1) Photographic

      (2) Magnetic tape recording

2. COMMUNICATION REQUIREMENTS

   a. Data Transmission to ground - Progress of experiment and physiological data by TM.

   b. Two-way communication data feedback from ground - Voice only'

      (1) Data processing on ground - Physiological for astronaut condition

      (2) Allowable delays - Routine unless critical conditions noted.

(3) Ground Transmission (one center to another) - Test Progress

(4) Accuracies - To be determined

(5) Data Recording - No special requirement

(6) Security - Crypto - None

ATTACHMENT 6

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME - 32 months from Pre-Phase I go-ahead to launch.

2. FINAL DEFINITIVE TEST DESIGN TIME - 15 months to completion of Phase I.

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED - Numerous ground test, several KC-135 Test and 3 MOL Tests.

4. TYPE OF DEVELOPMENT TEST ITEMS

   a. Vacuum Chamber - Tools, adhesives and AMU to hard vacuum.

   b. Shaker - Environmental simulation of T-IIIC & MOL.

   c. Thermal - Environmental simulation of T-IIIC & MOL.

   d. Acoustic - Environmental simulation of T-IIIC & MOL.

   e. Simulators - 5 degree of freedom air bearing for all tasks

   f. Aircraft - KC-135 Zero G test of AMU and other tests

5. SUPPORT EQUIPMENT DEVELOPMENT TIME - Compatable with AMU development

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

   a. Ground Test - One (qualification)

   b. Atmospheric Test in KC-135 - One

   c. Space Test - Two

7. DATE AVAILABLE FOR TESTS - Qualification unit August 1966 and flight units February 1967.

8. CURRENT DEVELOPMENT STATUS

a. RTD has been testing AMU's in KC-135's for two years and Gemini Experiments Program 631A is going into Phase II Hardware Procurement.

b. Funds expended to date - About $1 million Program 631A completion estimated to $4 million.

REMOTE MANEUVERING UNIT

I. TEST OBJECTIVE

The objective of this experiment is to determine man's capability to control a maneuvering unit remotely. In military operations it would be desirable to be able to control a maneuvering unit remotely as an aid to inspection, damage assessment, maintenance, logistics and rescue.

II. IMPORTANCE OF TEST

A remote maneuvering unit is important for future manned inspection missions. Such a controlled maneuvering unit could be used to approach and circumnavigate a target while the astronaut remains at a safe distance to prevent harm from an active defense or booby trapped target. In addition, a remote maneuvering unit could be used to carry sensors for a close inspection. In a logistics operation an unmanned spacecraft could be placed in orbit near the MOL and then rendezvoused with the MOL by remote control. In a rescue operation the system could be used in a manner similar to that of throwing a life bouy to a drowning person and hauling him in with the attached rope.

III. DESCRIPTION OF THE EXPERIMENT

a. The experiment equipment consists of the maneuvering unit, the associated control system necessary to remotely maneuver the unit, the required monitoring equipment and appropriate target. The major components of the maneuvering unit are: propulsion and attitude control subsystem; stabilization and control unit consisting of rate gyros and control logic computer; a command and data link which includes a TV transmission unit command, communications, and data telemetry; sensor unit consisting of a TV camera.

The major parts of the MOL control panel are: hand controllers (linear and angular), TV monitor, radar range and range rate readings from RMU to target. The monitoring equipment consists of equipment to record TV, radar, rate gyro output, command data, etc. The radar must be capable of monitoring both the target and the RMU. The target will be a passive inflatable structure with preselected surface characteristics and markings.

b. Vehicle Requirements Data

1. Power - 500 watts
2. Stabilization - required
3. Volume (a) RMU and target approximately 12 cu ft.
   (b) Console and recording equipment approximately 4 cu ft.
4. Weight (a) RMU and target 300 lbs.
   (b) Console and reading equipment 50 lbs.
5. Aperature (view ports)
6. Miscellaneous (a) Storage and ejection compartment direct to space for both target and maneuvering unit.
   (b) Console placed so that the RMU can also be viewed through port, while being controlled by the astronaut.

c. Test Procedure

A target is deployed from the MOL vehicle by ejecting the target vehicle at a small Δ V (several feet per second) such that it will cross the MOL orbit at an approximate distance of 5 naut mi. The MOL vehicle is maneuvered such that the target will remain at a constant distance for the test duration. The RMU is ejected so that the MOL is in the field-of-view of the RMU television camera. After the RMU reaches a distance of about 50 feet from the MOL, the propulsion system is activated and the astronaut assumes control. The RMU will be maneuvered around the MOL, at a safe distance, with and without direct viewing. All the equipment will be checked out for proper functioning (e.g., TV, radar, and control in all degrees of freedom). After checkout, the RMU is oriented to acquire the target and given a ΔV necessary to place it near the target. At the appropriate time the astronaut will start corrective maneuvers such that the RMU arrives in the vicinity of the target with a small relative velocity. The other astronaut will monitor the RMU and target on the MOL radar.

Attempts to rendezvous the RMU with the target will be made from a distance of 500 feet by using TV alone, radar alone, and combination of TV and radar.

The RMU will be maneuvered around the target in order to view it from all aspects and inspect the target surface markings. The relative distance between the RMU and target will be controlled as accurately as possible. At the conclusion of the test the RMU will be returned to MOL for recovery and reuse.

IV. PARTICIPATING GOVERNMENT AGENCIES

Sponsor: RTD (Aeropropulsion)

V. ADDITIONAL REQUIREMENTS

a. Special Security - to be determined.

b. Simulation - The basic attitude control system will be checked out in a five degree of freedom airbearing simulator and the zero "G" aircraft.

Since the maximum length of control time is 30 seconds in the Zero "G" aircraft and the length of the cabin is limited, translation control simulation would be limited. Also, firing of some higher performance propellants in the aircraft would be undesirable. Procedures for the rendezvous of the RMU with the target would be determined by running digital and/or analog simulated missions.

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED

2. WEIGHT: 300 lbs

3. VOLUME: 6.25 cu ft RMU, Control Panel 1.0 cu ft, Target 1.0 cu ft, MOL Radar 2.0 cu ft. Others to be determined.

CRITICAL DIMENSIONS - SHAPES - RMU(2.5 ft x 2.5 ft x 1 ft) Others to be determined.

4. POWER REQUIRED FROM MOL:

Command Transmitter	50
TV Receiver	50
Telemetry Receiver	25
Displays	25
Recorders	50
MOL Radar	100
	300 W

5. SPARES - to be determined

6. TOOLS - to be determined (Battery & propellant servicing; system adjustment.

7. HEAT OUTPUT - To be determined

8. STABILITY

a. .1 degree @ .01°/sec for launch of RMU and target

b. Moving parts - None

9. VIBRATION LIMITS - To be determined (T-IIIC Launch environment)

10. SHOCK LIMITS - To be determined (T-IIIC Launch Environment)

11. HAZARDS (fire, explosion, electrical, toxics, other) - To be determined

12. TEMPERATURE LIMITATIONS - To be determined (pad limits to outer space).

13. TYPE AND RANGE OF MEASUREMENT (definition of parameters to be measured while test is underway).

    a. Attitude and rates in all axis.

    b. Subsystems (power, autopilot, propellant) condition status.

    c. Sensor performance and condition status.

    d. Photos of TV and radar display.

14. SPECIAL ENVIRONMENTAL REQUIREMENTS - To be determined (in space at MOL altitudes).

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS - To be determined - (RMU must be able to approach target within 20 ft.)

16. EQUIPMENT OPERATING CYCLE

	R/C Transmitter	T/M & TV Receiver
Frequency	434 mc/sec	537
Time Duration	54 min	54 min

17. EQUIPMENT LOCATION REQUIREMENTS - Controls & displays in MOL Laboratory, RMU in air lock, electronic equipment in unpressurized volume of MOL.

18. SPECIAL MOUNTINGS REQUIREMENTS

    Apertures - View port required

    Antennae - 3 required (command transmitter, T/M & TV receiver and MOL radar).

    Bracketry - To hold RMU & target prior to launch & recovery

19. PRESSURE VESSELS - RMU stowed in air lock.

20. ELECTRO MAGNETIC INTERFERENCE - To be determined

21. MAINTENANCE REQUIREMENTS

Ground - To be determined

Space - To be determined - (replace batteries & refill propellant).

ATTACHMENT 2

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA

   a. Tape: Magnetic tape recordings will be made of the radar photoelectric and TV information sensed both in the MOL and by the ground stations.

   b. Film: Photographic recordings will be made by the MOL crew of the RMU maneuvering.

   c. Human: Observations will be recorded both on magnetic tape and on paper by MOL and ground stations crews.

2. HANDLING

   a. The experimental target will be stored in the MOL in suitable containers.

3. CALIBRATION:

   a. Calibration of test equipment or test support equipment will be required of those calibrations normal to the tracking radar, and TV.

4. JIGS AND FIXTURES - To be determined (boresighting TV, radar, autopilot and nozzle alignment).

5. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION:
   To be determined (RMU and target deployment, antenna coax, etc.)

6. SENSORS

   a. A tracking radar system yielding angular orientation target signature and range information will be desired in the MOL. A system at the ground station will perform similar tasks.

b. A TV camera on the RMU will provide about 600 line definition at about 25 frames per second. The display on MOL is convenient to the control panel.

7. TRAINERS/SIMULATORS

a. The MOL and RMU simulators provided for astronaut training will be required.

8. INSTRUMENTATION

a. Sequential frame or motion picture camera with suitable controls for varying the exposure duration, exposure setting, and focal length, and the camera position against the celestial background.

b. A radar tracking device including passive-tracking and active tracking features.

c. Recording equipment and associated amplifiers.

d. Indicators may display the radar information in the MOL.

e. Other indicators may be employed to indicate the quality of operation of the other sensors.

f. Such indicators already may be available as standard MOL instrumentation.

9. RELATED SUPPORT EQUIPMENT

a. Targets: 10 ft diameter expandable about 40 lbs.

b. Ground Stations: Ground stations already engaged in tracking the MOL will be employed to track and observe the decoys.

c. Tracking equipment already engaged in MOL tracking at the ground stations will be employed.

d. Handling Equipment: Special-purpose handling equipment will be required for folding the targets.

10. AGE

Most of the following equipment and facilities are anticipated as already being a part of the MOL program:

a. Equipment for checkout of control system, power, TV & radar.

b. Tracking SPADATS network for tracking of the test from earth.

c. Optical tracking facilities including photographic capabilities.

d. Recording equipment and associated amplifiers.

11. ENVIRONMENTAL TEST EQUIPMENT

Test equipment as normally used to perform environmental tests on space equipment will be required. Such tests will check limited environmental extremes as necessary to determine functional effects on target system performance.

12. FACILITIES

a. The MOL with its RMU will provide the orbital facilities for the target equipment and its related support equipment.

b. The ground stations will provide the facilities for ground-conducted observation of the tests.

ATTACHMENT 3

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS

   a. Altitude: 150 - 250 naut mi.

   b. Inclination: Less than 36°, use that normally planned for the MOL

   c. Epoch: No special epoch is applicable.

   d. Ellipticity: A circular orbit is preferable for early experiments; the effects of increasingly more elliptical orbits may be studied in succeeding experiments.

2. PLANE CHANGE: No change

3. ALTITUDE CHANGE: No change in altitude will be effected during any specific test; tests may be conducted at different altitudes.

4. TIME ON ORBIT: 30 days

5. TEST DURATION: To be determined

6. TOTAL NUMBER OF TESTS: To be determined (dependent on targets carried and ability to reservice the RMU).

7. TEST FREQUENCY: To be determined

8. INTERVAL BETWEEN TESTS: To be determined

9. CREW TEST LOADS

   a. Experiment preparation & deployment: 1 man for 1/2 hour.

   b. Experiment Performance: 1 man for operation and 1 man part-time for observation for duration of test.

10. CREW TASK FREQUENCY

Two astronauts will alternate between individual reciprocating periods of activity and rest as required. They may be performing interim duties between periodic intervals of observation if continuous observation becomes needless.

11. FIELD-OF-VIEW REQUIREMENTS: To be determined (RMU TV camera to have two field-of-view settings).

12. GROUND CONTROL LIAISON DURATION: As necessary when over tracking stations.

13. GROUND CONTROL LIAISON FREQUENCY

A specific ground station will observe a test so long as the MOL and the target can be tracked. Tracking will be passed from station to station.

14. EXTERNAL TEST ITEMS

a. Launched from MOL: RMU and targets.

15. QUALIFICATION TESTS:

a. Ground: Functional and environmental performance of RMU and targets to be determined.

b. Atmosphere: RMU in KC-135

16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT:

a. Coordinate with ground stations and activate all sensors and recording devices.

b. Eject target.

c. Release and maneuver RMU.

d. Observe, track, and record data.

e. Return RMU and recover

f. Repeat experiment. (May require reservicing.)

17. HANDLING PROCEDURES:

Normal procedures for transporting and stowing the targets packages will be sufficient. Special precautions with RMU propellant may be required.

ATTACHMENT 4

MANNING DESCRIPTION

1. ASTRONAUTS: Two technicians are required to perform the experiments. Their roles are to:

   a. Deploy target and RMU.

   b. Maneuver MOL and RMU.

   c. Observe the experiment and record results.

   d. Prepare raw data for subsequent transmittal to ground stations.

   Normal motor and perceptual skill levels are required for the execution of the orbital experiments. The astronaut should be average height, weight, and physique and capable of withstanding the high "G" launching environments and the weightlessness of space. He should be able to carry out his normal functions under temporary environmental extremes within human limitations and with the aid of normal life-support systems. There are no anticipated critical functions involved in the experiments. The astronauts will be required to stand and move about when performing the functions of (a) and (b) above and will be able to sit when performing (c), and (d) functions described above. Their tasks will be predetermined and scheduled according to instructions both on-board and on the ground and during pre-flight training. It is suggested that they possess scientific training in the fields of optics, radar and dynamics. During and following MOL launch no human performance measures are required, but some measure of physiological and psychological factors should be made for the following:

(1) Errors and erratic behavior

(2) Fatigue

(3) Visibility and vision

(4) Dexterity

(5) Motion sickness

Normal selection during astronaut training program will suffice. Specific training with a simulator in which normal MOL and RMU controls and procedures must be learned are a requisite prior to final selection and flight.

2. GROUND PERSONNEL

There are no unique requirements for the training of ground personnel. Persons normally employed at ground stations during space flights will provide adequate manning for the experiments. The number of men required will be contingent upon the number of ground stations employed.

Exp No. P-7

ATTACHMENT 5

COMMUNICATIONS AND DATA HANDLING

1. DATA HANDLING: ON-BOARD

   a. Functions to be measured - on-board radar, and RMU TV and radar data. Subsystem status information time correlated.

   b. Requirements for Processing and Analysis - To be determined.

   c. Permanent Data Records

      (1) Photographic

      (2) Magnetic Tape

2. COMMUNICATION REQUIREMENTS

   a. Data transmission to ground - None

   b. Two-way communication data feedback from ground - Voice only routine.

ATTACHMENT 6

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME - 32 months from Pre-Phase I go-ahead to launch.

2. FINAL DEFINITIVE TEST DESIGN TIME - 15 months to completion of Phase I

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED - Numerous ground test, several KC-135 Test and 2 MOL Tests.

4. TYPE OF DEVELOPMENT TEST ITEMS

   a. Vacuum Chamber - Tools, adhesives and AMU to hard vacuum

   b. Shaker - Environmental Simulation of T-IIIC and MOL

   c. Thermal - Environmental Simulation of T-IIIC and MOL

   d. Acoustic - Environmental Simulation of T-IIIC and MOL

   e. Simulators - 5 degree of freedom

   f. Aircraft - KC-135 zero G Test of RMU.

5. SUPPORT EQUIPMENT DEVELOPMENT TIME - Compatible with AMU Development

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

   a. Ground Test - One (qualification)

   b. Atmospheric Test in KC-135 - One

   c. Space Test - Two

7. DATE AVAILABLE FOR TESTS - Qualification Unit August 1966 and Flight Units February 1967.

8. CURRENT DEVELOPMENT STATUS

   a. RTD has been testing RMU's in KC-135's for two years and Gemini Experiments Program 631A is going into Phase II Hardware procurement.

b. Funds expended to date - About $0.4 Million, Program 631A completions estimated at $4.0 Million.

c. Ground transmission (one center to another) - Test Progress

d. Accuracies - To be determined

e. Data Recording - No special requirement

f. Security - Crypto - None

AUTONOMOUS NAVIGATION

I. TEST OBJECTIVE

The objective of the MOL Experiment on Autonomous Navigation is to evaluate the ability of man to act as a spacecraft navigator. The evaluation will be conducted by analyzing the performance of members of theMOL crew in the operation of data gathering, processing and display equipment while pursuing the experiment goal.

II. IMPORTANCE OF TEST

A basic requirement to be satisfied in the achievement of operational autonomy is the ability to determine and predict orbital position independently of ground based facilities.

A variety of spacecraft navigation techniques have been proposed employing horizon scanners, star trackers, terrestrial sightings and, in some cases, man. The introduction of man into the spacecraft navigation system tends to reduce the mechanical complexity of the system and renders it more flexible through the exercise of human judgement. Terrestrial landmarks and stars may be acquired and tracked with a minimum of automated devices. The most efficient combinations of equipment and data collection and reduction methods may be selected to meet the demands of particular situations.

The experiment on autonomous navigation proposed for incorporation on the MOL vehicle brings together the unique capabilities of man and the capabilities inherent in a variety of sophisticated navigation aids for the purpose of performing extensive experimentation in the area of manned space navigation. The experience gained in the development and/or operation of such guidance and navigation systems as present aboard the Gemini and

Apollo and the development of the Standardized Space Guidance System will be drawn on extensively. In addition, much use will be made of ground and aircraft simulation facilities during the development of the experiment techniques, procedure and equipment.

Space-borne testing of the navigation experiments is of great importance. While factors such as man-equipment relationship and duty cycle, astronaut response to sensor outputs, effect of training on astronaut performance, and the effect of astronaut, instrumentation and orbit model errors on navigation accuracy may be simulated through the use of terrestrially based facilities, a true understanding and appreciation of the above factors may be gained only through testing aboard a manned orbital vehicle.

The MOL is ideally suited for such a task as it is the first orbital vehicle designed for the purpose of exploring the man-machine relationship and investigating the utility of man as an integral component of military space activity.

III. DESCRIPTION OF THE EXPERIMENT

To provide maximum experiment flexibility, the MOL experiment on Autonomous Navigation is to be configured about a basic set of equipment, the major components of which are a pointing and tracking scope (PTS), a set of horizon scanners, a precision time reference system, two automatic star trackers; a re-programable digital computer, and various prepared navigational data. All of the above equipment, with the exception of the star trackers, will be available as components of the MOL or associated experiments.

A variety of navigation techniques will be developed employing the above equipment.

The astronaut will utilize information provided by star sightings, terrestrial landmarks, horizon scanners and inertial measuring units to determine the orbital orientation and position of the MOL. Orbital corrections will be predicted and executed on the basis of navigational data generated by the on-board systems. The accuracy of the orbit prediction, and corrections, will be established by the on-board comparison of predicted and actual orbit state. The experiment evaluation would be accomplished by comparing recorded flight data with ground track information.

The astronaut(s) would serve as spacecraft navigator(s) during the course of the experiment. The astronaut(s) would acquire terrestrial and/or celestial references as required by the experiment to determine the spacecraft orbital position and would select the experiment mode of operation and requisite displays. They would provide data to the computation system and monitor its operation, interpret the forthcoming navigational data, and determine and execute the orbital corrections required to establish a specific, pre-selected orbit.

It is required of any orbital navigation system which intends to establish the position of the spacecraft in terms of geocentric coordinates that measurements be made of inertial and terrestrial references as functions of time. In practice, the inertial coordinate frame is established by the spacecraft inertial platform which is periodically updated by celestial sightings; in some instances, celestial sightings, with star trackers, are utilized to obtain the inertial reference without recourse to a true inertial platform. Terrestrial references are obtained through measurements of the earth's horizon or the sighting of landmarks. Data filtering and smoothing techniques are applied to the above measurements, which are often redundant, and the resulting information is utilized to obtain the spacecraft orbital elements in geocentric coordinates thereby establishing the position of the spacecraft relative to the earth.

An Experiment in orbital navigation, typical of the above description, may be conducted utilizing the following equipment components and man.

1. Inertial Measuring Unit (IMU)

   Typically, a combination of gimballed gyros and accelerometers.

2. Star Trackers

   An optical system sensitive to the stars emissions which, when positioned, will track a given star by virtue of its spectral characteristics.

3. Pointing and Tracking Scope (PTS)

   An optical sighting system of variable magnification which is coupled to the IMU for measurement of the line-of sight in the inertial coordinate frame.

4. Time Reference System (TRS)

   An accurate clock.

5. Spacecraft Displays

   Equipment which will inform the operator of the spacecraft position relative to the earth, the spacecraft orientation in inertial space, absolute and relative time, etc., and which will allow the operator to monitor and control the operation of the system.

6. Spacecraft Computational Facilities

   A computer, with sufficient capacity and memory, will filter and correlate measurement data, store celestial and terrestrial reference positions as functions of time, store astrodynamic constants and models and monitor the peripheral data gathering equipment. Additional equipment related to the computation system (e.g., Manual Data Insertion Unit) may be required.

7. Adequate Data Recording and/or Telemetry Capacity

   Data on measurements and operation will be obtained from the spacecraft and the ground tracking network to allow post-flight analysis of the experiment.

The experiment will utilize the above equipment to establish an inertial coordinate frame (IMU with star trackers) and obtain earth references by sighting known terrestrial landmarks (PTS). As an example of experiment variations which would be performed, the spacecraft horizon scanners could be used to establish a terrestrial reference in lieu of the PTS.

The determination of the MOL orbital position would be accomplished through the use of the mechanized elements of the navigation system by operator. At a suitable point in the MOL mission profile, the astronaut would prepare the computer for the experiment by positioning required programs and navigational data through the selection of a computer operating mode. Requisite equipment, such as the IMU, would be activated. The astronaut would select two stars from the catalog available to him, enter their codes into the computer and acquire them with the star trackers. Once the stars were within the trackers field-of-view, the star trackers, would be allowed to track the stars automatically. The trackers, in conjunction with the IMU, would establish the inertial coordinate frame. Similarly, a terrestrial landmark appropriate to that phase of the MOL mission would be selected and its code entered into the computer. The astronaut would sight the landmark with the PTS and register a number of readings into the computer. The data provided by the star trackers and PTS would be used by the mathematical orbit model to determine the spacecraft's orbital position. This positional information would be displayed to the astronaut in terms of equivalent earth latitude and longitude and, perhaps, pictorially through the use of a simulated ground trace. The operation described above would consist of a course, preliminary orbit determination scheme, based on relatively few measurements, to establish the initiation point for a refined orbit determination scheme utilizing greater quantities of measurement data as they would become available.

The second portion of the experiment would call for increased astronaut participation. The astronaut would introduce specific orbit perturbations into the computer and predict, through computation, the effect on the MOL orbit. From displays giving the spacecraft orientation, the astronaut would establish the desired spacecraft attitude and execute the orbit perturbations mentioned above through the application of incremental velocity. The orbit determination scheme described earlier would then be repeated and the resulting orbit compared with that predicted.

A typical navigation problem would be the over-flight of a pre-selected point on the earth. The desired accuracy of the over-flight would be dependent on the mission to be performed over the terrestrial point. If a sensor such as the PTS was to be used for viewing purposes, the over-flight accuracy would be dependent on the field-of-view of the PTS. In such an instance an over-flight deviation on the order of 10 miles may be tolerable. Once the coordinates of the terrestrial point and an acceptable deviation were fed into the computer through the Manual Data Insertion Unit, the computer would compare the projected ground trace of the established MOL orbit to the location of the terrestrial point. Adjustments to the established MOL orbit, in terms of orbit inclination and/or period, may be required. If such was the case, a number of potential orbit adjustments would be suggested by the computer. The astronaut would select the most suitable orbit adjustment, in keeping with time and propulsive energy requirements, and execute the correction at the appropriate time. The resulting orbit would be determined with the on-board instrumentation and compared with the predicted orbit. If required, a portion of the above procedure would be repeated.

In all instances, the flight data obtained from on-board instruments and ground track would be recorded for subsequent post-flight analysis.

IV. EXPERIMENT FUNDING

Based on estimated provided for the 631A Program, the total funding required for the MOL Experiment on Autonomous Navigation would approach ten million dollars. The following breakdown of costs would be typical:

ITEM	COST (millions)
1. Experiment development fabrication	6.5
2. Installation, integration and support	2.5
3. Simulation & Misc.	1.0

V. PARTICIPATING AGENCIES

Sponsor: AFSSD/Aerospace

ATTACHMENT A

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. Equipment to be Tested (Used in the Test):

   IMU (MOL equipment)
   Stellar Trackers (Experiment Equipment)
   Pointing and Tracking Scope (MOL Equipment)
   Horizon Scanner System (MOL Equipment)
   Time Reference System (MOL Equipment)
   Spacecraft Navigational Display System (Experiment Equipment)
   Spacecraft Computer (re-programable) (MOL Equipment)
   Data Recording and Telemetry System (MOL Equipment)

2. Weight: 65 lbs (approx.)

3. Volume: 7 ft^3 (approx.)

4. Power:

   a. Continuous: 200 watts
   b. Stand-by: 50 watts
   c. Average operating: 200 watts
   d. Peak: 225 watts to 250 watts
   e. Duty cycle: Not known

5. Spares:

   No estimate available at present

6. Tools

   No estimate available at present

7. Heat Output: 200 watts

8. Stability: (At least 1 degree, .25 deg/sec)

9. Vibration Limits: Titan III spectrum

10. Shock Limits: Titan III spectrum

11. Hazards: Negligible

12. Temperature Limitations: Undefined at present

13. Type and Range of Measurement: Angles; 0° to 90°
14. Special Environmental Requirements: Those of astronaut for experiment equipment.
15. Orientation and Position Accuracy Requirements: Variable orientation for earth/star sightings with a pointing accuracy of approximately 1.0°.
16. Equipment Operating Cycle: Continuous operation from min of 1.0 to max. of 8.0 hours.
17. Equipment Location Requirements: Star tracker on "upper" section of MOL to view stars.
18. Special Mounting Requirements: Apertures: None Booms: None Windows: Optically flat windows for star tracker and pointing/tracking telescope, Bracketry: None, External: Body mounting of horizon scanners:
19. Pressure Vessels: None
20. Electromagnetic Interference: None
21. Maintenance Requirements: None anticipated at present.

Exp No. P-8

ATTACHMENT B

TEST SUPPORT EQUIPMENT

1. Recording Media: Tape; possible photograph star backgrounds for post-flight analysis.
2. Handling: None
3. Packaging: No special requirements.
4. Calibration: Alignment and calibration of star trackers (PTS, horizon scanners and inertial platform)
5. Jigs and Fixtures: Alignment
6. Number of Leads from Outside to Inside Station: Horizon scanner leads
7. Sensors: Horizon scanners; pointing/tracking telescope, stellar trackers
8. Trainers/Simulators: Undefined at present
9. Instrumentation: Navigation data display; individual instruments not defined at present.
10. Related Support Equipment
    a. Targets: None
    b. Ground stations: Earth landmarks
    c. Tracking: Existing tracking network
    d. Handling Equipment: None
11. AGE: Check-out for star trackers, navigation displays (horizon scanners)
12. Environmental Test Equipment: Existing and low vacuum
13. Facilities: No estimate available at present

ATTACHMENT C

TEST OPERATING CHARACTERISTICS

1. Orbital Parameters:
   a. Altitude: 150 to 250 naut mi
   b. Inclination: Less than 36°
   c. Eccentricity: Zero
2. Plane Change: Not defined at present
3. Altitude Change: Not defined at present
4. Time on Orbit: Up to 30 days
5. Test Duration: Variable, 1 to 10 orbits
6. Total Number of Tests: Approximately 50
7. Test Frequency: Not defined at present
8. Interval between Tests: Up to 1 day
9. Crew Task Loads: Approximately 200 man-hours
10. Crew Task Frequency: Not defined at present
11. Field-of-view Requirements: $\pm$ 180°
12. Ground Control Liaison Duration: None
13. Ground Control Liaison Frequency: None
14. External Test Items: None
15. Qualification Tests (Other than space): Not defined at present
16. Sequence of Events as they Occur During Flight
   a. Coarse alignment
   b. Data gathering
   c. Data processing and smoothing
   d. Readout of autonomous navigator
   e. Interpretation of results.
17. Handling Procedures: Not critical

ATTACHMENT E

MANNING DESCRIPTION

1. Astronauts

   a. Number Required; One (maximum of two)

      (1) Man's function

         (a) As part of test: Coarse Alignment; initial set-up; data interpretation.

         (b) As technician conducting test: Monitor all functions.

   b. Crew Skill Requirements: Highly knowledeable in navigation theory and practice.

   c. Manpower Profile (Per test)
   One man continuously for up to 2 hours.

   d. Critical Functions: Control of spacecraft

   e. Work Positions: Seated at console

   f. Time Controlled Tasks: Thrusting of spacecraft engines

   g. Human Performance Measures: Not critical

   h. Physiological and Psychological Measures: Not critical

   i. Selection Factors: Not critical.

   j. Training Requirements: Navigation theory and practice.

2. Ground Personnel: Check-out of experiment and spacecraft equipment.

ATTACHMENT F

COMMUNICATIONS AND DATA HANDLING

1. Data Handling: On-Board

   a. Functions to be measured: Angles - optical and horizon scanner data.

      (1) Data rate/frequency response))
      Volume of data) - not defined at present
      Accuracy required)

      (2) Form of data: Digital and analog

      (3) On-board processing: Computer

      (4) Communication requirements (to ground): Ground tracking information sent to vehicle for comparison purposes.

   b. Requirements for Processing and Analysis

      (1) Data reduction: Comparison of predicted to determined position

      (2) Computation: On-board computer

      (3) Evaluation and Interpretation: Astronaut function

      (4) Pictorial Analysis: None

      (5) Real-time monitoring: Continous during experiment

      (6) Displays: All navigational information

   c. Permanent Data Records (for fly-down in a recovery capsule): None

2. Communication Requirements

   a. Data transmission to ground: Not defined at present

   b. Two-way communication data feedback from ground: Not defined at present.

Exp No. P-8

ATTACHMENT G

DEVELOPMENT CHARACTERISTICS

All items, with the exception of star tracking and display equipment, would be developed as part of the MOL system.

Experiment No. P-9

NEGATION AND DAMAGE ASSESSMENT

OBJECTIVE

The objective of this test is to evaluate man's ability in carrying out a negation and damage assessment function.

IMPORTANCE OF EXPERIMENT

The objectives of satellite inspection are to gain intelligence, identify the mission of unknown satellites, and negate satellites determined to be hostile. The object of negation is to incapacitate or physically destroy the satellite as required. The satellite inspector could contain its own negation equipment and be directed to carry out the negation following an inspection mission. It is presently anticipated that negation missiles would use non-nuclear warheads and that the missiles could be guided, unguided, or carried in a guided-unguided mix.

The potential of placing weapons in either near or far earth orbits is closely related to the reliability and cost-effectiveness such systems can attain in the future. The possibility of an enemy using this type of system cannot be fully substantiated at the present time. Investigation of the basic techniques involved in storing weapons in space and their precision delivery are currently underway. Thus, it is necessary to determine the advisability of developing counter systems based on requirements, capabilities and limitations of orbital negation systems and the contribution that an astronaut can make to such a military system. These tests will also contribute to the considerations for our own possible delivery systems in reducing vulnerability of our retaliatory forces.

The other important application of negation is to self defense missions when it has been determined that an inspection or surveillance satellite is under actual or imminent hostile attack. It could be expected that this encounter would not necessarily be from a rendezvous situation, but involve greater velocities and crossing angles. Thus, the most appropriate weapon might be an automatic tracking missile with a proximity fuse and shrapnel or pellets. However, the development of the negation system would follow the same lines as above and this experiment would indicate the capacity of an astronaut to aim, fire and successfully destroy an attack missile within a reasonable extrapolation of the range and closing velocities employed in the experiment.

BACKGROUND

The 706 Program has been conducting studies of negation devices to be launched from a satellite inspector to destroy a target satellite. Studies conducted included four contracted efforts prior to Phase 0 with General Dynamics/Pomona, Aerojet-General, Raytheon, and Hughes. These studies considered the problem of unmanned operations at very short ranges. Additionally, in-house studies are underway which are also considering both guided and unguided systems for unmanned and manned/unmanned operations at various ranges. These studies have been supported by information from the Army (Picatinny Arsenal) and R&TD Detachment 4 at Eglin AFB, and are scheduled to be completed in June 1964. These 706 studies have provided sufficient preliminary information and trends to begin a pre-Phase I in-house experiment definition.

Studies have been conducted by the R&TD Detachment 4 and the Avionics Laboratory at Wright-Patterson AFB on various aspects of weapon characteristics, launch and guidance problems, effectiveness against different targets, and kill probability, although these studies have concentrated on other than a space-to-space mission.

Analysis of the above studies indicates that a penetration type weapon gives greatest assurance of complete destruction of a bomb warhead. A destruct charge would probably be preceded by a shaped charge in order to penetrate into the weapon interior through any armor which might be used. Pellets and shrapnel might be effective against softer targets, and would reduce the accuracy requireme for guided missiles and increase the effective range for unguided missiles.

For the guided missiles, consideration will be given to beam rider, radio, wire,visual, and IR guidance systems, and reaction jet attitude control. Capabil: to penetrate a specific desired location on the target will be determined.

While the effective range of unguided missiles is considerably less becaus of accuracy requirements and dispersion, they do allow reduction in the complexit of the missile and on-board checkout equipment with the higher probability of successful operation.

DESCRIPTION OF EXPERIMENT

Equipment: A console would be located convenient to the pointing and tracking scope that would allow the astronaut to control the experiment while observing the target. Switches and controls would be provided that would deploy the target which would then have a sequenced expansion.

The target to be employed for the negation and damage assessment experimen will be an expandable structure approximately 10 ft in diameter that will be deployed from the MOL at a very low velocity, about 1 ft per sec. Initial tests will have previously been made to determine the desired coating and surface characteristics. Results of R&TD lab tests indicate the unexpanded target should weigh about 40 pounds and occupy about two cu ft when stored. It may be necessary to install a low powered C band battery operated radar beacon in order to accurately determine the range and range rate for complete evaluation of the tests. Also, since some momentum will be imparted to the target when struck by the negation missile a code signal could be added to the beacon in order to denote a hit. This would allow knowledge of a hit if the pointing and tracking scope is unable to assess the damage and it is not desired to expend the ΔV of the MOL to effect a close rendezvous with the target.

The experiment control console would also contain the arming switches and firing switches for launching the missiles, as well as displays indicating the condition of the missile system. An on-board system very similar to that used for aircraft launched GAR's would be appropriate. A launching tube containing about four guided missiles and six unguided missiles would be extended upon command, and upon acquisition and aiming of the launcher by means of the pointing and tracking scope the missile would be fired. It would be considered appropriate for the experiment to use the Gemini type interferometer radar for cooperative range and rate rather than an ATS system which would be more suitable for an operational device.

The 706 studies have indicated that it is desirable to have all burning take place within the launching tube in order that obscuration of the target by the rocket combustion flame and products be minimized.

The requirements of the experiment may well be satisfied by adaptation of existing systems. For example the TOW missile being manufactured by Hughes for the Army uses wire guidance with about a mile of wire, with radio backup. Unguided missiles may be adapted from the Army's M-72 LAW or WASP, both of which are light-weight, ground proof-tested missiles. Adaptation of other guided and unguided systems is considered feasible. The missile warhead would probably consist of a shaped charge as a penetration device ahead of the destruct charge which might depend on shrapnel for more effective destruction of a warhead. It would be expected that some timing device would explode the warhead at a safe distance similar to that currently employed in anti-aircraft shells. A proximity fuse should be considered in order to assess misses, although its use in an operational weapon would be more effective for self defense missions.

The checkout equipment would consist of devices to determine the integrity and safety of arming and firing circuits, ability of the launcher to extend, the capability of the target deployment system to function, and bore sighting equipment to align the launcher with the pointing and tracking scope. In addition, there would be equipment to check the guidance system of the guided missiles, and facilities to attach fuses for wiring and firing charges for the remote motors with safety during the late hour of the missile countdown. It is considered that equipment and procedures common to aircraft would be appropriate.

<u>Procedure:</u> The experiment would begin at the appropriate time which would allow for the best target visibility by the astronaut who would deploy a target, and after it has proceeded about 2000 ft away for guided missile tests or 400 ft for unguided tests, effect an appropriate maneuver of the spacecraft

to stabilize the range rate. The point and tracking scope is used as the sighting device and the missile launcher is extended, the missiles checked out, and aimed and fired at the target. The higher power of the pointing and tracking scope would be used to assess the damage to the target and, if sufficient ΔV is available, to rendezvous with the target for a close evaluation. Reception of coded radar signals might prove sufficient to establish hits. In order that an adequate test be performed, several rounds should be fired at two or three targets that would be deployed in various lighting conditions, directions and distances from spacecraft. It is possible that this experiment may be completed with a remote maneuvering unit which would be used to deploy the target and return it to the vicinity of the MOL for assessment of damage, if the basic RMU systems are not damaged by a hit. This portion of the test of course, be conducted after tests of the ability of the RMU to maneuver. An alternative would be to deploy the RMU to survey the target damage which would could minimize the ΔV to be supplied by the MOL in the event that some velocity is imparted to the target by the missile impact. A further alternative would be to station the MOL in the vicinity of the target at the time the test is to begin. The evaluation of the experiment will consider the ability of the astronaut to accurately provide initial aiming of the missile which can be assessed from the PTS camera record. The accuracy of the missile and the amount and type of damage likewise will be determined from astronaut comments and PTS camera records and possibly video records from the RMU if employed. Previous pointing and tracking tests and visual observation capability tests will determine man's ability to use the equipment provided and determine when ~~negation should be taken against targets, whether for on-orbit weapon destruc-~~ tion or self defense.

Simulation: Extensive simulation of this experiment is possible and required. Most of the accuracy determination and initial aiming of the launcher by the pointing and tracking scope will be obtained from this experiment's simulation program. Expected performance of various types of missiles can be extrapolated from ground tests, although most current missiles employ aerodynamic stabilization rather than reaction jet stabilization. This aspect will be the most difficult characteristic to simulate and is a reason for conducting on-orbit tests. The damage to various targets can be assessed by firings at Eglin AFB by R&TD. The human factors evaluation of the experiment can be a part of the observation simulation tests by adding the sufficient controls and displays required for the missile launches. Also, assessment of damage by the pointing and tracking scope can be simulated during these tests.

Studies: It has been considered appropriate to conduct the pre-Phase I experiment definition in-house as an extension of the 706 Program negation study. This effort will be closely coordinated with R&TD at Eglin AFB. However, the Phase I effort will require contractor study in order that preliminary design concepts be available for integration into the MOL lab plan design at an early date.

MULTIBAND SPECTRAL OBSERVATION

I. TEST OBJECTIVES

The primary objective of the multiband spectral experiment is to evaluate man's ability to operate specialized radiometric and related equipment as aids in the following military mission and related scientific activities:

1. Acquisition and tracking of orbiting objects and/or ballistic missiles during their boost, midcourse and re-entry phases.
2. Detection of high flying aircraft in clear weather or against a cloud background.
3. Determination of temperature profile of ground and sea, and of orbiting targets. Detection and identification of camouflage, day and night observations.
4. Collection of data essential to the design of improved horizon sensors from which advanced attitude control subsystems may be derived.
5. Collection of a wide range of background measurements, in particular, earth albedo and sky background data which will be used to design advanced sensing systems.

II. IMPORTANCE OF TEST

The MOL vehicle provides a unique opportunity to assess the ability and utility of man to perform tests of military value. The sensor will consist of an IR/UV multiband scanning radiometer capable of measuring radiation from cooperatively launched missiles, from orbiting objects, high flying aircraft, and from the most adverse earth background configurations. In addition, the sensor will be capable of obtaining the thermal profile of selected regions of the earth's surface as well as orbiting targets. The experiments, which will be conducted under complete control of the astronauts, will provide fundamental data of crucial value to the proper design of advanced sensors for various military space systems such as 461, 706, 893, SSGS, infrared reconnaissance, etc.

The use of the MOL vehicle will permit measurement of extreme value to be made of areas of greatest interest while uninteresting areas are disregarded, thus avoiding swamping the system with nonessential data. Furthermore, in just a few orbits crucial information will be obtained which could require years of measurement at prohibitive cost from unmanned satellites.

The MOL multiband spectral observation of targets and backgrounds does not constitute a duplication of Gemini experiments 4 and 9 presently under consideration. In the Gemini experiments both the man's role and the sensor performance are limited. While in the Gemini experiments the astronaut's function is essentially restricted to turning the equipment on and off and aligning the sensor for maximum deflection, in the MOL experiments the astronaut will perform additional functions such as select interesting areas for measurement; change detectors, filters, scanning mechanism, and associated equipment; make preliminary evaluation of the data presented to him on the console. The Gemini and MOL sensors are entirely different. The Gemini experiments 4 and 9 will make radiance measurements with non-scanning radiometers and interferometers in the spectral region from .2 to 12 microns. In the MOL experiments the multiband sensor will be used both as spatial and spectral scanning radiometer covering the UV band and various IR bands from one to 30 microns. In addition, the multiband sensor will have the capability to acquire and continuously track the targets of interest.

III DESCRIPTION OF THE EXPERIMENT

The multiband sensor will consist of an all reflective optical system which may be operated both as a spatial and spectral scanning radiometer each being capable of accommodating several detector assemblies to be used for measurements in the infrared or in the ultraviolet, as required during the various phases of the experiment.

The optical system will be mounted on what is normally the earthward side of the MOL vehicle, and it will be possible to rotate it about two axes so that any portion of the portion of the earth observable from the satellite may be brought into the field of view.

Configuration of Test Item

The multiband spectral sensor may be housed either in the pressurized first module or in the unpressurized second module of the MOL vehicle. If housed in the unpressurized second module, it will be remotely operated, as a slaved unit, by an astronaut from the pressurized first module of the MOL vehicle. In either case, a pointing and tracking scope (PTS) Paragraph 3.8) will be available for use as an optical director. As a design goal, the optics needed for the subject sensor will be limited to an all-reflective system with a maximum of 12 inches in diameter, and a weight of 65 pounds or less.

The remaining portions of the radiometer and auxiliary equipment (including cryogenics) will be limited to 250 pounds with a maximum power consumption of 300 watts.

Test Support Equipment Required

It is anticipated that most of the required support equipment will be available from other MOL Experiments.

1. On Spacecraft

a. A Pointing and Tracking Scope (PTS). During the experiment the multiband spectral sensor may be remotely connected and slaved to the PTS to provide accurate pointing of the sensor. When targets, invisible to the human eye, are being sought, the PTS will be used as a goniometer if advanced target location data are available to the astronaut.

b. A 16 MM stop frame camera with which the astronaut photographs the object being tracked.

c. A display console for the radiometer outputs.

d. A magnetic tape recorder capable of up to 5 MC read-in and 1 MC read-out with up to 30 minutes temporary storage.

e. A star tracker to provide reference angles during the horizon sensing phase of the experiment.

2. On the Ground

a. An Aerospace ground equipment (AGE).

b. A computer to process results of each test as soon as the data are received so that the measurements may be interpreted and the program for succeeding experiments may be modified so as to converge on the desired goal as rapidly as possible

Test Procedure

The astronauts will play a crucial role during all phases of the experiment. Their activities shall include the following:

1. Pointing of optics in the direction of phenomena or target using the PTS or other controls.

2. Selection of area for measurement.

3. Changing of detectors, scanning mechanisms and associated equipment.

4. Changing of filters.

5. Adjustments and calibrations.

6. Preliminary evaluation, recording of data, and verbal descriptions.

7. Coordination with the ground.

During one MOL mission the following phases of the experiment will be covered:

1. Infrared Background Measurements

During this phase of operation, the multiband spectral sensor will be used both as a spatial and a spectral radiometer.

Two modes of operation are contemplated, (1) a visual search with manual scanning mode performed by the astronauts and (2) an automatic scanning mode. It will be an objective of this study to determine whether the additional complexity of an automatic scanning mode is justifiable in terms of the quality and amount of data collected.

a. Manual Scanning. The visual search with manual scanning mode will be accomplished as follows:

(1) One astronaut will search visually for regions of strong background return, while the other observes the output of the spatial scanning array on his display console. They will then selectively record and/or telemeter the output of their array and their commentaries on what was observed visually during the measurement. This will be done for several strong return areas.

(2) The astronauts will scan similar areas with the spectral scanning radiometer.

(3) These data will be analyzed and the astronauts will insert an optimum filter (or filters) to use in the scanning array.

(4) Using this optimum filter they will study as many regions of high return as possible. They will track these regions so as to view them from a range of aspect angles and to determine whether there are rapid temporal changes. The scanning array will observe a large enough area so that the sizes and spatial distributions of the regions of strong return can be determined.

b. Automatic Scanning. The automatic scanning mode will be accomplished as follows:

(1) The astronaut will start the atuomatic mode after setting a radiance threshold for each of the spectral bands to be used in the measurement.

(2) The field-of-view used in the scanning operation will be adjusted by the astronaut.

(3) Whenever the preset thresholds are exceeded the radiometer stops scanning, locks on the area generating the signal, and proceeds with spectral scanning using a preprogrammed group of filters for the purpose of determining sizes, spatial and spectral distributions of the regions of strong return.

2. Infrared and Ultraviolet Sensing of Ballistic and Orbital Targets

During this phase of operation, the multiband spectral sensor will be used primarily as a spatial scanning radiometer to perform the function of detecting and tracking cooperative ballistic missiles and orbiting objects through the longest possible portion of their flight, or orbit, from boost to re-entry inclusive. During this mode, one additional important function of the sensor will be to obtain spectral signature of the target. The astronaut's functions in these tests are to: (1) make measurements in regions of interest only, (2) track targets, (3) point the scanner across regions of interest, (4) assembly and adjust the many possible equipment combinations, and (5) calibrate and maintain the equipment.

Once the astronaut is notified of a ballistic launch, he is given the relative target coordinates, and selects the proper sensor spectral bands required for detection of the ballistic missile in the boost phase. The astronaut points the sensor in the direction of the target with the help of the slaved PTS, used as a goniometer only, if target is invisible to the human eye, and starts searching a relatively small space volume which is expected to contain the target. In the case of orbiting objects, these may be either active or inactive artificial cooperative satellites or targets of opportunity including some in orbits higher than the MOL vehicle. In all cases, the experiment shall be designed to provide data on man's ability to detect the targets described, using the multiband spectral sensor alone or in conjunction with other sensors or aids such as radar and the SPADATS network.

Upon detection of a target, the astronaut will commence automatic or manual tracking using the PTS or the output of the radiometer itself. He will continue tracking as long as possible throughout the midcourse and re-entry phases of the missile trajectory. Filters may be changed, in rapid succession, during this part of the test procedure.

The sensor output shall consist of detection signals and identification of the spectral bands providing the signals, as well as angle and angle rate. This output shall be recorded for later ground evaluation as well as being displayed to the astronaut for his information on the conduct of the experiment.

In the acquisition and tracking mode, the multiband sensor must be compatible with MOL operation, and shall have automatic sequencing capability through the spectral bands, pre-set before mission onset or modified by the astronaut, as required by the experiment.

3. Thermal Profile of Ground and Space Targets

During this mode of operations, the multiband spectral sensor will be used as an optical scanning radiometer. Using the proper filter-detector-radiometer combination, the astronaut will point the radiometer to the region of the earth to be mapped. An attempt will be made to detect thermal structures produced by ocean currents and sea states, harbor activities, shipping and wakes, air field activities, meteorological formations, geological formations, underground nuclear tests and man-made structures such as missile sites and underground factories.

Pictorial data of cooperative targets will be furnished and displayed by rear screen projection in an easily accessible manner which will facilitate comparison with the actual target. The astronaut will select targets based on orbit configuration, and cloud cover consideration. Visual sighting and photographic imaging of targets will be made for comparative purposes.

For daylight targets, the astronaut will concentrate largely on camouflage discrimination using various filter combinations and detectors in the red, near and intermediate IR. A few daylight measurements in the far IR will also be made to assess target thermal emission contrast with adjacent surroundings for comparison with orbital night measurements.

During orbital night, measurements will be made with carefully selected filters and resolution elements (detector size) in the 8 - to 14-micron region. Orbital targets, approached by MOL in a station-keeping mode, at ranges of 2000 feet or less, will also be submitted to a radiance profile analysis.

The astronaut will be obtaining on-the-job (in space) training for this type of observation.

4. Horizon Sensing Data

During this mode of operation, it is desired to measure the radiance profile of the earth's horizon as a function of line-of-sight angles for various spectral regions in the infrared over a wide variety of meteorological conditions and geographical locations. The experiment will provide a better understanding of the radiation characteristics of the horizon and the variations to be expected.

The astronaut will select the desired filter-detector-radiometer assembly. He will scan the horizon spatially and spectrally to determine the sharpness of the horizon for the optimum spectral response of the radiometer. The position of the horizon will be determined for various azimuth angles, latitudes, sun positions and weather conditions.

5. Detection and Tracking of High Flying Aircraft

An attempt will be made to detect and track high flying aircraft against the sunlit earth background.

The sensor operation in this mode is identical to that used in the detection and tracking of ballistic missiles and orbiting objects outlined in Paragraph 3.4.2.

Category of Experiment

The multiband spectral observation experiment is considered category 1 because it places a rather heavy demand on the astronaut.

Cost

The multiband components are expected to be all within the state of the art, no new development will be required, and hence the cost can be kept relatively low.

	Prior	FY 65	FY 66	FY 67	FY 68	FY 69	Total
1) Pre-Phase I Study	$200k						$200k
2) Engineering & Development		700k	700k	400k			1800k
3) Installation				400k	400k		800k
4) AGE			75k	75k	50k		200k
5) Training & Simulation			100k	100k	200k		400k
TOTAL	$200k	700k	875k	975k	650k		3400k

Schedule

1. Availability for Test

   Eighteen months after contract is let.

2. Flight Readiness

   Twenty-four months after contract is let. This includes a training program for the astronaut with tests in an aircraft.

Participating Government Agencies

Sponsor: AFSSD/Aerospace   Participant: OAR

Additional Requirements

1. Special Security

   Equipment unclassified.

   Background data confidential.

   Target data secret.

2.

3.

4. Facilities

   Existing and planned ground facilities should be sufficient.

5. Simulation and Training

   a. Astronaut

a. Astronaut (continued)

Equipment to be tested and astronaut trained in aircraft.

A well trained team of scientists and computer engineers must be on duty during measurements. Computer programs must be tested during the pre-flight training of the astronaut.

TEST OPERATING CHARACTERISTICS

1. Orbital Parameters desired.
    a. Altitude - approximate 200 miles
    b. Inclination - near polar desired but 30° acceptable.
    c. Epoch - not critical
    d. Eccentricity - Approximately circular
2. Plane Change - none required.
3. Altitude Change - none required.
4. -
5. Test duration - Twenty-five daylight hours minimum for background tests plus half hour measurements each on as many cooperative targets as possible.
6. Total Number of Tests - See 5.
7. Test Frequency - no specific frequency.
8. Interval between tests -

    Background tests - daylight side only

    Target tests - depend upon target availability
9. Crew Task Loads - 40 man hours.
10. Crew Task Frequency - as in 8.
11. Field of View Requirements -

    Instantaneous - 2° to 5° cone

    Scan possibility - From nadir to 60° elevation angle, and all azimuths for background tests. Target to be tracked for target studies. Highly desirable that vehicle be able to turn over for target measurements.
12. Ground Control Liason Duration

    Communication as required for data reception, and for transmittal of ground commands.
13. Ground Control Liason Frequency

    Once per orbit during background tests

    Continuously during target tests

14. External Test Items.
   a. Launched from Station - None
   b. Launched from Resupply - None
   c. Launched from Ground - Cooperative targets as available preferably from MOL launch facility.

MANNING DESCRIPTION

1. Astronauts
   a. Number required - two during test
      (1) Man's function
         (a) As part of test
            Select areas of interest
            Track object being measured
            Record Verbal description
            Record photographs of object
            Operate radiometers and record their output
         (b) As technician
            Change filters, detectors and scanning mechanism
            Install proper radiometer as commanded
            Telemeter recorded data to ground station
            Perform routine calibrations, checks, and adjustments
   b. Crew skill requirements
      Must be excellent technicians
      Scientific training desirable but not essential
   c. Manpower profile - 80 man hours
   d. Critical functions - All items under a. are critical
   j. Training requirements - must go through/preflight training and equipment checkout in aircraft before equipment is installed in satellite

GENERAL PERFORMANCE IN MILITARY SPACE

I. Test Objective:

The objective of this test is to assess the psychological status of the operator on a day-to-day basis throughout the mission with respect to his readiness to perform tasks that are basic to his contribution to system and subsystem effectiveness.

II. Importance of Test:

The performance measurements to be made will provide information that is needed for two purposes. First, the broadly defined biomedical status of the operator must be further delimited by precise information about the man's alertness, general performance capabilities and performance reserve vis a vis the problems presented by the systems management functions and the re-entry profile. Second, the operation of the vehicle and military subsystems entails two potential sources of variance - the equipment and the man. Since we typically will have incomplete knowledge about the detailed nature of the forcing functions which "drive" these subsystems these general performance measures are required to provide an index of the man's performance as a possible source of variance in subsystem operation.

III. Description of Experiment:

a. Configuration of Test Items - The performance tasks will be mounted in a panel that will occupy a volume of .3 cu. ft. (3" x 8" x 15"); the weight of the panel will be approximately 15 pounds; the power drain of the panel of displays will be about 20 watts.

b. Test Support Equipment Required - This device would be programmed by a suitable on-board computer that could presumably be acquired as an existing or modified general purpose mission task computer.

c. Test Procedure - Each operator would be tested on this device on alternate days at the rate of 30 minutes per session, two sessions per day, for a total of one man-hour per day. The daily schedule of testing should provide for one of the test sessions to occur at a fixed time each day, e.g., at 0800; the second test session will occur alternately at a time approximately 8 or 16 hours after the first test session for that operator on that day.

The specific tasks to be included will provide measures of the following psychological functions: (1) Monitoring of static and dynamic displays, (2) Visual discrimination, (3) Short-term memory, (4) Psychomotor performance, and (5) Intellectual activities.

The chart below names the specific tasks and shows the proposed performance schedule for a given 30-minute session:

	0	5	10	15	20	25	30
Warning Lights	X	X	X	X	X	X	X
Probability Monitoring	X	X	X	X	X	X	X
Tracking	X						X
Mental Arithmetic		X	X	X			
Code Lock			X	X	X		
Target Identification					X	X	

d. Category of Experiment - This item falls in both Categories A and C.

e. Cost - See Atch 4.

f. Schedule - See Atch 7.

IV. Participating Government Agencies:

Sponsor: AMD (6570 AMRL, Wright-Patterson AFB, Ohio)

Test Equipment Acquisition: 6570 AMRL, Wright-Patterson AFB, Ohio

V. Additional Requirements:

a. Special Security - N/A

b. Manning Description Summary - See Atch 5.

c. Logistics - To be determined.

d. Facilities - Existing AMRL facilities will be sufficient.

e. Simulation and Training - See Atch 5, Section 1, Item j.

VI. General: See Atchs 6 and 7.

Exp No. P-11

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED: Performance Battery
2. WEIGHT: 15 pounds
3. VOLUME: Stored - .3 cubic feet; In use - .3 cubic feet

   CRITICAL DIMENSIONS - SHAPES: 8" x 15" x 3"
4. POWER:
   a. Continuous - N/A
   b. Stand-by - N/A
   c. Average Operating - 20 watts
   d. Peak - 20 watts
   e. Duty Cycle - 30 minutes/8 hours
5. SPARES:
   a. Volume - 12 cubic inches
   b. Quantity - Miscellaneous light bulbs, etc.
   c. Weight - 8 ounces
6. TOOLS: N/A
7. HEAT OUTPUT: To be determined
8. STABILITY: N/A
9. VIBRATION LIMITS: 2 g's rms 5-100 cps
10. SHOCK LIMITS: To be determined

11. HAZARDS (fire, explosion, electrical, toxics, other): N/A

12. TEMPERATURE LIMITATIONS: + 390° Fahrenheit

13. TYPE AND RANGE OF MEASUREMENT (definition of parameters to be measured while test is underway): See Section III. c.

14. SPECIAL ENVIRONMENTAL REQUIREMENTS: N/A

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS: N/A

Station

Equipment

16. EQUIPMENT OPERATING CYCLE:

Frequency: Once/8 hours

Time Duration: 30 minutes

17. EQUIPMENT LOCATION REQUIREMENTS: At station keeping console

18. SPECIAL MOUNTING REQUIREMENTS: N/A

19. PRESSURE VESSELS (fluids, gasses, etc.): N/A

20. ELECTRO MAGNETIC INTERFERENCE: N/A

21. MAINTENANCE REQUIREMENTS: None

Exp No. P-11

TEST SUPPORT EQUIPMENT

1. **RECORDING MEDIA: Magnetic tape**
2. **HANDLING (special equipment required to handle items being tested): N/A**
3. **PACKAGING: N/A**
4. **CALIBRATION (alignment, deployment): N/A**
5. **JIGS AND FIXTURES: N/A**
6. **NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION: N/A**
7. **SENSORS (Transducer-Output Signals): To be determined**
8. **TRAINERS/SIMULATORS: Currently existing at Lockheed-Georgia Co.**
9. **INSTRUMENTATION: Requires programming from digital computer**
10. **RELATED SUPPORT EQUIPMENT: N/A**
11. **AGE: N/A**
12. **ENVIRONMENTAL TEST EQUIPMENT: N/A**
13. **FACILITIES: N/A**

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS (desired): N/A
2. PLANE CHANGE: N/A
3. ALTITUDE CHANGE: N/A
4. TIME ON ORBIT: N/A
5. TEST DURATION: 30 minutes/8 hours
6. TOTAL NUMBER OF TESTS: 60
7. TEST FREQUENCY: 2/day
8. INTERVAL BETWEEN TESTS: 8 hours
9. CREW TASK LOADS (manhours): 1 hour/day
10. CREW TASK FREQUENCY: 2/man/on alternate days
11. FIELD OF VIEW REQUIREMENTS: N/A
12. GROUND CONTROL LIAISON DURATION: Transmission time
13. GROUND CONTROL LIAISON FREQUENCY: 1/8 hours
14. EXTERNAL TEST ITEMS: N/A
15. QUALIFICATION TESTS (other than space): N/A
16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT: See Section III. c.
17. HANDLING PROCEDURES: N/A

FUNDING SUMMARY
BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing	1,250M	40M	300M				
Integration & Installation	To be determined						
AGE	None						
Simulators/Trainers	None						
Data Reduction	Minimal						
Equipment Rework	To be determined						
Other							
TOTAL							

Source of Funds - Hitch Line Number - 62405124

MANNING DESCRIPTION

1. ASTRONAUTS:

   a. Number Required: 2

      Man's function - As subject in test, self administered

   b. Crew Skill Requirements: Not specific

   c. Manpower Profile: Not specific

   d. Critical Functions: Not specific

   e. Work Positions: 1

   f. Time Controlled Tasks: 30 minutes/8 hours

   g. Human Performance Measures: See Section III. c.

   h. Physiological and Psychological Measures: See Section III. c.

   i. Selection Factors: Adaptability to 4-hours work/4-hours rest schedule.

   j. Training Requirements: Section i above and this requirement could be satisfied simultaneously in a 10-day period.

2. GROUND PERSONNEL:

   Number Required: There is a requirement for a psychologist experienced in research on the performance effects of environmental stress to be available to integrate data on day-to-day basis.

Exp No. P-11

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE: 2 transmissions/day; 24 data points/30 minutes of performance.

2. FUNCTIONS TO BE MEASURES: See Section III. c.

3. TYPE OF ANALYSIS REQUIRED: Means

4. PICTORIAL DATA REQUIRED: None

5. REAL TIME MONITORING REQUIREMENT: N/A

6. DATA EDITING OR COMPRESSION: N/A

7. READ-OUT TIME: To be determined

8. REQUIREMENTS FOR PERMANENT DATA RECORDS: Yes

9. MANUAL AND/OR AUTOMATIC CONTROL: N/A

10. SIMULTANEITY: N/A

11. GROUND COMMANDS REQUIRED: N/A

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME: 16 months

2. FINAL DEFINITIVE TEST DESIGN TIME: 12 months

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED: N/A

4. TYPE OF DEVELOPMENT TEST ITEMS:

   a. Vacuum Chamber - N/A

   b. Shaker - 2 g rms, 5-100 cps

   c. Thermal - + 390° Fahrenheit

   d. Acoustic - To be determined

   e. Simulators - Existing simulators will do the job

   f. Aircraft - N/A

5. SUPPORT EQUIPMENT DEVELOPMENT TIME: N/A

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

   a. Ground Test - 1

   b. Atmospheric Test - N/A

   c. Space Test - 1

7. DATE AVAILABLE FOR TESTS: January 1966

8. CURRENT DEVELOPMENT STATUS: Program is approved and purchase request for the design study is to be initiated in July 1964. Contract for an in-house laboratory version now being negotiated.

Funds Expended to Date - $1,250M

EXPERIMENT P-12

BIOMEDICAL AND PHYSIOLOGICAL EVALUATION

The Identification, Analysis and Control of the Biological Changes and Adaptive Mechanisms within the Body of Man During MOL Missions

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Experiment P-12

SUMMARY

23 March 1964

BIOMEDICAL AND PHYSIOLOGICAL EVALUATION

I. OBJECTIVE:

The biomedical tests are designed primarily to evaluate those effects of weightlessness which can potentially compromise mission success. Sufficient data is required to validate supportive measures employed, devise improved methods, if necessary, and afford plausible estimates of biomedical status for missions longer than 30 days.

II. DESCRIPTION:

By taking full advantage of pre-flight and post-flight studies, as well as all previous manned orbital flight experience, the only tests to be conducted during flight are those which fulfill the necessary and sufficiency statements given in the test objectives. Measurements will be made of the following functions considering the effects of weightlessness, environmental loads and body demands: a) blood volume, pressure, and flow, b) the electro-mechanical behavior of the heart, c) fluid and electrolyte levels and balance, d) gastrointestinal function and nutritional status, e) metabolism of selected body materials; e.g., calcium and protein, 5) respiratory mechanics and rate of energy metabolism, g) nervous system functions; e.g., muscle strength and coordination, general mental status. Important associated environmental parameters will be measured, including physical and tissue equivalent radiation measurements.

A. Experimental Equipment: Sensors for electrical, mechanical, and chemical measurements, signal analyzers and converters, data recording and storage systems. (2) Equipment for selective data transmission. (3) Voice communication equipment. (4) Real-time TV or motion picture recording, if feasible.

B. Test Procedures: Typical procedures will include donning a vest with sensors and leads, switching on recording systems, and monitoring results to assure adequate recording; recording fluid and food intake; measuring and recording urine output and preserving sample for subsequent analysis; performing sample chemical (spectrophotometric and electrode chemistry) determinations on urine and occasionally on blood. Specific sequence of procedure will be determined by ground-based studies and simulation in Prephase I, Phase I. These procedures will be carried out by giving one member of the crew the requisite training to conduct all the tests in a reliable manner.

C. Evaluation Procedures: Results will be partly interpreted in real-time both in flight and through transmission of selected data to ground. Quantitative data obtained are directly and unequivocally translated into meaningful evaluation of normality or deterioration in physiologic status of the astronauts. Other data along with pre- and post-flight data will be used to evaluate over-all results, devise subsequent test plans and guide future flight procedures.

III. IMPORTANCE OF TEST:

The physiological effects of long-term weightlessness can be predicted to some extent qualitatively, but cannot be determined quantitatively with an adequate level of confidence through ground-based studies. The MOL 30-day flights presume prior 14-day weightless NASA flights; while these add some applicable data and an additional level of confidence, they do not eliminate the requirements for tests during the 30-day MOL missions. The measures proposed reflect a reasonable concern for both the astronaut's health and the need for his support to ensure mission success.

The mission profiles and manned operational modes envisioned for useful military applications (e.g., in enhancing reconnaissance capabilities) require that the crew be maintained in good physiological status. Tests are essential to establish that such status, in fact, exists. The severe configuration and operational constraints of providing an artificial gravity implies that it is mandatory to secure the type of test data indicated. Such data will serve to devise improved preventive measures--short of aritificial gravity--or for a major decision to employ some gravity mode.

IV. VEHICLE REQUIREMENTS:

Power	30 watts avg., 300 watts peak
Volume:	12 cu.ft.
Weight:	260 lbs.
Aperature:	The omnidirectional proton, electron, and alpha spectrometer should be mounted externally or extended from the unpressurized compartment during operation. In the cosmic ray emulsion experiment, an aperature must be available through which emulsions can be extended and exposed for predetermined periods of time.

V. SIMULATION PROGRAM:

PREPHASE I: Simulation of all biomedical tests in realistic sequence in a MOL environmental mock-up to establish test validity, equipment modification and location, and task-time requirements. The radiation measurements will also be simulated as part of the biomedical experiment. This simulation work will be accomplished in-house by AMD.

PHASE I: Build prototype mock-up and integrate biomedical tests with other experiments and station operations. Establish crew function and activity time parameters for test plan.

VI. EXPERIMENT DEFINITION:

PREPHASE I: Validation study of proposed biomedical tests; parametric studies for feasibility of procedures and man-activity. Evaluation of existing instruments and feasibility of modifications to ensure flight-rated items. These studies will be accomplished in-house by AMD.

PHASE I: Integrate experiment procedures and equipment--parametric studies. Initiate equipment developments. Design procedures and equipment for flight environment compatibility.

THROUGHOUT: Aggressive ground-based studies are essential to develop and confirm weightlessness countermeasures.

VII. FUNDING REQUIRED:

PREPHASE I: No additional funds required.

PHASE I: To be determined.

VIII. PARTICIPATING AGENCIES

Sponsor: AMD

FOREWORD

The challenge presented to the Biomedical Panel of preparing the experimental program required for accomplishment aboard the Manned Orbiting Laboratory has led to an exciting and fruitful analysis of the problems to be encountered by man on this mission. This document reflects the distilled resultant of this analysis. Although the document appears lengthy, the biomedical studies presented here are considered to be the minimum tests essential if we are to answer the questions of man's utility in performing in military space vehicles and if we are to be able to provide guidance for extending man's exposure to a weightless environment beyond the first MOL missions.

The authors felt it to be important to present backup information which was used to arrive at the proposed test protocol in order that it will be clear as to how the in-flight studies evolved to their present state. The series of annexes at the end of the document attempts to fulfill this goal.

It is realized that in a document of this complexity it is difficult to integrate segments of the study to meaningful information that can be used to measure the impact upon the total program. In the miscellaneous section, an attempt to aid the reader in meeting this task has been done.

This document will require future refinement through continuous literature review, extensive ground based studies, and further detailed analysis of the feasibility of performing some of the proposed tests in a space environment. However, the need for the information is valid. If the tests need to be curtailed due to technical or operational reasons, the ability to answer the fundamental questions concerning man's adaptability to the space environment and therefore his utility in performing while there will be curtailed.

This document is the consolidation of the thoughts of an Air Force Biomedical Panel and a group of outstanding consultants. These people should be recognized for their efforts, both individually and in their joint efforts which lead to the experimental package.

Exp No. P-12

General Biomedical experimental program integration was accomplished by Lt. Colonel Stanley C. White, USAF (MC), Headquarters AMD, and by Gerald McDonnell, M.D., UCLA School of Medicine, Los Angeles, California.

Dr. Bryce Hartman of USAR SAM has acted as the technical bridge between the Biomedical and the Human Performance panels. In this capacity he has provided excellent continuity in our efforts and save many hours for the Biomedical panel

The members of the team include:

Area	Air Force Team & Affiliation	Consultants & Affiliation
1. Cardiovascular	Lt Col John Ord USAF (MC) Wilford Hall Hospital	A. Stuart Bondurant M.D. Univ. of Indiana College of Medicine Indianapolis, Indiana B. Earl Wood Ph. D. Mayo Brothers Clinic Rochester, Minn.
2. Central Nervous System	Ed Liske M.D. USAF SAM	
3. Gastrointestinal Tract & Nutrition	Capt Gerald Parker USAF (MC) Wilford Hall Hospital	A. Marvin Schleisenger M.D. Cornell University New York City, N. Y.
4. General Metabolism	Lt Col Robert Johnson USAF (MC) USAF SAM Capt Theodore N. Lynch USAF (MC) USAF SAM	A. Gilbert Gordon M.D. Univ of Calif Medical Center San Francisco, Calif B. David Kipnis M.D. Barnes Hospital St Louis, Mo.
5. Renal & Fluid Balance & Electrolytes	Capt John McPhaul USAF (MC) Wilford Hall Hospital	A. William B.Schwartz M.D. Tufts New England Medical Center Boston, Mass.
6. Pulmonary	Capt Paul Stevens USAF (MC) USAF SAM Dr. Stephen Cain USAF SAM	A. Herman Rahn Ph.D. Dept of Physiology Univ of Buffalo Buffalo, N. Y.
7. Deconditioning & Control	Capt Duane Graveline USAF (MC) Hq AMD	A. Stuart Bondurant M.D. B. Earl Wood Ph.D. M.D.

Exp No. P-12

THE IDENTIFICATION, ANALYSIS AND CONTROL OF THE BIOLOGICAL CHANGES AND ADAPTIVE MECHANISMS WITHIN THE BODY OF MAN DURING THE MOL MISSIONS.

I. Test Objective:

A. The experiments, studies and observations accomplished throughout the flight program will provide the criteria needed to understand the human adjustments occurring during the exposure of the crew to mission durations of the MOL. Further, through integration of the data collected during flight with that obtained by the pre-flight and post-flight control studies and the data accumulating on man's system changes measured during exposures up to 14 days by the NASA Gemini and Apollo programs and the future Russian manned flights, the guidance for future mission planning will be obtained. Qualification of changes, analysis of the significance of the changes and definition of the provisions for maintaining a reliable functioning man will be obtained. Prediction of the rate of extension of mission duration based upon the limits dictated by man will be assessed. Evaluation of the medical status of man through trend changes will permit analysis of the inclusion of man in more complex assignments during missions of similar 30-day mission duration.

II. Importance of the Test:

A. This test program will provide essential information in the following areas:

1. The weightless effects upon man remains as one of the main open areas in manned space flight. The only way to assess this area is through flight. The MOL mission from its onset plans to extend the time of exposure of the crew to continuous weightlessness by a factor of 2 over that obtained by present NASA programs. There are several indications of significant changes expected and predicted which could effect the crew's well-being and ability to perform either "in orbit" or during re-entry that will become manifest in the period of 4-weeks exposure.

2. The MOL program is dedicated to the measurement of man's utility in the military missions. The bioastronautics measurement of man's abilities is predicated upon not only mission performance but also upon his readiness to perform or upon the changes

which will lead to deterioration or unsatisfactory performance in the future. Further, assuming there are changed which will become significant enough to depreciate his worth, the data obtained will permit the quantifying of the effects and the design of countermeasures to offset these effects. Through this cause, effect, countermeasure approach, the mission requirement for providing flexibility for crew utilization will be met.

3. The accomplishment of this study and the closely related human performance studies will provide the documented proof of man's utility in space. If the mission goes well, the data obtained will give technical depth as to how successful man is. Data obtained will give essential information needed to introduce the crew more deeply into the following missions. If there are problems found, this data, when integrated with the human performance results, will provide understanding as to whether the problems were man's inherent failure or whether he was overwhelmed through poor operational scheduling or through poor systems design.

4. The data obtained as part of this study program will be available for operational integration during the mission and will be useful during the daily flight control assessment. Decisions concerning mission modification can be made using the study program data as well as flight safety information. Man, as an important system aboard the vehicle will thereby be studied as completely as the engineering systems aboard the MOL.

B. This test program must be studied in space because it is based upon the study of man while he is exposed to the total spectrum of space stresses. Even though a great amount of ground simulation and aircraft experience will need to be done in preparation for the flight data, the final proof can only be obtained through the space flight experience.

III. <u>Description of Experiment:</u>

A. The experiment is designed to analyze the total man through specific testing of the body systems presently predicted to have a high probability of changes which could embarrass the man's performance. Each body system is discussed and presented as a separate area of study below, however, integration of instrumentation and data analysis are already planned to provide for total man assessment. Further, the data obtained by this experiment will be integrated with the human performance results for the purpose of answering the prime objective of the MOL mission. The following sections discuss the studies needed for each body system:

1. Study of Cardiovascular Effects Resulting from Missions of MOL Duration.

2. Study of Central Nervous System and Motor Effects Resulting from Flights in MOL.

3. Study of the Effects on the Gastro-Intestinal Tract and Nutrition by the MOL Mission.

4. Study of the Effects on Metabolism Resulting from flights on MOL.

5. Renal, Fluid, and Electrolyte Effects Resulting from MOL Mission.

6. Evaluation of the Pulmonary Functions During MOL Missions.

7. Study and Control of System Deterioration and Associated with MOL Mission.

Sections IV, V, and VI of the suggested experimental protocol will be covered within each of the seven areas for study noted above. Attachments 1 through 8 of the experimental format will be considered for each study area as well.

1. Study of the Cardiovascular Effects Resulting from Missions of MOL Duration.

The cardiovascular experiments have been selected to provide important information regarding the two paramount problems anticipated to be produced by the weightless environment and the gravitational stresses of launch and re-entry, while at the same time providing the essential observations required for mission safety. The tests are designed to give data concerning loss of normal cardiovascular regulation and changes in blood volume, with quantitation of their magnitude and some clarification of the time course of their production. Relatively small time costs are involved and no onboard interpretation of data is required.

a. Configuration of Test Items

(1) Gemini (for both astronauts).

(a) ECG, real time, frequency 0.1 to 50 cps, one or two bipolar chest leads.

(b) Blood Pressure, real time, reading 1 per minute. Korotkoff sound technique.

(c) Ear Oximetry, tape recorded, two channels, D.C.-20 CPS.

(2) MOL

(a) Heart Rate, instantaneous, fundamental frequency 20-200/min. System being developed at Bioengineering, SAM, based on R-R interval coding would be ideal. H.F. T.M. desired. Personal electronic package to obviate interference with astronaut freedom should be provided.

(b) Blood Pressure, one automatic system, Korotokoff sound type, 1 reading per minute. Manual system for astronauts to record each other's blood pressure with digitally keyed or voice transmission.

(c) Electrocardiogram, there channel orthogonal lead system, Frank or Schmidt, frequency 0.1 to 100 cps, quick don electrode belts or vests.

(d) Ballistocardiogram, three channel, low frequency (0.1 to 20 cps). Three orthogonally oriented accelerometers required. Coupling to free floating man over a relatively noncompliant body area must be developed.

(e) Body Mass, one channel, low frequency (to be determined), accelerometer determination of period of oscillation of mann-constant spring device.

(f) Body Volume, determined by ambient pressure measurement (strain gauge of high sensitivity) before and after the sudden addition of a known volume of gas to a sealed, calibrated free volume section of the MOL. An air lock would be ideal. One channel (DC to 10 CPS).

(g) Total Body Water, determined by analysis of equilibrated urine or serum labeled by ingestion of a known amount of D_2O. The analysis would require mass spectrometry. Account will have to be taken of contamination of water supply through recycling, etc.

(h) Blood Volume. Determined by intravenous injection of known amount of T-1824 blue dye, and determining hematocrit and indicator volume dilution on a venous blood sample. The procedure requires calibrated needles and syringes, simple bench type centrifuge and tubes and photocolorimetric reading at approximately 610-620 mm. The photometer output will be D.C. and can be meter read and/or taped.

(i) Cardiac Output and Oximetery. A calibrated red and infrared sensing earpiece with two channel output (0-20 CPS) will be used for both. Time concentration curves of the T-1824 injected for blood volume yield quantitative cardiac output, arm to ear circulation time and qualitative systemic circulation time and blood mixing volume. Measurement of occlusive pressure of the earpiece balloon (strain gauge, one channel, DC-20 CPS) will provide qualitative head level pulse pressure and systolic pressure. Arterial oxygen saturation at head level is accurately determined.

(j) Venous Pressure. Strain gauge, one channel, DC-20 CPS, mean pressure measurement.

(k) Catecholamine Excretion. Aliquots of urine processed for analysis on ground following mission completion.

(l) Oxygen Consumption and CO_2 Production. Appropriate sensors of O_2 and CO_2 content of expired air samples after drying, and determination of timed volume of ventilation. Mass Spectrometric sensing of O_2 and CO_2 would be useful because of the speed of analysis. (See pulmonary section).

(m) Autonomic Stress Maneuvers.

1. Calibrated exercise response (heart rate, blood pressure, ECG, cardiac output, oxygen consumption and CO_2 production, catecholamine excretion).

2. Valsalva maneuver. Airway pressure should be recorded (one channel-strain gauge). (Response observed in ECG-heart rate, manual blood pressure).

b. Test Support Equipment Required

(1) Spacecraft - no requirement.

(2) Age - no requirement.

(3) To be determined.

c. Test Procedure

(1) Continuous real time monitoring of ECG and blood pressure from the Gemini vehicle must be performed during launch and re-entry. This is a mission safety requirement and will also provide data concerning cardiovascular tolerance for comparison with G profile centrifuge runs prior to the mission. Oximetry should be recorded on tape aboard the Gemini during launch and re-entry. The re-entry phase is especially important in that the effects of prolonged weightlessness on transverse G tolerance can be assessed using a measurement of arterial oxygen saturation which is most likely to be seriously deranged.

(2) Heart rate should be monitored constantly or at least during long periods involving recurrent performance of the same astronaut functions throughout the missions and sampling all forms of activity. This will provide means of amassing a large volume of data for machine analysis of directional changes in response of the cardiovascular system. HF telemetry would provide continuous real

time data with few receiving stations, and would allow simple computer detection of significant rate and rhythm changes indicative of danger. In any case this system must-be available for medical emergencies in real time. Respiratory rate is a fall-out measurement obtainable by this technique.

(3) Blood Pressure. Either the automatic or manual blood readout should be obtained with each recording of ECG-BCG at rest and after exercise, and with the Valsalva maneuver the manual system will be used.

This parameter must also be available for real time transmission in event of an emergency.

(4) ECG-Ballistocardiogram. At each measurement as programmed below the three simultaneous EGG leads would be recorded for 30 sec. on each astronaut, following which one lead (orthogonal projection selected for each individual) of ECG and BCG would be simultaneously recorded for 30 sec. The taped data could then be dumped to ground on a convenient fly-over later in the same day.

This program should be performed as soon as possible and at +6-8 and ± 24 hours after entering orbit. At the ± 24 hour test a second and third program, each to run for 2 minutes should be obtained immediately after programmed exercise and with and following a 30 second Valsalva maneuver.

At the same Greenwich hour as the ± 24 hour test, an identical rest, exercise and Valsalva program should be transmitted on approximately the 3rd, 5th, 7th, 10th, 15th, 20th and 25th days. On the 29th day (assuming re-entry on day 30) the same recordings would be repeated, and if blood volume and other measurements indicated the need for administration of plasma expander or other reparative measures prior to re-entry would again be performed on day 30. Consideration should be given to the possiblity of resting measurements of ECG during partial G suit inflation immediately prior to re-entry.

The ECG must be readily available for emergency use, all three channels, on a real-time basis.

(5) Body Mass, Body Volume, Total Body Water, Blood Volume.

These measurements will be made four times during a 30-day mission, on approximately the 2nd, 9th, 20th and 29th days of weightlessness. Hematocrit will be simultaneously determined. The measurement should be made under standard conditions relative to ground time, probably fasting and with controlled fluid intake during the previous 12 hours. The final determination will indicate the need for infusion of a plasma expander or for other protection prior to re-entry.

Three hours for equilibration of the tracer dose of D_2O for total body water should be allowed prior to blood sampling for blood volume. The urine formed during the last hour of this equilibration or serum drawn for dye concentration may be used for the mass spectrometric analysis. Results of dye and D_2O dilution analyses and body mass and volume data may be transmitted on later passes by voice or digitally keyed.

(6) Cardiac Output will be simultaneously determined with blood volume. The dose of T-1824 should be administered in two increments, after warming the arm to increase flow rate, one at rest and one immediately after programmed exercise to allow indicator dilution recording from the earpiece. 10-15 minutes after the exercise injection a venous sample for blood volume is obtained. ECG, blood pressure and oxygen consumption - CO_2 production should be obtained with or immediately after the indicator dilution curves. Taped record may be dumped later. Routine oxygen saturation should be obtained prior to dye injection.

(7) Venous pressure should be measured at rest when the blood blank for blood volume determination is made. Strain gauge calibration and signal may be taped for later telemetry.

(8) Urinary catecholamine excretion should be performed on aliquots of urine formed during launch, at rest and during exercise after adaptation to weightlessness on about the sixth and 25th days, and during re-entry. The first three samples must be freeze-dryed and stored for return and ground analysis.

(9) Oxygen consumption-CO_2 production will be determined with cardiac output above and as programmed under metabolic and pulmonary sections.

(10) General. All of the above MOL parameters will require

participation of both astronauts, either as subject or tester, with the exception of the heart rate measurements. (See attachment 3 - not applicable).

d. Category of Experiment

All phases listed are Category A or B.

e. Cost - To be determined.

f. Schedule

(1) Instruments ready for test by July 1965.

(2) Instruments and software flight ready by July 1966.

IV. Participating Agencies

Sponsor: AMD - Lt Colonel John W. Ord, USAF, MC, Wilford Hall USAF Hospital, Lackland AFB, Texas.

Test Equipment Acquisition: AMD. December 1964.

V. Additional Requirements

A. Special security - Some aspects of instrumentation details will require Secret classification, and all will be considered limited medical access.

B. Manning Description Summary - Reference attachment 5.

C. Logistics - To be determined.

D. Facilities - Existing facilities are adequate for all phases of preflight testing and training except for the need for a mock up MOL within an altitude chamber for actual mission testing and rehearsal. A Gemini flight simulator will also be required. Requirement may develop for a central laboratory facility for intricate metabolic analyses.

E. Simulation and Training

1. Astronaut. The experiments listed require technician

level training only, and are not of a difficult or complex nature. The results do not require on board interpretation by the astronauts. The training will entail instruction, demonstration, supervised practice and application in mission simulation. One hour weekly for eight months is a gross estimate of time required for training.

2. Ground Personnel. Physicians will monitor the data and provide immediate interpretation. Minimal training will be required for carefully selected personnel. Special training in specific analytic procedures for ground analysis of metabolic balance samples will need to be provided for both physicians and medical technologists.

3. Equipment. Training equipment should for the most part be actual mission equipment. Conventional instruments may be employed for theory and early phases of demonstration and practical training.

VI. General

A. Communications and Data Handling Requirement. Frequency band widths required have been indicated. With the exception noted, all of the data may be taped on board and dumped at a single biomedical ground facility when convenient. The limited real time requirements for monitoring and emergencies have been identified and indicate a need for 3 or 4 stations capable of receiving one or two channels of biomedical data. The desirability of a single HF channel for constant telemetry is indicated. Relatively simple digital machine analysis may be required.

B. Development Characteristics. - To be determined.

C. Reference 1a, Atch 1; 1b(3), Atch 2; 1e, Atch 4 and VI A, Atch 6 - To be determined later.

D. Reference Annex 1, Study of the Cardiovascular Effects Resulting from Missions of MOL Duration.

Exp No. P-12

Attachments 1 - 4 (To be determined)

MANNING DESCRIPTION

1. ASTRONAUTS

a. Number required: Two per mission.

(1) Man's function

(a) As part of test - yes.

(b) As technician conducting test - yes.

b. Crew skill requirements - limited medical technician.

c. Manpower Profile - To be determined.

d. Critical Functions - see basic document and Annex 1.

e. Work Positions - see basic document and Annex 1.

f. Time Controlled Tasks - see basic document and Annex 1.

g. Human Performance Measures - not applicable.

h. Physiological and Psychological Measures - not applicable.

i. Selection Factors - see Annex 1.

j. Training Requirements - One hour weekly for 8 months prior to flight. Using flight equipment in and out of simulators.

2. GROUND PERSONNEL

a. Number required: To be determined.

(1) Man's function

(a) As part of test - in training of astronaut and interpreting flight data.

(b) As technician conducting test - in training of astronaut.

b. Crew skill requirements - physician, medical technologist.

c. Manpower Profile - To be determined.

d. Critical Functions - Interpreting flight data, ascertaining accuracy of inflight and postflight measurements.

e. Work Positions

f. Time Controlled Tasks

g. Human Performance Measures

h. Physiological and Psychological Measures

i. Selection Factors - see Annex 1.

j. Training Requirements - see Annex 1.

Attachments 6 - 7 (To be determined)

2. Study of Central Nervous System and Motor Effects Resulting from Flights in MOL

In the final analysis, man's utility in space is dependent on his nervous system. It is with his nervous system that he detects changes in his environment, whether they be events taking place at a distance or near at hand, such as the movement of a pointer on a dial. With this information he can make calculations, comparisons, and evaluations which will ultimately lead to an executive decision. The decision to act will require use of his sensorimotor apparatus, such as adjusting a vernier or throwing the proper switch. Measurements of nervous system activity are necessary to evaluate the ability of the brain to function during prolonged exposure to weightlessness.

The following tests will be done:

(1) Electro-oculograms (EOG)

(2) Egocentric visual localization of the horizon (EVLH)

(3) Sleep electroencephalograms (EEG)

(4) Muscle tone measurement

(5) Muscle strength measurement

(6) Motor coordination

(7) Intellectual functions

When the aforementioned test results are obtained and compared to the astronauts prelaunch measurements, the manner in which his nervous system was affected by prolonged weightlessness can be judged.

Problems which might be encountered cannot be predicted with certainty, but a reasonable approach would start with the gravity sensing organs and lead to the nervous system circuits with which they are immediately concerned, viz; ocular control, postural tone, sensorimotor movements, and possible disorders of sleep and respiratory regulation. A group of less predictable problems concerns nausea, vomiting, disorientation, and vestibulogenic convulsions.

a. <u>Configuration of Test Items</u> (see attachment 1)

(1) Miniaturized DC amplifier weighing less than 50 gms. with electrodes and wire leads. Volume of 1 cu. inch. Located on bulkhead in MOL.

(2) EVLH weighing less than 50.gms. Volume 4" x 2" x 1". Stored in MOL. No power required.

(3) Sleep EEG. Weighs approximately 50 gms. Size and shape of silver dollar. In addition, a headband. Located in MOL.

(4) Muscle tone scale. When stowed will occupy 3" x 1" x 1". Weighs 50 or less gms. No power requirements.

(5) Muscle strength. When stowed will occupy 4" x 1" x 3" and weigh approximately 50 gms. No power required.

(6) Motor coordination. No equipment necessary.

(7) Intellectual functions (per Dr. Bryce O. Hartman). A panel box 18" x 10" x 8". Weighs 4 pounds. Located in MOL.

b. <u>Test Support Equipment Required</u>

(1) Spacecraft

(a) FM tape recorder to store EOG and EEG until transmission to earth. (PCM is equivalent)

(b) AM voice tape recorder to store results of EVLH, muscle tone, muscle strength, and motor coordination until transmission to earth.

(c) A bi-valve or harness-and-tether to stabilize astronaut near EEG amplifier when sleeping. This should include rubber bands to keep hands from drifting near head when asleep.

(d) Dispenser with die-cut rings of colostomy tape (3M) for attaching electrodes.

(e) Disposal system for tape rings after each use.

(f) Tube of electrolyte paste (Redux) with hollow needle tip cap for dispensing.

(g) Small vacuum cleaner for removing dried paste from skin and electrodes. Can be modified vacuum-operated shaver.

(h) Circular-head shaver (Norelco-type) for shaving electrode-scalp sites. Can be same shaver used for beard.

(2) AGE

(a) FM or PCM tape recorders to store EOG and EEG data.

(b) AM voice tape recorders to store readings from muscle tone, muscle strength, motor coordination tests, and EVLH.

(c) Tape recorder to store results of intellectual functions test.

(d) Medical examination room near launch area.

(e) Grass EEG machine in or near medical examination area.

(f) EEG write-out machine to yield paper tracing at time EEG is transmitted to earth. To be used to monitor sleep adequacy by EEG during the flight.

c. Test Procedure

In the months prior to launch, serial sleep EEG's will be obtained on each astronaut so that their EEG sleep profile is familiarized. Excerpts from various stages of sleep may be mounted in celluloid and bound so a sleep reference on each astronaut is readily available. A complete neurological examination is done the week before the flight. Muscle tone, strength, and coordination scores will be recorded.

During the flight, the seven measurements noted in III will be carried out, always watching the relationships between the new data and the data obtained prior to the flight.

After recovery, a complete neurological examination will be done. Serial EEG's will be made. An interpretation of the data will result.

Man's role will be both active (applying electrodes, using equipment, recording observations) and passive (generating brain potentials while asleep). He will be utilized as both subject and as observer. His contributions will be measured by comparing the measurements obtained on the flight with those obtained prior to the flight.

Testing sequence. The neurological testing sequence will begin 20 minutes before his sleep period. He will apply the two peri-orbital electrodes and record eye movements when viewing first a distant object, then a near object. Next, he will move his eyes through a full range in the vertical and horizontal planes and maintain end point conjugate positions for 10 seconds each. The electrodes are removed.

During the 10 minutes the electrodes are stabilizing, he will perform the intellectual functions tests per Dr. Bryce O. Hartman.

The astronaut next puts on the EVLH instrument and records his subjective horizon.

The muscle tone instrument is put in place and finger flexor tone is measured. The hand grip dynamometer is used next. Then, finger-to-nose and heel-to-toe tests are done. Finally, the EEG is applied to his scalp by his fellow astronaut and he goes to sleep. Upon awakening, the EEG is removed, ending the neurological sequence.

d. Category of Experiment

(1) Category a.

e. Cost. To be determined.

f. Schedule

(1) Hardware and software available for test:

1 Grass EEG machine needed for ground tests in the week prior to launch.

1 EEG technician needed to operate the EEG machine.

1 FM tape (7-channel) recorder, Ampex FR1300

1 Electronic Coupler for tape recorder

1 3" oscilloscope to check signal reaching the tape

1 Neurologist

1 Secretary to handle the large paper workload.

Paper, ink, electrodes, collodion, and other expendables

1 DC recording Offner EEG for EOG's and portable work

(2) Hardware and software flight readiness date.

Should be ready 3 months prior to the flight. In addition to the hardware necessary for the flight, there should be 2 identical replacements for each on-board piece of equipment used in the CNS studies.

IV. Participating Government Agencies

Sponsor: U. S. Navy (Captain Ashton Graybiel), Pensacola, Florida

Test Equipment Acquisition: The EVLH device

V. Additional Requirements

a. Special Security. None

b. Manning Description Summary. (see attachment 5)

	CY 64	CY 65	CY 66	TOTAL
c. Logistics:				

(1) Manpower. To be determined

(2) Hardware Development. To be determined

(3) Installation. To be determined

(4) Operation. To be determined

(5) Additional Support. To be determined

d. Facilities

Need only a medical examining area and the EEG facilities one week prior to launch to perform the preflight neurological evaluation on the astronauts. During the flight itself a facility will be needed where the EEG write-out in real-time can be visually interpreted. This can be located near the launch area or at the USAF School of Aerospace Medicine, Brooks AFB, Texas.

e. Simulation and Training

(1) Astronauts. He would not have to be a scientist, he can be trained as a technician. Level of knowledge need not be high. Motive is more important; he must want to do the medical tests well. A single knowledge of electronics whould be desirable. Training could be accomplished by three hours of lectures, three hours of demonstration, and three hours of participation by the candidates themselves. Finally, the 30-day run in the MOL mock-up under every condition of the flight itself (except actual blast-off and prolonged weightlessness) will be mandatory for his training.

(2) Ground Personnel:

For the sleep study: EEG technicians should, at the minimum, be Air Force-trained and then have an additional 3 months OJT training and lectures at SAM.

Neurologist, trained in the usual manner.

(3) Equipment:

The equipment peculiar to the training situation is identicle to that used in flight.

VI. General:

a. Communications and Data Handling Requirement. (see attachment 6)

(1) FM or PCM tape storage is required on board to store sleep EEG until spacecraft can transmit it to earth receiver.

(2) Earth telemetry receiver compatible with the spacecraft transmitter.

(3) FM tapes to store all EEG data for later processing

(4) EEG write-out, pen and ink, paper speed 30 cu./sec. for real-time visual interpretation.

(5) FM or PCM tape recorder on board to record DC EOG's until transmitted to earth.

(6) Earth receiver and FM tape recorder to store EOG data.

(7) Paper, pen, ink write-out system for EOG data for real-time interpretation.

(8) Voice tape recorder on board to record muscle tone, strength, and coordination for later transmission to earth.

(9) Tape facilities for storing high functions scores for late analysis.

(10) Write-out device to chart trends of higher functions scores in real-time.

(11) Voice transmission link from medical officer to space laboratory to counsel astronauts in the event of neruological emergency on board, such as a convulsion.

b. Development Characteristics. (see attachment 7)

c. Refer to Annex 2 - Study of Central Nervous System and Motor Effects Resulting from Flights in MOL, for more detailed discussion of this area.

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED: Miniaturized EEG, miniaturized DC EOG, muscle tone scale, muscle strength dynamometer, EVLH, and intellectual functions test box.

2. WEIGHT: Weight of all test equipment, exclusive of intellectual test functions box, should be less than 400 gms.

3. VOLUME: Stored: Less than 20 cu. inches. In Use: Less than 15 cu. inches.

CRITICAL DIMENSIONS - SHAPES: EEG the shape of a silver dollar with rounded edges so that chances of it catching on anything are minimized. A headband will aid stability.

4. POWER: The EEG and the EOG would draw power of a few milliwatts. Of course, voice recording the readings of the muscle tone, muscle strength, and EVLH scales will require power to operate the AM voice tape recorder. Intellectual functions box of Dr. Hartman will draw power to be determined. EEG would draw a few milliwatts of power throughout the 6 to 8 hours of sleep.

5. SPARES: No spares aboard the aircraft. Two spares of every piece of equipment needed for central nervous system study should be available on the ground prior to launch.

6. TOOLS: No tools required.

7. HEAT OUTPUT: Negligible.

8. STABILITY: No factor, except in EEG and EOG where attempts will be made to attach the equipment to the scalp surface as mechanically stable as is possible.

9. VIBRATION LIMITS: EEG will measure the slightest vibration causing a change in the impedance between the scalp electrode and scalp surface. Vibration should be kept minimal.

10. SHOCK LIMITS: To be determined.

Attachment 1

11. HAZARDS: Hazards are minimal. Electrodes will be fastened to the scalp with colostomy tape made by the 3M Corporation rather than by collodion or other adhesive with a volatile solvent. Electrode paste is of the Redux variety and contains no known toxic products.

12. TEMPERATURE LIMITATIONS: Both the EEG and EOG will be adversely affected by temperatures which will produce visible perspiration on the skin of the astronaut.

13. TYPE AND RANGE OF MEASUREMENT: Scalp voltage changes from 0.5 cps to 100 cps will be measured. EOG will measure a dipole of 500 to 800 millivolts at the source, but probably greatly reduced at the point of measurement. Muscle tone will be measured in grams, muscle strength in grams, and other measurements will be digital.

14. SPECIAL ENVIRONMENTAL REQUIREMENTS: Temperatures between the range of 65° to 75° F. are ideal for the CNS tests.

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS:

Station: The test stations should be located where the astronaut will sleep.

Equipment: Equipment should include a bi-valve or harness to stabilize the astronaut when he sleeps so that he will not drift away or twist the leads. In addition, rubber thongs should hold his hands so that he will not involuntary pull the electrodes while asleep but is able to free himself quickly in an emergency.

16. EQUIPMENT OPERATING CYCLE:

Frequency: EEG will be used on Astronaut "A" every 48 hours and should alternate with Astronaut "B" every 48 hours so that one sleep EEG is done every 24-hour cycle. Other neurological tests are keyed to the astronaut's sleep in a similar fashion.

Time Duration: Time duration is listed more clearly in description of the experiment.

17. EQUIPMENT LOCATION REQUIREMENTS: Again this is required near where the astronauts sleep.

18. SPECIAL MOUNTINGS REQUIREMENTS: The amplifiers will be mounted on a bulkhead near the head of the astronaut when he is

asleep. The EOG amplifier should be mounted on a bulkhead near the porthole so the astronaut may view outside the spacecraft while his eye movements are being recorded. It would be nice to have this porthole window near where the astronaut sleeps so that CNS equipment could be centralized.

19. PRESSURE VESSELS - fluids, gasses, etc. N/A

20. ELECTROMAGNETIC INTERFERENCE: This is critical for EEG. Electric field alternating at a frequency of 1 to 200 cycles per second are bothersome. Sparking commutators, discharge gas tubes, magnetos, will all interfere with the EEG if not shielded or too close to the astronaut's head.

21. MAINTENANCE REQUIREMENTS: Electrodes will have to be kept clean of particulate matter after each use and the colostomy tape discs used for affixing them to the scalp will be disposed of after each use.

Exp No. P-12

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA.

   a. FM or PCM tape in addition to AM or voice recording tape.

   b. N/A

   c. N/A

2. HANDLING (special equipment required to handle items being tested). Usual handling of magnetic tape.

3. PACKAGING. The usual required for handling recording tapes.

4. CALIBRATION - alignment, deployment. This will be done prior to launch.

5. JIGS AND FIXTURES. Not applicable.

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION. Not applicable.

7. SENSORS (TRANSDUCER - OUTPUT SIGNALS). Not applicable.

8. TRAINERS/SIMULATORS. Not applicable for the inflight study.

9. INSTRUMENTATION - cockpit and/or laboratory (note effect of time sharing instruments with other experiment). Not applicable.

10. RELATED SUPPORT EQUIPMENT. As better described in the experiment. From the ground will be required appropriate telemetry receivers and FM tape recorders to permanently store the EEG, EOG, and AM tape recorders to store information from E.V.L.H. muscle tone, testing, muscle strength testing and motor coordination tests. Dr. Hartman will want intellectual functions stored on tape on the ground in addition.

11. AGE - not applicable.

12. ENVIRONMENTAL TEST EQUIPMENT. Not applicable.

13. FACILITIES. Not applicable.

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS (desired). Not critical.

   a. Altitude -

   b. Inclination -

   c. Epoch -

   d. Ellipticity -

2. PLANE CHANGE. Not critical.

3. ALTITUDE CHANGE: Not critical.

4. TIME ON ORBIT. Not critical.

5. TEST DURATION. Entire test can be performed 20 minutes prior to the sleep period and then EOG recording throughout sleep, 6-8 hours.

6. TOTAL NUMBER OF TESTS. Each astronaut will get a series of neurological tests once every 48 hours.

7. TEST FREQUENCY. Each astronaut will get neurological sequence of tests every 48 hours.

8. INTERVAL BETWEEN TESTS. Each astronaut will get test once every 48 hours.

9. CREW TASK LOADS - man hours. Twenty minutes every 48 hours and then entire sleep period of 6-8 hours.

10. CREW TASK FREQUENCY. Once every 48 hours.

11. FIELD OF VIEW REQUIREMENTS. Not critical.

12. GROUND CONTROL LIAISON DURATION. Not critical except during a medical emergency.

13. GROUND CONTROL LIAISON FREQUENCY. Not critical except during a medical emergency.

14. EXTERNAL TEST ITEMS:

    a. Launched from Station - none.

    b. Launched from resupply - none.

    c. Launched from ground - none.

15. QUALIFICATION TESTS (other than space)

    a. Ground - none.

    b. Atmosphere - none.

16. SEQUENCE OF EVENT AS THEY OCCUR DURING FLIGHT. This is described in the sequence of events in the experimental package.

17. HANDLING PROCEDURES. Not applicable.

FUNDING SUMMARY

BUDGET REQUIREMENTS BY FISCAL YEAR

To be determined.

Exp No. P-12

MANNING DESCRIPTION

1. ASTRONAUTS

a. Number required - one is a minimal requirement.

(1) Man's function

(a) As part of test - subject.

(b) As technician conducting test - the same astronaut is also the technician.

b. Crew skill requirements - Very few skills requirements are necessary. Critical is the application of the instruments to the scalp, of the skin near the eyes and in applying the muscle tone cables.

c. Manpower Profile - Not applicable.

d. Critical Functions - Applying the scalp electrodes properly.

e. Work Positions - In the sleeping position.

f. Time Controlled Tasks - None.

g. Human Performance Measures - In a sense everything is a human performance measure.

h. Physiological and Psychological Measures - Should meet the psychological and physiological requirements of a pilot candidate of the USAF.

i. Selection Factors - Should meet the qualifications of a pilot in the USAF. In addition, he should have a very high motive for performing medical tasks on himself.

j. Training Requirements - This is better described in the experiment package.

2. GROUND PERSONNEL

a. Number required

(1) Man's function

(a) As part of test - not applicable.

(b) As technician conducting test - Not applicable. However, a neurologist should be interpreting the sleep EEG in real-time to detect any serious deviations from normal. In addition, the data sent back on muscle tone, muscle strength, EVLH, and motor coordination as well as intellectual functions should be charted on a graph in real-time so that the general trends of the CNS are obtained in real-time.

b. Crew Skill Requirements - Neurologists familiar with the astronaut's EEG sleep patterns is required.

c. Manpower Profile - not applicable.

d. Critical Functions - not applicable.

e. Work Positions - On the ground near EEG write out from radio telemetry set.

f. Time Controlled Tasks - None.

g. Human Performance Measures - In a sense, everything is human performance.

h. Physiological and Psychological Measures - Not critical.

i. Selection Factors - not critical.

j. Training Requirements - Usual training requirements for a neurologist.

Exp No. P-12

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE. Data should be transmitted to the earth as often as possible so that tape recorder storage facilities on board need not be too large. Neurological tests will require data for 20 minutes out of every 48 hours for a given astronaut. Interdigitated will be date from the other astronaut every 48 hours, thus 20 minutes plus a full sleep period will come down every 24 hours from the space ship if two astronauts are aboard.

2. FUNCTIONS TO BE MEASURED. There are seven areas to be measured: (1) EEG, (2) EOG, (3) Muscle Tone, (4) Muscle Strength, (5) EVLH, (6) Motor Coordination, and (7) Intellectual Functions.

3. TYPE OF ANALYSIS REQUIRED. Real-time visual analyses of the data is required during the time the neurological tests are being performed during the 24 hour cycle.

4. PICTORIAL DATA REQUIRED. An analog record of the EEG during sleep is required.

5. REAL TIME MONITORING REQUIREMENT. Real-time monitoring requirement for all the neurological tests is desired.

6. DATA EDITING OR COMPRESSION. Not applicable.

7. READ_OUT TIME. This depends entirely on the capability of the equipment available. The EEG write out should have a paper speed of 30 centimeters per second. Pen and ink writers are preferred over the heat stylus and wax paper.

8. REQUIREMENTS FOR PERMANENT DATA RECORDS. FM or PCM tapes are required for permanent records of EEG and EOG. AM or voice tapes are required for the other data for the neurological tests.

9. MANUAL AND/OR AUTOMATIC CONTROL. Not applicable.

10. SIMULTANETTY. Not applicable.

11. GROUND COMMANDS REQUIRED. None unless a medical emergency arises.

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME. One year.

2. FINAL DEFINITIVE TEST DESIGN TIME. One year.

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED. Ground testing concerning the inflight package is primarily aimed at astronaut training and familiarization with the use of the simple pieces of equipment needed in the central nervous system as programmed. As stated in the training session this will require 3 hours of instruction, 3 hours of demonstration and 3 hours of participation. After this preliminary approach a full scale flight in the MOL mock-up inside the vacuum chamber is necessary for final corrections to be made . No flight test would seem necessary at this time.

4. TYPE OF DEVELOPMENT TEST ITEMS. The miniaturized EEG would need to be developed only from a standpoint of small space and size and low power requirements. Basic configuration (i.e., that of a differential amplifier) is well known and needs no further development. The muscle tone gauge would have to be fabricated at the SAM workshop, but being of simple design and consisting only of a spring and cable with graduated scale and pointer, should prove no real problem. Stoelting hand grips dynamometer exists.

a. Vacuum Chamber

b. Shaker

c. Thermal

d. Acoustic

e. Simulators

f. Aircraft

5. SUPPORT EQUIPMENT DEVELOPMENT TIME. To be determined.

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

a. Ground Test - Not applicable.

b. Atmospheric Test - Not applicable.

c. Space Test - This will be the test itself.

7. DATE AVAILABLE FOR TESTS. End of 1965.

8. CURRENT DEVELOPMENT STATUS

a. Proposed only -

b. Project or program is approved and test item is under study, breadboard stage, etc. -

c. Funds expended to date -

3. Study of the Gastrointestinal Effects Resulting from Missions of MOL Duration

This experiment intends to determine the degree of alteration, if any, in the human gastrointestinal tract during the stresses of prolonged orbital flight. The specific parameters to be observed and investigated are nutrition, digestion, absorption and excretion. The experiment is deliberately designed to interface with tests being performed in the metabolic, renal and cardiovascular areas so that the knowledge compiled by the biomedical panel will give the broadest possible basis for assessment of the physiologic responses of man during the MOL mission with the least possible expenditure of time during the MOL flight (flight safety). By examination of the pre-flight, in-flight and post-flight biomedical data, it is anticipated that extrapolation will be possible to allow reliable predictions concerning man's status during longer flights (growth potential).

Considerable knowledge concerning function of the gastrointestinal tract may be obtained by providing a diet which contains known amounts of calories, protein, carbohydrate, fat, vitamins and minerals and measuring the level of constituents in the blood and the amount of excreted substances in feces and urine. This "in-flight" metabolic balance study is considered essential to assess the multiple body systems of man for 30 days of weightless existence. This particular experiment intends to feed the astronauts a diet containing known nutritional constituents and several non-toxic test materials; to collect and return all feces in a lyophilized form and all urinary solids in a similar form; and to analyze these wastes for the test materials and other organic constituents. No in-flight monitoring will be necessary. An accurate record of diet must be provided in a daily taped report in order to insure that the occupants of the MOL are consuming adequate nutrients. The astronauts will serve as their own controls during the experiment. Pre-flight and post-flight studies are imperative in order to establish an assessment of the overall effect of prolonged space flight.

a. Configuration of the test items

(1) Diet

It is anticipated that a 2400 Kcal liquid diet, reconstituded in flight, will be used (Ref. Annex 3), although ground tests and Gemini-Apollo flights may prove that a freeze-dehydrated diet is more acceptable. This liquid diet will contain approximately 70 gm protein, 300 gm carbohydrate and 100 gm fat. It will be artifically flavored with reasonable variety and palatability, will be fortified with vitamins and minerals and will contain less than 500 mg of calcium in order to reduce the degree of hypercalcemia and hypercalciuria anticipated from calcium mobilization in the weightless state. The diet will be consumed 4-5 times daily and will utilize 250 ml. of water for reconstitution at each feeding. Assuming a water allowance of 2500 ml/man/day, there will be 1250-1500 ml/man/day remaining for drinking and washing. Space requirements in the MOL for such a liquid diet are not well determined but are anticipated to be appreciably less than an isocaloric amount of freeze-dehydrated food. It is anticipated that space requirements for freeze-dehydrated foods on the Gemini and Apollo vehicles are already determined. Since freeze-dehydrated food may be found to be satisfactory for Gemini flights and estrapolation allows their use on MOL flights, weight and volume specifications should be on the basis of freeze-dehydrated foods. (See Atch 1, "Design Characteristics").

(2) Ingestible test doses

One ingestible test dose is considered: d-xylose (a pentose). This substance may be pre-packaged in granular form in the diet packet, dissolved in water and consumed as part of the diet at a specified time in flight, but since the diet may delay gastric emptying, it is advisable to have the test dose taken as a solution in a fasting (6 hour post prandial) state. The urine is to be collected, lyophilized and returned. No in-flight analysis of this test is necessary.

Two (2) twenty-five (25) gram packets of d-xylose occupying 42.5 cubic centimeters of space each (total space 85 cubic centimeters) if packaged in plastic wrapper and reconstituted in flight are required. The d-xylose may be pre-packaged in a plastic container separated from 250 ml. of water by a diaphragm. When the diaphragm is punctured, the water will be mixed with the sugar, producing a palatable solution which may be consumed by means of a drinking spout. Such a container would occupy a total space of approximately 350 cubic centimeters and weigh approximately 300 grams. Total space and weight requirements for two astronauts would be 700 cubic centimeters and 600 grams. Tablets of d-xylose are not recommended since crumbling of the tablets poses a threat of aspiration to the astronaut. Furthermore, since the test is a function of time, and a certain delay due to dissolution of the tablet in the stomach will occur, the test results may be invalidated.

(3) Injectable test doses

No injectable test doses are necessary for this particular experiment but an injection of tracer substances requiring recovery of urine and feces is considered by the metabolic section.

(4) Blood

Collection of 10 ml. of venous blood (total) from each astronaut is necessary for analytical study by the metabolic section, the renal section and the gastroenterology section on days 2, 7, 14, 21 and 26. From the serum recovered after coagulation and centrifugation, analysis of calcium, alkaline phosphatase, bilirubin (conjugated and unconjugated), 5-nucleotidase, serum transaminases (SGOT and SGPT), urea, amylase, lipase, lactic dehydrogenase and protein electrophoresis will allow indirect evidence of hepatic and pancreatic function, during the weightless period as well as provide information concerning hematopoetic activity, bone activity and hepatic parenchymal degeneration. No in-flight analyses are necessary for this portion of the experiment. The serum is to be lyophilized, packaged, labeled as to content, subject, date, and time and must be returned in the Gemini vehicle for analysis and comparison with pre-flight and post-flight determinations.

(5) Urine

No in-flight analysis of urine is necessary for this experiment. The lyophilization and return of urine for post-flight analysis is extremely important to this experiment however, for constituents in the urine can give indirect evidence of hepatic and pancreatic function, intestinal microfloral activity and intestinal absorptive ability. Analyses to be performed on the returned urine includes: 5 hydroxy indole acetic acid, indole acetic acid, indican, calcium, sulfur, 24 hour uropepsin, amino acids, urobilinogen, bile and d-xylose. The total urinary solids to be returned for use by the gastroenterology, renal, and metabolic sections will be approximately 1800 Gm/man/month (total weight 3600 Gms). Total volume of these dried urinary solids is approximately 2000 cubic centimeters.

(6) Feces

The total accumulation of feces produced by each astronaut during the mission must be lyophilized and returned for analysis in order to evaluate the gastrointestinal and metabolic function of the individual during the mission. No in-flight fecal analysis is necessary for this experiment. Approximately 900 Gms of dry feces/man/month will be produced (total weight 1800 Gms occupying approximately 1000 cubic centimeters of space). Post-flight analysis will include the determination of bile pigments, total fat and partitioned fat (neutral fat, fatty acids, etc.), and trypsin. Bacterial cultures for viable clostridial spores, etc. will also be performed. These analysis will give indirect information concerning intestinal absorptive capacity, pancreatic function, hepatobiliary function, and intestinal microflora activity.

b. Test Support Equipment Required (See Atch 2)

(1) Spacecraft

(a) Diet: Storage space for diet should, for purpose planning, be the same as that for Gemini. It is conceived that the diet will be labeled in a digital form, identifying total calories and constituents. The diet consumed by each man is to be recorded on tape and data dumped each 24 hours. Appropriate tape for biomedical data is necessary on board. Details for separating biomedical data from other data should be developed to facilitate analysis each 24 hours at the ground based biomedical center.

(b) Lyophilizer with water recycling equipment: At present, there is no apparatus designed for incorporation into the MOL vehicle. Development is imperative for the performance of this experiment.

(c) Centrifuge for blood specimens: Development is imperative.

(d) Containers for lyophilized stool and urine: These containers should be flexible, leakproof, easily labeled, and capable of being placed on board the Gemini vehicle for return. Plastic containers appear to be the most satisfactory type at this state of the art.

(e) Labeling equipment: Small marking pencils similar to the commercial "Magic-Marker" appear to be ideal for labeling containers, especially plastic ones.

(2) Ancillary Ground Equipment

Ancillary ground equipment necessary for this experiment during the flight consists of a receiving station for biomedical data. Post-flight analysis of the specimens will require a laboratory of the highest reliability. Such a laboratory could be developed from in-service sources, combining the talents of the USAF Epidemiological Laboratory, SAM and Wilford Hall USAF Hospital.

c. Test Procedure (See Atch 3, "Test Operating Factors")

(1) The occupants of the MOL are to consume a diet containing approximately 2400 Kcal each 24 hours. Each astronaut will carefully record his dietary intake by reciting the digital coded label of the packages he consumes onto data tape. If he is unable to consume all of his diet, he will measure the residual by placing it into a volumetric measuring device, record the amount of unconsumed liquid on data tape, and discard the waste. Calculations of calories, etc. lost can be made at the biomedical data area. Every encouragement will be given to the occupants to consume all of the diet once it is reconstituted.

(2) All feces produced during the flight will be collected, emulsified and lyophilized. It has not been determined whether each individual stool should be immediately lyophilized or whether the collective stools from each astronaut should be lyophilized each 24 hours. When the packet containing the stools is lyophilized, it should be labeled as to subject, time, date and then stored. At the completion of the flight, the packets should be placed on board the Gemini vehicle and returned for analysis. Space on board the Gemini could be made available by off loading part of the emergency food supply from the Gemini to the laboratory portion of the MOL prior to detachment and de-orbit.

(3) During a specified 5 hour period on the 14th flight day, and while in a fasting state, one MOL occupant will consume a packet containing 25 Gm of d-xylose. All urine collected for the next five hours will be lyophilized, appropriately labeled as to subject, day, hour and stored. On flight day 15, the second occupant of MOL

will perform the test on himself. It is not necessary that the astronaut fast after the test but it is advisable that one hour pass from the time the d-xylose is taken until food is consumed. The lyophilized urine of the second subject will also be returned in the Gemini vehicle.

(4) On days 2, 7, 14, 21 and 26, ten ml. (10) of venous blood will be obtained by venepuncture (vacutainer) from each astronaut, centrifuged and the serum lyophilized. The dried serum will be labeled as to subject, date, time and stored. The packets will be placed aboard the Gemini vehicle prior to re-entry and analyzed following the flight.

d. Category of Experiment

An experiment which contributes to the MOL primary objective but does not have a significant influence on the design characteristics of the orbital laboratory (Category B).

e. Cost

It is as yet undecided whether diet funding will be from MOL funds or experimental funds. See Atch 4, "Funding Summary".

f. Schedule

(1) Hardware and software available for test: The date of testing for a lyophilizer and centrifuge are undetermined. Commercial liquid diets and hospital liquid diets are available at the present time. These items can be tested for acceptability and metabolic effects immediately. Freeze-dehydrated foods are within the state of the art, have been shelf tested and evaluated in sealed cabin environments and found to be acceptable. Packaging of both liquid and freeze-dehydrated diet is not satisfactorily developed but must be developed by FY 66-67.

(2) Hardware and software readiness date: To be determined but anticipated for FY 67.

IV. Participating Government Agencies

Sponsor: Captain Gerald W. Parker, USAF, MC, Gastroenterology Service, Department of Medicine, Wilford Hall USAF Hospital, Aerospace Medical Division (AFSC), Lackland Air Force Base, Texas.

Test Equipment Acquisition: Aerospace Medical Division

V. Additional Requirements

A. Special Security

Development of the lyophilizer and centrifuge may require special security. Medical records of astronauts and results of all biomedical determinations should have limited access.

B. Manning Description Summary

See Atch 5, "Manning Description".

C. Logistics

To be determined.

D. Facilities

Existing facilities are adequate for performance of all pre-flight testing, training and post-flight testing except for the need for a mock-up MOL within an altitude chamber for actual mission testing and rehearsal. A Gemini flight simulator will also be required. Adequate biomedical analytical laboratory facilities are available from in-house facilities including the USAF Epidemiological Laboratory, SAM, and Wilford Hall USAF Hospital. A laboratory should be specifically set up for testing, quality control and modification of existing techniques as applied to the MOL mission. One of the specific missions of the USAF Epidemiological Laboratory is to perform just such quality control and it appears that this facility would be ideal for establishing laboratory procedures, maintaining quality control, and supervising and performing all analytical determinations.

E. Simulation and Training

1. Astronaut: Will perform as a technician. Simulation can be achieved by a moderate amount of medical training which could be accomplished in conjunction with other biomedical sections.

2. Ground Personnel: Physicians will monitor data. Minimal training will be required. Members of the MOL biomedical

panel could monitor the data with the greatest amount of facility since they would be familiar with the entire biomedical package and its interfaces. Specific physicians should be designated to collect all specimens and personally deliver them to the appropriate laboratory.

3. Equipment; Training equipment should be actual mission equipment.

VI. General

A. Communications and Data Handling

The data required for this experiment during the in-flight portion consists of a daily log of dietary (food and water) intake and verbal notification of symptoms concerning the gastrointestinal tract if emergency or simi-emergency conditions exist. No real time data is required. Information regarding dietary intake may be dumped at a biomedical data area and calculated in order to assure adequate nutritional intake. (See Atch 6, "Communications and Data Handling").

B. Development Characteristics (See Atch 7)

C. Justification of Experiment (See Atch 8 and section E, Reference Annex 3)

D. Reference Material (See Reference Annex 3)

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED: D-xylose containers, 1 each occupant
2. WEIGHT: 300 Gms each
3. VOLUME: Stored 350 cc each in use same
4. POWER: None
5. SPARES: 1 each occupant
6. TOOLS: None
7. HEAT OUTPUT: None
8. STABILITY: Indefinite until mixed
9. VIBRATION LIMITS: Undetermined
10. SHOCK LIMITS: Undetermined
11. HAZARDS: None
12. TEMPERATURE LIMITATIONS: Limits of plastic container
13. RANGE OF MEASUREMENT: Absorptive ability of small intestine
14. SPECIAL ENVIRONMENTAL REQUIREMENTS: None
15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS: None
16. EQUIPMENT OPERATING CYCLE: N/A
17. EQUIPMENT LOCATION REQUIREMENTS: Placed in living area MOL
18. SPECIAL MOUNTINGS REQUIREMENTS: None
19. PRESSURE VESSELS: Fluids (water) in plastic container
20. ELECTROMAGNETIC INTERFERENCE: None
21. MAINTENANCE REQUIREMENTS: None

Exp No. P-12

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA: Voice tape for dietary log reporting

2. HANDLING: Specimens stored in MOL, onloaded to Gemini prior to de-orbit

3. PACKAGING: Plastic bag containers for specimens

4. CALIBRATION: N/A

5. JIGS AND FIXTURES: None

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION: None

7. SENSORS: None

8. TRAINERS/SIMULATORS: Mock-up MOL with Gemini, metal, in altitude chamber. FY 66

9. INSTRUMENTATION: None

10. RELATED SUPPORT EQUIPMENT: Lyophilizer for biomedical specimens 12" x 12" x 12" FY 66

11. AGE: Biomedical data gathering station

12. ENVIRONMENTAL TEST EQUIPMENT: None

13. FACILITIES: Laboratory facilities for analysis of in-flight specimens

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS: N/A

2. PLANE CHANGE: N/A

3. ALTITUDE CHANGE: N/A

4. TIME IN ORBIT: 30 days

5. TEST DURATION: 30 days

6. TOTAL NUMBER OF TESTS: One in flight plus analysis of urine and feces collected

7. TEST FREQUENCY:

   a. D-xylose - day 14 astronaut "A", day 15 astronaut "B"
   b. Urine lyophilization, packaging, labeling and storing daily, each astronaut
   c. Fecal lyophilization, packaging, labeling and storing approximately every 3 days, each astronaut
   d. Blood - aspiration, centrifugation, lyophilization, packaging, labeling and storing on days 2,7,14,21 and 26

8. INTERVAL BETWEEN TEST: As in Item 7

9. CREW TASK LOADS:

   a. D-xylose: 6 minutes each astronaut
   b. Urine: 15 minutes one astronaut
   c. Feces: 15 minutes one astronaut
   d. Blood: 10 minutes each astronaut

10. CREW TASK FREQUENCY: Undetermined

11. FIELD OF VIEW: N/A

12. GROUND CONTROL LIAISON DURATION: Undetermined

13. GROUND CONTROL LIAISON FREQUENCY: Undetermined

14. EXTERNAL TEST ITEMS: None

15. QUALIFICATION TESTS: Undetermined

16. SEQUENCE OF EVENTS: See Item 7

17. HANDLING PROCEDURES: Samples of blood, urine and feces to be on loaded to Gemini vehicle, stored and returned for laboratory analysis

FUNDING SUMMARY

BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing							
1. Diet		10,000	10,000	10,000	10,000		40,000
2. Lyophilizer		10,000	15,000				25,000
Integration & Installation			Undetermined				
AGE			Undetermined				
Simulators/Trainers			Undetermined				
Data Reduction			Undetermined				
Equipment Rework			Undetermined				
Other							
TOTAL		20,000	25,000	10,000	10,000		65,000

Source of Funds - Hitch Line Number

It is undetermined whether engineering, development and testing of diet will be funded by MOL funds or research funds.

MANNING DESCRIPTION

1. Astronauts

a. Number required: 2

b. Man's function

(1) As part of test: Astronaut will act as his own control in assessing parameters of physiologic function and their ability to withstand a prolonged weightless environment.

(2) As technician conducting test: Astronauts will perform at a medical technician level and require talents for venepuncture, chemical analysis, waste collection, recording and reporting.

c. Crew skill requirements: Must be able to accurately record dietary intake, collect urine and feces and process the wastes for later analysis, perform venepunctures on companion astronaut and process blood for later analysis, and must have basic knowledge of first aid.

d. Manpower profile: N/A

e. Critical functions: None

f. Time controlled tasks: None

g. Work positions: Undetermined

h. Human performance measures: None

i. Selection factors: Astronauts must have no primary gastro-intestinal disorder or functional bowel syndrome. Past appendectomy with no complications desirable. Must have no evidence of hiatus hernia or free reflux from stomach to esophagus.

j. Training requirements:

2. Ground Personnel

Ground personnel requirements consist of two major groups: subjects and biomedical experimenters. During the development stages, at least 100 subjects will be necessary in order to test the acceptability, digestibility and toxicity of the proposed liquid diet. Biomedical personnel will be required to perform these tests and gather data for interpretation. During the in-flight tests, only members of the biomedical panel will be necessary to analyze data and provide instructions. Following the flight, laboratory facilities and technicians will be necessary to make chemical determinations and biomedical personnel will be necessary to correlate the data and arrive at conclusions.

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE: Records of intake of food and water and output will be necessary from both astronauts on a 24-hour basis.

2. FUNCTIONS TO BE MEASURED: Caloric intake, fluid intake, urinary output and number of defecations.

3. TYPE OF ANALYSIS REQUIRED: Ground analysis only to determine nutritional status of occupants of MOL.

4. PICTORIAL DATA REQUIRED: None.

5. REAL TIME MONITORING REQUIREMENT: None.

6. DATA EDITING OR COMPRESSION: Biomedical data should be separated from operational data, compressed and data dumped every 24 hours.

7. READ OUT TIME: 5-7 minutes each 24 hours.

8. REQUIREMENTS FOR PERMANENT DATA RECORDS: Taped records sufficient.

9. MANUAL AND/OR AUTOMATIC CONTROL: N/A

10. SIMULTANEITY: N/A

11. GROUND COMMANDS REQUIRED: Verbal communication from ground to astronaut required.

Exp No. P-12

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME:

   a. Liquid diet: FY 66
   b. Lyophilizer: FY 66

2. FINAL DEFINITIVE TEST DESIGN TIME: FY 67 for both items

3. NUMBER OF GROUND OR FLIGHT TEST REQUIRED:

   a. Liquid diet: 4-6 ground tests
   b. Lyophilizer: 10-12 ground tests

4. TYPE OF DEVELOPMENT TEST ITEMS:

   a. Liquid diet: Vacuum chamber, shaker, thermal, simulators, aircraft.
   b. Lyophilizer: Vacuum chamber, shaker, thermal, simulators.

5. SUPPORT EQUIPMENT DEVELOPMENT TIME: Same as Item 1.

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

   a. Ground test
      (1) Diet: 100-200 man days
      (2) Lyophilizer: One(1) for MOL mock-up, 3 for development testing.
   b. Atmospheric test
      (1) Diet: 30 man days
      (2) Lyophilizer: None
   c. Space test: One (1) for each MOL.

7. DATE AVAILABLE FOR TESTS: Crude liquid diets available FY 64 for acceptability tests.

8. CURRENT DEVELOPMENT STATUS:

   a. Liquid diet in granular form for reconstitution in space proposed only. Lyophilizer proposed only.
   b. Project is not approved and is not under study.
   c. No funds have been expended to date.

JUSTIFICATION OF EXPERIMENT

A need exists not only to assess man's work performance while he is performing mission oriented duties in an orbiting vehicle, but also to gather information concerning as many parameters of physiological function as possible without compromising weight and space requirements or the primary mission of the MOL. It is to this end that this experiment has been designed. At the present state of knowledge, there is no proof that intestinal absorption proceeds normally during orbital flight but respected opinions of consultants result in the impression that it will (1,2,3,4). Two studies of the absorptive ability of the small intestine have been performed during U. S. orbital flights. The pilot of MA-6 (Glenn) ingested a 5 gram tablet of d-xylose in a non-fasting state and excreted 34.9% of the administered dose by the fourth hour (normal test) (5). The pilot of MA-7 (Carpenter) excreted only 25.7% of the 5 gram test dose (6) but urinary collection was inaccurate and the test cannot be relied upon. While Glenn consumed his test dose of d-xylose at 23 minutes 11 seconds g.e.t., Carpenter took his test at 2 hours 41 minutes 35 seconds g.e.t. in the hope that any gastrointestinal changes would be more marked after a longer time. Disappointed at the failure to obtain information during the second flight, the biomedical investigators suggested that "if this test is to be used on future flights, the accurate timing of xylose ingestion and urination must be known. Ideally, urine specimens passed while the subject is under the influence of gravity should be separated from those specimens voided while he is weightless". (6) A critical analysis of information available reveals that the only knowledge obtained to date about intestinal absorption is that carbohydrate absorption (as reflected by d-xylose) appears to occur normally during an orbital flight of 4 hours 55 minutes.

In an attempt to determine the ability of the intestine to absorb carbohydrate <u>after prolonged weightlessness</u> the d-xylose test is again recommended. It is a simple, inexpensive, convenient test to perform, requiring only the ingestion of 25 grams of d-xylose in 250 milliliters of water and collection of the urine excreted for the next five hours. If 4.5 grams of d-xylose are recovered from the urine, absorption can be considered normal. With lyophilization of the urine, the xylose will remain indefinitely and the sample can be reduced to a few grams in weight so that it may easily be returned. No careful volume measurements are necessary since it is the total <u>amount</u> of xylose excreted in the specified time which is important in assessing the absorptive function of the small bowel. The use of a 25 gram test dose rather than a 5 gram tablet is recommended because it has been shown that there is better reproducibility of results using the 25 Gm dose (7). Furthermore, a solution is preferable to a tablet for ingestion because there is greater assurance that a complete test dose has been administered.

The ability of the intestine to absorb fat can be assessed without imposing undue burden on the subjects. There is presently no knowledge available concerning fat absorption during weightlessness. Considering that the protein, fat and carbohydrate content of the foodstuffs ingested is known, the pilots of the MOL can serve as their own control since pre-flight and post-flight absorption studies are also contemplated. Analysis of fecal fat while the astronauts are at ground level can be easily and conveniently ascertained by fecal fat analysis before the flight and after the flight. With minimal technical knowledge, the astronaut can collect his feces during flight, lyophilize it and return with it. The total space requirements in the return vehicle will amount to approximately 1000 cubic centimeters. The fat content will be unaffected by lyophilization.

These two tests are proposed because their performance does not require a great deal of technical knowledge by the astronaut, they are inexpensive, the samples returned will impose no appreciable weight or space penalties on the vehicle, can be stored indefinitely without loss of constituents. The information obtained will be a valuable addition to the total assessment of the physiological functions of man under the stresses of space and will bear strongly on flight safety and growth potential for future flights.

The requirement for the experiment which necessitates test support equipment is the lyophilizer. There is a need in the metabolic, renal, cardiovascular and pulmonary biomedical sections for the return of blood, urine and fecal specimens. A centrifuge for blood specimens is a requirement of other sections. It appears to be the consensus of all biomedical sections that the return of specimens should be in a form which imposes the least weight and volume penalty on the returning vehicle. The use of lyophilization procedure in obtaining specimens for studies of intestinal absorption would integrate well with contemplated collection of specimens in other sections. Present engineering problems concerned with installation of such a device in the MOL are not available at this writing. Although present laboratory lyophilizers appear to be bulky and heavy, (8) the major components consist of refrigerating compressors and vacuum. It appears that the space environment offers cold temperature and vacuum - the very elements necessary for lyophilization.

References

1. Sleisenger, M. H. (Civilian Consultant in Gastroenterology to MOL Project): Personal communication

2. Kipnis, D. M. (Civilian Consultant in Metabolism to MOL Project): Personal communication

3. Gordon, G. (Civilian Consultant in Metabolism to MOL Project): Personal communication

4. Palmer, E. D. (Chief, Gastroenterology Service and Chairman Department of Medicine, Brooks Army Hospital): Personal communication

5. Results of the First U. S. Manned Orbital Space Flight, NASA, 20 Feb 1962

6. Results of the Second U. S. Manned Orbital Flight, May 24, 1962, NASA SP-6

7. Christiansen, P. A. , Kirsner, J. B., and Ablaza, J.: D-xylose and its use in the diagnosis of malabsorptive states. Am. M. Med. 27:433, 1959

8. Catalog, Scientific Products Division, American Hospital Supply Corp., 1210 Leon Place, Evanston, Ill. Local source: 2505 Butler Street, Dallas 35, Texas

4. Study of Effects on Metabolism Resulting From Flights on MOL.

This test is designed to provide inflight determinations of serum calcium and glucose and of urinary calcium at approximately weekly intervals. Abnormalities in the metabolism of either of these substances may constitute a definite threat to astronaut safety and mission success. The tests rely heavily upon chemical determinations which can be adapted to the MOL requirements. In addition, inflight samples of blood, urine and feces will be collected for later ground analysis of numerous metabolic and endocrine parameters. Current techniques will allow the accumulation of a large amount of metabolic data which will characterize the metabolic changes secondary to weightlessness on space flights of 30 days duration. Data from these samples collected inflight will be compared with preflight and post-flight data to provide a relatively comprehensive view of important metabolic changes and thus provide a basis for protective measures essential to extension of space flights for periods longer than 30 days. The inflight studies will be validated by an extensive ground research program.

It is not anticipated that serious problems will be encountered in accomplishing the tests. Minimal training of the astronauts will be required. Some work on the development of a suitable technique for measuring calcium will be needed and it will also be necessary to devise a simple apparatus to collect, measure and lyophilize the biological specimens to reduce the volume and weight of material sufficiently for later return to earth.

a. Configuration of Test Items: Design Characteristics Test Equipment.

(1) Equipment to be tested: Inflight testing upon small volumes of blood and urine which the two astronauts will furnish. Urine calcium and blood calcium and glucose samples will be determined five times during the 30 days inflight period. From the same collection five blood specimens will be centrifuged, the plasma lyphilized, packaged, stored and later returned. Urine specimens will be collected continuously throughout the flight by an automatic process which will also provide lyophilization and packaging. Equipment requirements consist of a collection and lyophilizing device for each astronaut and equipment for onboard analysis of blood and urine specimens. The former will require a centrifuge for processing.

(2) Weight: Weight of the packaged blood and urine samples collected inflight from both astronauts is estimated to be in the neighborhood of five pounds after lyophilization. Weight of collecting, lyophilizing, and testing equipment is to be determined.

(3) Volume: Volume of the lyophilized blood and urine specimens to be returned is estimated to be in the neighborhood of approximately one-sixth cubit feet. Volume of collecting and lyophilizing device and of chemical determination equipment is to be determined. Shape of lyophilized and packaged samples will be flexible since they will be in small individual plastic packages. Dimensions and shapes of the lyophilizing device and chemical testing equipment is to be determined.

(4) Power:

(a) No requirements for continuous power.
(b) Stand-by power for analytical equipment to be operated for approximately one hour during the entire flight.
(c) To be determined.
(d) To be determined.
(e) To be determined.

(5) Spares:

(a) N/A.
(b) N/A.
(c) N/A.

(6) Tools: None.

(7) Heat Output: To be determined.

(8) Stability: To be determined.

(a) Moving parts: Limited to the small centrifuge necessary for obtaining plasma from blood specimens.

(9) Vibration Limits: To be determined.

(10) Shock Limits: To be determined.

(11) Hazards: None anticipated.

(12) Temperature Limitations: To be determined.

(13) Type and Range of Measurement: Chemical determination of calcium and glucose in blood and of calcium in urine.

(14) Special Environmental Requirements: Equipment used for collecting and measuring urine samples and blood and the recording method, requires only the environment of the enclosed MOL vehicle. Environmental limitations for the specimens will be those of the plastic containers, which must be determined.

(15) Orientation and Position Accuracy Requirements: N/A.

(16) Equipment Operating Cycle: Ten times for each astronaut for a 30 day flight. Each of these tests is estimated to require approximately 10 minutes. Blood specimens, to be lyophilized and returned to earth, will be obtained 9 times on each astronaut during flight. This process estimated to require 10 minutes for each collection and preparation. Two injections to be given to each astronaut will require approximately 7 minutes per astronaut. Collection and lyophilization of urine specimens are estimated to require a total of 360 minutes per astronaut. Application of filter paper twice by each astronaut for collection of sweat specimen is estimated to require ten minutes.

(17) Equipment Location Requirements: Flexible. Non-critical areas can be utilized.

(18) Special Mountings Requirements: None.

(19) Pressure Vessels: N/A.

(20) Electro Magnetic Interference: N/A.

(21) Maintenance Requirements: To be determined.

b. Test Support Equipment Required.

(1) Recording Media: Tape, electronic or visual write-out.

(2) Handling: Urine collecting container of approximately 2500 cc volume for each astronaut for collection of 24 hour urine

volumes, attached container of approximately 100 cc volume for obtaining an aliquot of each 24 hour urine specimen, and lyophilizing equipment are all envisioned as a closed single liquid system. Plastic bags for specimens which conform to lyophilization requirements are to be developed.

(3) Packaging: Special plastic bags suitable for use in lyophilization.

(4) Calibration: Limited to electronic recording device if such is used.

(5) Jigs and Fixtures: Collecting container, centrifuge, and testing equipment are all to be stationary and permanently mounted in non-critical areas.

(6) Number of Leads From Outside to Inside Station: None.

(7) Sensors: Calcium electrode or other sensing device.

(8) Trainers/Simulators: None for this test.

(9) Instrumentation: Limited to electronic analytical equipment, to be used during non-working periods only.

(10) Related Support Equipment: N/A.

(11) Age: To be determined.

(12) Environmental Test Equipment: None.

(13) Facilities: To be determined.

c. Test Procedure

The test itself requires the collection of blood and urine samples and onboard analysis of calcium and glucose, with each astronaut to perform these tests on 5 blood specimens and 5 urine specimens during the flight. The man will be required to perform venipuncture and obtain blood specimens, to operate centrifuge for separation of plasma from the blood specimen, and to perform the chemical determinations for calcium and glucose. The chemical determination in the case of both blood and urine specimens will be simple and require no complicated operation, with only simple manipulations required for operating an electronic measuring device and either a visual read-out or recorder for later transmission of data to earth. The collection of urine specimens will be designed to make minimum requirements upon the man's time by the use of automatic methods.

Test Operating Characteristics

(1) Orbital Parameters: N/A.

(2) Plane Change: N/A.

(3) Altitude Change: N/A.

(4) Time on Orbit: N/A.

(5) Test Duration: Daily operation of urine collecting and lyophilizing device will require 10 minutes per astronaut per day. Collection of urine and blood for onboard analysis will require approximately 20 minutes per astronaut on 5 occasions at approximately weekly intervals during flight. Two injections during flight for each astronaut on approximately the 12th and the 22nd day require approximately 7 minutes.

(6) Total Number of Tests: As in 5.

(7) Test Frequency: As in 5.

(8) Intervals Between Tests: As in 5.

(9) Crew Task Loads: Total time requirement for each astronaut is estimated to be 9 hours for the entire flight. The specimens collected during these times will be shared with other areas. The volumes and times of urine and blood collections listed here are essentially those required for all tests in other areas as well as the metabolic area.

(10) Crew Task Frequence: As in 5.

(11) Field of View Requirement: N/A.

(12) Ground Control Liaison Duration: N/A.

(13) Ground Control Liaison Frequency: N/A.

(14) External Test Items: N/A.

(15) Qualification Tests:

(a) Ground: Validation of the methods of determination and equipment for such determinations will be required. Suitable plastic for collection and lyophilization of specimens must be tested. Centrifuge adapted for inflight use must be developed and tested. Urine collection, aliquot separation, and lyophilization equipment must be developed and tested.

(b) Atmosphere: None.

(16) Sequence of Events as they Occur During Flight: Collection of urine will be on a continuous basis. The 24 hour collection device, and aliquot separation device should require no more than the turning of a valve at the time that the aliquot of the 24-hour urine specimen is obtained. This will be done once daily for each astronaut except on 4 days when aliquots from 2 twelve-hour specimens are collected. The aliquots of the 24-hour and 12-hour urine specimens will be 100 cc in volume and will be collected in plastic bags or containers which can be sealed, exposed to cold and vacuum for lyophilizing, stored in an out-of-the-way area, later gathered, stored in non-critical area of Gemini capsule, and returned. Blood specimens, to be obtained for lyophilization, will require centrifugation, separation of plasma, and lyophilization. On 5 of these 9 occasions when blood must be drawn determinations will be made inflight. On the same day 5 urine specimens will also require onboard determinations.

(17) Handling Procedures: As described in 16.

d. Category of Experiment

(1) Category a: None.

(2) Category b: These tests contribute to the primary MOL objectives. With the possible exception of the urine collection and lyophilization system they should have no significant influence on design characteristics.

(3) Category c: None.

e. Cost: Ground research studies begun 2 years ago by Clinical Sciences Division, School of Aerospace Medicine, will be continued with in-house funds.

f. Schedule

(1) All hardware and software required for the tests is available except for an optimal method and equipment to measure calcium levels of urine and serum during flight, a suitable centrifuge suit and the equipment necessary to collect, measure, aliquot, package and lyophilize biological specimens.

(2) To be determined.

IV. Participating Government Agencies

Sponsor: School of Aerospace Medicine.

Test Equipment Acquisition: To be determined.

V. Additional Requirements

a. Special Security: N/A.

b. Manning Description Summary:

(1) Astronauts

(a) Number required: Two

1. Man's function

a. To function as a subject of the test and operate equipment to collect and lyophilize biological specimens and perform venipunctures, intravenous injections and chemical analysis of biological specimens.

b. All of the performance will be as technician.

(b) Crew skill requirements: Technician level which will require little special training. Minimal training will be required to develop the ability to perform venipuncture and intravenous injections and to operate equipment.

(c) Manpower Profile: Tests required for the metabolic area can be performed by one man working alone except for intravenous injections and venipunctures which will require two astronauts working together and which should not require longer than 30 minutes during a 30 day mission.

(d) Critical Functions: Accurate performance of chemical determinations.

(e) Work Positions: Flexible.

(f) Time Controlled Tasks: Collection of urine over 12 and 24 hour periods. Performance of venipuncture no less than 6 hours after a meal.

(g) Human Performance Measures: N/A.

(h) Physiological and Psychological Measures: N/A.

(i) Selection Factors: Not critical insofar as these tests are concerned.

(j) Training Requirements: As in (b) above.

(2) Ground Personnel

(a) Number required: One or two to monitor, correlate and analyze returned data.

(b) Crew Skill Requirements: Board-qualified Internist.

(c) Manpower Profile: N/A.

(d) Critical Functions: Analysis of significance of returned data.

(e) Work Positions: N/A.

(f) Time Controlled Tasks: To be determined.

(g) Human Performance Measures: N/A.

(h) Physiological and Psychological Measures: N/A.

(i) Selection Factors: N/A.

(j) Training Requirements: Board-qualified Internist.

c. Logistics: To be determined.

d. Facilities: Existing facilities are adequate at present to continue ground research applicable to MOL. A mock-up of the Gemini Flight Simulator would be desirable to assist in the minimal training which the astronauts will require to carry out the technician type tasks.

e. Simulation and Training

(1) Astronaut: Technician level of required tasks will require minimal training of individuals otherwise qualified for mission facilities, for training including inflight methods and equipment, will be available at the School of Aerospace Medicine.

(2) Ground Personnel: No additional requirements at present.

(3) Equipment: No additional requirements at present.

VI. General:

a. Communications and Data Handling Requirement

(1) Data Rate: Barring the occurrence of emergency situations requiring diagnosis and treatment, results of tests could be transmitted once very 24 hours.

(2) Functions to be Measured: Serum calcium, glucose. Urine calcium.

(3) Type of Analysis Required: Chemical.

(4) Pictorial Data Required: None.

(5) Real Time Monitoring Requirement: None.

(6) Data Editing or Compression: N/A.

(7) Read-out Time: N/A.

(8) Requirements for Permanent Data Records: None.

(9) Manual and/or Automatic Control: N/A.

(10) Simultaneity: N/A.

(11) Ground Commands Required: None.

b. Development Characteristics

(1) Development Time: To be determined.

(2) Final Definitive Test Design Time: To be determined.

(3) Number of Ground or Flight Tests Required: Ground tests only would be required except for flight-testing equipment. Those involving astronaut training would probably be limited to several sequences of collecting and testing procedures, preferably in a simulator. Metabolic studies covering approximately seven weeks on the two astronauts is desirable.

(4) Type of Development Test Items:

(a) Vacuum Chamber: All testing equipment.
(b) Shaker: All testing equipment.
(c) Thermal: All equipment.
(d) Acoustic: All equipment.
(e) Simulators: As in (3) above.
(f) Aircraft: No requirements in connection with tests or ground research.

(5) Support Equipment Development Time: To be determined.

(6) Number of Test Articles Required For:

(a) Ground Test: Two each of collecting and lyophilizing device, centrifuge, suitable equipment for determination of calcium and glucose in biological specimens.

(b) Atmospheric Test: To be determined.

(c) Space Test: To be determined.

(7) Date Available for Tests: To be determined.

(8) Current Development Status:

(a) Proposed Only: Calcium electrodes. Further refinements to increase reliability required.

(b) None.

(c) Funds expended to date: None.

c. See Annex 4 Study of Effects on Metabolism Resulting From Flights on MOL.

5. Renal and Electrolyte Effects Resulting from MOL Mission

This experiment is designed to reflect and elucidate the processes which represent the acute adaptive responses to weightlessness and also the steady state which probably will occur with prolonged weightless flights of 30-120 days. Project Mercury flights provided information that astronaut personnel sustained definite body fluid losses which were manifested by weight loss, evidence of dehydration and serious cardiovascular instability. To this time, data are not available which clearly demonstrate the mechanisms of this fluid loss in each. Moreover, none of our orbiting personnel can be judged to have achieved a steady state of equilibration in the weightless environment. Hence, it is expected that careful studies in future flights will enable us to make sound decisions as to the pathophysiological processes utilized, and enable us to have in hand the necessary data to compensate for any serious fluid shifts or losses encountered in flight. The analyses and records relate directly to flight safety.

a. Configuration of Test Items

(1) Photoelectric spectrophotometer: approximately 1 cu foot volume, square, 4#, in the MOL

(2) Sodium electrode: 12 x 24 x 12 inches, oblong, 4#, in the MOL vehicle.

(3) Micro-pH-meter: 12 x 24 x 12 inches, oblong, #4, in the MOL.

(4) Optical refractometer: 12 x 3 x 3 inches, cylinder, 1#, in the MOL.

(5) Centrifuge (torque - countertorque probably necessary), 1 cu foot volume, 5# weight, cylinder, in the MOL.

(6) Volumetric cyclinders for measuring urine volume, in the MOL.

(7) Calibrated syringes, stopcocks, containers and sample bags

(8) Biological sample lyophilizer: no estimate at present, located in the MOL.

(9) Body mass meter: from a calibrated spring gauge, in the MOL.

b. Test Support Equipment

(1) Spacecraft: needles, syringes, stopcocks, standard solutions necessary.

(2) AGE: Duplicate equipment must be mounted in simulators to familiarize personnel prior to flight. Other equipment (duplicate) will have to be thoroughly tested in lab, and flight personnel taught the technical details of equipment usage to assure accurate, reproducible results.

c. Test Procedure: The test is to observe and record the fluid shifts occurring in the flight personnel by recording food and fluid intake and measurable fluid output. Body mass (as a measure of weight) will be recorded daily, urinary solute excretion will be measured and the net serum stabilization will be assessed using hematocrits and serum sodium determinations.

(1) Orbiting crew members will make the observations, testing each other. They will therefore be the subjects as well as the technicians for the experiment.

(2) Man will be used to the extent that his adaptation is under scrutiny and it is he who is making the observations. The observations will be judged by the serial changes recorded in the physiological systems being tested.

(3) Testing sequence: certain tests will be performed daily in the early phases of flight, thereafter, testing will be at greater intervals, viz, weekly.

(a) Daily tests: to be done each day by each crew member

1. Record of 24 hour intake - fluid and food

2. Collection of 24 hour urine excretion will be aliquoted and approximately 100 cc of each 24 hour volume lyophilized. The residue is to be labelled and returned to earth with crew members.

3. Measurement, in flight, of daily urinary sodium excretion (from aliquot of 24 hour volume) and urinary total solids from optical refractometer (also calibrated for urinary specific gravity and total serum solids).

(b) Daily tests: done each day during the early (first week) of flight or until steady state is achieved.

1. Body mass
2. Capillary hematocrit
3. Total serum solids (can be taken from supernate of hematocrit)

(c) Periodic tests: will be done at intervals during for example on the 2nd, 7th, 14th, 21st and 28th days. They can be done at other times if clinical situation is thought to warrant it, as in medical emergency.

1. General physical examination: more in the nature of inspection - look for petechie, edema, assess skin and tongue turgor, auscultation of chest (if indicated) and abdomen (likewise).

2. Urinary protein, glucose, pH (dip sticks)

3. Blood volume: using injection of known amount of T1824 dye and sampling in 30 minutes for spectrophotometric determination of dye density.

4. Body water: using D_2O as marker, mass spectrometry of urine can be used to assess body water in flight.

5. Serum sodium: can be measured from venous sample on cationic exchange electrode (glass)

6. "Arterialized" capillary pH: on capillary micro - pH meter

7. pCO_2: can be approximated from end-alveolar sample using a CO_2 sensing device, specifically a mass spectrometer.

8. Blood calcium, B.U.N.: for former the detection of hypercalcemia is sufficient and exquisite accuracy is not necessary, for the latter also a rough quantitative estimation is sufficient. A colorimetric determination on spectrophotometer, or kit, will suffice.

9. Plasma sample (15cc) will be lyophilized weekly and preserved for return to earth, appropriately labelled. The results of all these tests can be determined and calculated visually in flight or the electrical impulses from colorimetric reactions read-out on demand. Real time records are not critical, but results should be retrieved the day of testing so that important trends are not overlooked.

(d) If alarming values are reported, or consistent trends detected which require urgent action, the orbiting crew can be commanded from the control station to carry out the critical test on "instantaneous" basis or to test at more frequent intervals. If illness should develop in flight, or if puzzling behavior or performance supervene, the capability to detect major metabolic alterations and the equipment necessary is aboard in the form of pH meter, sodium electrode, total solid meter, etc. This is a definite "flight safety" feature of the test.

(e) In terms of efficient expenditure of time one crew member will be responsible for the analytical work and the other for aliquoting samples and recording values. In this way greater efficiency and minimal time investment will be achieved.

(f) Tests that will be performed on aliquots of urine returned (stool specimens should also be returned) are the following:

1. Urinary nitrogen
2. Creatinine
3. Uric acid
4. Calcium
5. Phosphorus
6. Sodium
7. Potassium
8. Chloride
9. Protein
10. Indican
11. Uropepsin
12. Amylase
13. 5-hydroxyindoleacetic acid
14. Oxalate
15. Ascorbic acid
16. Aldosterone
17. Cortisol and intermediary products
18. Anti-diurectic activity
19. Hydroxyproline

These analyses will give definite insight into the intermediary metabolism of man in prolonged weightless flight. The analyses will be performed in research laboratories under the direction of a central laboratory supervisor.

d. Category of Experiment: the entire experiment is category a. The equipment required may be specifically categorized:

(1) Spectrophotometer: category a.
(2) Sodium electrode (cationic exchange glass): a
(3) Micro-pH meter (capillary): a
(4) Optical refractometer: b
(5) Centrifuge: a
(6) Volumetric devices: b
(7) Calibrated syringes, etc: b
(8) Lyophilizer: a
(9) Body mass meter: a

e. Cost

(1) E&D: $10,000 FY 65
(2) Installation: $10,000 FY 66
(3) Ground Support: $10,000 FY 67

Data retrieval will already be programmed from the MOL

f. Schedule

(1) Hardware and software available for test: Dec 1965
(2) Hardware and software available for flight: June 1966

IV. Participating Government Agencies

Sponsor: John J. McPhaul, Capt, USAF, MC
Wilford Hall, USAF Hosp
AMD, AFSC

Test Equipment Acquisition: AFSC

V. Additional Requirements

a. Special Security: probably for official use only
b. See attachment 5
c. N/A
d. Facilities: no new facilities required, except duplicate equipment must be installed in a simulator and complete flight simulation carried out using and proving the equipment
e. Simulation and Training: for the test contemplated the tasks are complex enough that training is required. The level of knowledge necessary is not critical. The crew member who is to operate the test equipment must have sufficient practice so that read out data supplies accurate information. It is sufficient that a pilot or engineer be aboard; it should not require a technologist or physician. The training will entail two phases:

    (1) Introduction to the equipment and the techniques of use so that crew members are thoroughly familiar with its use. Personnel will also be taught proper methods of venipuncture, specimen handling and recording of observations. The crew members must be able to judge whether instruments are functioning optimally. Technique checkout prior to flight will indicate sufficient familiarity.
    (2) "Flight" of short duration in an MOL simulator should be performed prior to actual orbital missions in oder to thoroughly familiarize personnel with position of instruments and importance of precision analytic work. This will afford opportunity to detect flaws and correct errors of technique under simulated flight conditions.
    (3) Equipment necessary is a complete setup of analytic monitoring and testing equipment as it will be flown on MOL.

VI. General:

a. Communications and Data Handling Requirement: No real time observations are needed except in emergencies. Data can be dumped by telemetry from tape in one location daily - preferably in a central medical facility, such as S.A.M.

b. Development Characteristics:

(1) Attachments 1 through 4 to be determined.
(2) See attachments 5 through 7.

c. See Annex 5 Renal Fluid and Electrolyte Effects Resulting from MOL Missions for more detailed information in this area.

Attachments 1-4 to be determined.

MANNING DESCRIPTION APPENDIX

A. Astronauts

1. Number required: 2

a. Man's function

(1) As subject - both must be subjects
(2) As technician - only 1 need be actual technician - it is preferable that 1 man do all the testing consistently.

b. Crew skill requirements - must do venipunctures, perform injections, measure accurately, and carry out the test protocols exactly as pre-planned and practiced prior to flight in lab and simulator. Must operate the testing equipment as per instructions.

c. Manpower profile - will require 1 man 25 minutes daily to perform the capillary finger sticks, hematocrit, total solids determination and urine analysis. Will require 25 minutes additional to record urinary volumes, fluid volumes, and diet intake, and lyophilization of biological samples to return. This is 50 minutes total time (of 48 hours available from both astronaughts). After initial adaptation period (probably 1 week) only aliquoting and urine analyses will be daily work.

d. Critical functions - careful technique of measuring, pursuit of protocol and use of equipment.

e. Work positions - can be performed sitting.

f. Time controlled - must be done daily at same time of day, preferably post-absorptive.

g. Human performance measures - are biological measures. Consistent skill of performance will serve as an added indicator of reliability and ability to follow direction.

h. Physiological and psychological measures - this is the test.

i. Selection factors - no particular skills required beyond crew selection of qualified astronauts and proper preflight training in lab and in simulator "flight".

j. Training requirement - will require 2 hours of work overall with each piece of equipment to attain familiarity and consistency in its use; can be supervised by qualified laboratory personnel. Venipuncture requires little practice. Additional requirement of complete mockup simulator "flight" with actual equipment.

B. Ground Personnel

1. A medical director can coordinate the medical monitoring and supervise the distribution of daily and periodic biomedical data for evaluation and interpretation.

2. Proper data reception, processing, and print-out must be assured.

3. Emergency changes may be dictated by in-flight trends, symptoms, or analytic results.

Exp No. P-12

Communications and Data Handling

1. Data rate: daily; spread
2. Function to be measured: test result, can be direct voice or code
3. Type of analysis required: data recovery only
4. Pictorial data required: none
5. Real time monitoring requirement: none, except in acute medical emergency
6. Data editing on compression: none
7. Readout time: 3 minutes
8. Requirement for permanent data records: on reception only
9. Manual control or automatic: no preference; manual in emergency
10. Simultaniety: all data to one receiver site
11. Ground commands required: only in emergency

Exp No. P-12

Development Characteristics of Equipment

1. Development time: 18 months
2. Final definitive test design time: 6 months
3. Number of ground tests required: 2 complete simulator runs prior to flight
4. Type of development test items

   a. Simulator reliability needs demonstration prior to flight
   b. Must be stable enough to withstand severe vibration

5. N/A
6. Number of test articles required

   a. Ground testing: 2
   b. N/A
   c. Should be aboard each of unmanned flights so as to assess stability and durability

7. Date available for tests: June 1966
8. Current development states:

   a. Proposed only: lyophilizer, sodium electrode for space use, body mass gauge, suitable centrifuge, and spectrophotometer
   b. On shelf: optical refractometer

6. Evaluation of Pulmonary Function During MOL Missions

Because respiration serves as an interface between man's external and internal environment, it is more accessible to measurement than any other body system. Furthermore, dysfunction in any other body system will be reflected by changes in respiratory parameters. Broad spectrum monitoring of pulmonary function, therefore, is eminently practical and will provide a sensitive early warning system of detrimental change in not only pulmonary function but also of any other physiologic system which could affect man's operative abilities in a military space mission. If the primary site of physiologic alteration is pulmonary in origin, the change can be qualitated and quantitated so that proper corrective measures can be instituted or an accurate estimate of duration limitation can be made. The pulmonary test items were selected with the above goals in mind.

a. Configuration of test items

(1) In Gemini capsule

(a) Impedance pneumograph: uses ECG electrode

(2) In MOL

(a) Face mask: modified CWS gas mask for collection of expired gases; weight, 1 lb.; volume, approximately 144 cubic inches; plastic shape.

(b) Capillary pneumotachometer: gas flow measuring device from which volume of gas can be obtained by electrical integration; weight, 1 lb.; volume, 20 cubic inches; shape, bisymmetrical truncated cone.

(c) Pressure transducer: sensitivity of ±0.3 p.s.i. differential; weight, 1 lb.; volume, 18 cubic inches; shape, cylinder.

(d) Müller-Franz dry test gas meter: direct reading and automatic sampling of mixed expiratory gas volumes; weight, 8.5 lbs.; volume, 0.8 cubic feet; shape, rectangular block.

(e) Gas analysing equipment; specifications to be added to operational equipment in MOL control system for gaseous environment (see below).

(f) Associated paraphernalia: assorted sizes of rubber balloons for gas collection, large bore stopcocks, rubber tubing, drying agent, pinchcocks; total weight, approximately 12 lbs.; volume and shape, can be packed in carton occupying 0.7 cubic feet.

b. Test support equipment required

(1) Spacecraft

(a) Gas environment control system: analysers or sensors to be sensitive to at least 0.1% (v/v) CO_2 and O_2; accessible to astronauts for sample analysis and calibration; response time of 95% in 0.1 second.

(b) Tape recorder

(c) T/M

(d) Meter read out

(e) Operational amplifier and integrator

(2) AGE. no special requirement

c. Test procedures

The specific parts of the test procedure provide broad spectrum monitoring of pulmonary function. All tests will be performed by the subject on himself and will only rarely require aid from a second person. The data will be interpreted on the basis of previously acquired control data at ground simulation of MOL mission. The tests will provide medical safety monitoring as well as an assessment of man's ability to function in space in relation to his ability to perform the same mission operations at ground level. Priority of specific test procedures are shown in "Annex to Area 6 - Respiration" attachment.

(1) Timed vital capacity (TVC) and vital capacity (VC). These will be measured by the integrated signal of the pneumotachometer while the subject is at rest and fasting every third day in orbit. The tests provide a simple means of measuring total incremental lung volume as well as indicate (in the case of TVC) the presence of changes in airway resistance. These tests, therefore, assess the lungs' ventilatory function. The respiratory maneuvers necessary to the measurement are themselves of therapeutic value in maintenance of airway patency and re-expansion of shrunken alveoli.

(2) Alveolar partial pressures of carbon dioxide (P_{ACO_2}) and oxygen (P_{AO_2}). These will be obtained by gas analysis of a Haldane alveolar gas sample, which consists of trapping the gas expelled by a forced, rapid expiration at the end of a normal expiration. The derived P_{ACO_2} and P_{AO_2} will furnish an assessment of the lungs' function in gas exchange between the tissues and the external gaseous environment. In addition, repeated daily measurements of P_{ACO_2} will provide qualitative indications of acid-base derangement and, by judicious examination of sequential changes, whether such derangement is primarily respiratory or metabolic.

(3) Discrete oxygen utilization. Measurement of individual oxygen consumption rates at specific phases and levels of activity will be carried out by the open circuit method utilizing the Müller-Franz dry test meter and analysis of automatically collected mixed expired gas. Direct measurement of this parameter requires the presence of an inert gas in the environment, but an accurate estimate can be obtained by the same method even in the absence of an inert gas. Except for special test requirements (such as basal state measurements), this determination can be carried out without interference with other assigned duties. Information derived by calculation from the test will also provide data on carbon dioxide production, respiratory exchange ratio (respiratory quotient when a steady state exists), and minute expiratory volumes. In addition to its extrapolative value for prolonged mission system design features, such information will also provide a measure of man's acclimatization to the weightless state in terms of efficiency of physical movements.

(4) Carbon dioxida response curves. By permitting the subject to rebreathe into a suitable volume of 100% O_2, carbon dioxide concentration will increase in a regular manner. By measuring the end-tidal concentration of CO_2, together with the instantaneous ventilatory rate by integration of the signal from a serially connected pneumotachometer, a dose-response curve for carbon dioxide is obtained. From such information garnered periodically, the state of CNS respiratory regulation mechanisms can be ascertained. If acclimatization to carbon dioxide is taking place, the quantitative progress to this end can also be evaluated. The former area can be best assessed by making the test during sleep. That would require the services of the second astronaut for a maximum period of 10 minutes.

(5) Maximal breathing capacity (MBC). Measured by maximal voluntary hyperventilation through the pneumotachometer for a 15-second period. This will also serve as a cardiovascular test sequence. The MBC is a reliable, well-standardized, reproducible index of total expiratory potential in healthy stimulated individuals. It affords not only an estimate of actual parenchymal function but also provides an estimate of musculoskeletal coordination, psychological motivation, and alertness. It provides a relatively more sensitive index of airway resistance than the TVC. The deep forced respiration necessitated by this measurement can also be regarded as a form of respiratory exercise with beneficial effects.

(6) Pulmonary compliance. A single experimental point will be measured on the combined relaxation pressure volume curve of the lung and chest. This will be obtained by relaxing the chest at a known lung volume while the open airway is connected to a pressure transducer. The pulmonary compliance is calculated from the slope of the line connecting this point to the origin. Changes in this parameter may be used as an index of venous admixture and will give early indications of alteration in pulmonary blood volume distribution and parenchymal tissue damage.

(7) Breath sounds. A suitable microphone will be used, if available, for transmission of chest sounds from preselected points on a real-time or T/M basis. If other measures of pulmonary function detect clinically significant changes, the astronaut will be instructed to place the microphone in a specified sequence on predetermined locations of the chest. This will serve as a further diagnostic aid to the physician on duty at the Mission Monitoring Station.

d. Category of experiment

All tests performed in the area of respiration fall into Category e. The results will contribute directly to the MOL program primary objective by providing information on which to base the decision of whether or not respiratory function will prove limiting to man's realization of full operating potential in a military space mission. Respiratory function tests will pay a major role in design characteristics in that they will provide the most sensitive detection and direct physiologic raflection of possibly debilitating contaminants in the atmosphere. MOL system validation procedures should be incorporated with the bioastronautics ground tests for these reasons.

e. Cost

All test items are "on-the shelf" and require no further development nor any special installation. The only exception to this is the engineering and development of suitable gas analysers. Since it is proposed only to place a further requirement on those used for environmental control, their cost considerations do not appear here.

f. Schedule

(1) All items are presently available for test.

(2) Flight readiness date of test items can be set within 30 days after procurement.

IV. Participating Government Agencies

Sponsor: SAM; Dr. Stephen M. Cain and Captain Paul M. Stevens

Test Equipment Acquisition: SAM and SSD

V. Additional Requirements

a. Special security: Results of this test are identical to medical status data and only limited access should be granted.

b. Manning description summary: To be determined.

c. Logistics: To be determined.

d. Facilities: For evaluation of test items and procedures as well as preliminary training of MOL candidates, facilities of USAF SAM can be used without modification. A complete MOL simulation run in a low pressure chamber with provisions for actual mission simulation will be required for final training and control data acquisition.

e. Simulation and training

(1) Astronaut

Any motivated intelligent person can be trained sufficiently well to carry out these tests successfully. Graduates of the Space Research Pilot's School, for example, would be suitable. Some indoctrination into the physiologic reasons for the tests would be imparted to provide enough understanding so that the importance of the tests became intuitively self-evident. After thorough familiarization with the tests under ideal laboratory conditions (approximately 1 to 2 weeks), training would be restricted to full dress-rehearsal in MOL simulator.

(2) Ground personnel

Competent, experienced professional personnel will be required to make appropriate judgments of the quality of data received daily and to make fully qualified recommendations on the basis of such data, either in respect to mission safety or possibly with respect to some treatment or therapy when indicated.

(3) Equipment: (See "Configuration of test items" above.)

VI. General

a. Communications and data-handling equipment: (See Bioinstrumentation Section.)

b. Development characteristics: N/A

c. Annex - Section 6 - Respiration: (Attached)

Exp No. P-12

ATTACHMENTS TO AREA 6

1. Design Characteristics Test Equipment: To be determined
2. Test Support Equipment: To be determined
3. Test Operating Characteristics: N/A
4. Funding Summary: To be determined
5. Manning Description: To be determined
6. Communications and Data Handling: To be determined
7. Development Characteristics: To be determined

7. Study and Control of System Deterioration and Associated with MOL Missions.

One of the most important and completely unstudied problems of manned space flight relates to the cumulative, time-dependent, and adaptive changes of prolonged exposure to weightlessness. It is probable that extended exposure to zero gravity will result in deterioration of certain gravity oriented physiologic systems by disuse. Such deconditioning in an environment of reduced or absent gravitational force may seriously impair man's ability to tolerate normal or increased gravitational forces after this exposure. The problem becomes: How can gravity oriented biologic systems be maintained in the absence of gravity?

An astronaut support program must be devised which will insure maintenance of physical well-being during and subsequent to deorbit and provide information necessary to extend man's operational effectiveness for longer duration missions.

Although ground based laboratory research has been and will continue to be vital in the definition of the magnitude of this potential problem area, validation of the experimental data can be made only in the weightlessness of space.

Manned orbital experiments of one and two-week duration preceding MOL are expected to provide information vital to this area and will permit rational modification of this test protocol as operational information becomes available.

a. Configuration of the Test Items

(1) Muscle Conditioning Technique

The Soviets have placed great emphasis upon the requirement for effective muscle exercise regimens during prolonged exposure to weightlessness. From the onset of their man-in-space program they have utilized inflight exercise routines designed to maintain anti-gravity muscular effectiveness. Their early regimens apparently were primarily isometric in nature. In addition to the isometric exercises of his predecessors, Cosmonaut Bykovskiy utilized an isotonic device[1] suggesting that isometric exercises alone may not not have been entirely adequate. Continued and increased emphasis on this requirement, despite the information available to them from orbital flights of up to five day's duration, suggest that perhaps even the isometric-isotonic combination may not be completely effective and may require revised concepts.

Information derived from ground based deconditioning studies indicate that with prolonged exposure to relatively hypodynamic conditions, programmed muscular exercises are required to maintain control level musculoskeletal effectiveness.[2,3]

It appears mandatory that a specific muscle exercise regimen will have to be incorporated into the MOL for routine use and an effective exercise schedule developed.

An approach which appears to offer some promise and which can be easily integrated into the MOL vehicle is the use of the bicycle ergometer technique. This device can be engineered to exercise both upper and lower extremities simultaneously, thereby involving all major muscle groups in a combined isometric-isotonic approach.

It can be designed into the astronaut's "rest and test" area as part of a couch or platform which also will serve as the site of selected biomedical testing and as the sleeping area or facility.

Having previously been calibrated during ground studies to arrive at optimum astronaut work rates, this technique lends itself to precise quantification of total work performed.

It is probable that with appropriate design of the ergometer, useful work can be derived such as operation of a generator or battery charger.

This device should meet the demands for maintenance of musculoskeletal (and, in part, cardiovascular) effectiveness during MOL, be adaptable under dynamic operational conditions and have a growth potential for longer duration missions.

(2) Space Suit Modification to Permit Deorbit Counterpressure, If Required

Literature available from deconditioning research to date, using bed rest and immersion techniques reveals that deficiencies of blood volume and venomotor tone appear to play a prominent role in the altered stress tolerance following such deconditioning. Several such studies have amply documented the effectiveness of a bladder type G-suit, or a modified lower torso and extremity counterpressure suit, to compensate for both blood volume deficiencies and altered venomotor tone. Such simple mechanical devices restore control equivalent stress tolerance.

In light of available information it appears to be highly desirable to design this capability into our astronaut support systems for expected probable use during deorbit. It can be considered a reliable, simple, mechanical form of insurance.

A separate quick-don counterpressure garment consisting of what amounts to an optimization of the existing operational G-suit may prove to be more feasible than integrating this capability into the space suit. It could have its own separate air source, if necessary, and can be designed and fabricated to have minimal weight and volume.

(3) Muscle Strength Measurements

Direct readings of the strength of any particular muscle group, especially the anti-gravity musculature, on a routine basis will be mandatory for assessing effectiveness of cosmonaut support techniques such as muscle exercise and to permit valid predictions of astronaut physical potential during deorbit.

Available evidence indicates that musculoskeletal adaptation to weightlessness is time dependent and indicators of this will be of continued interest for astronaut support during future longer missions.

An electrical strain gauge dynamometer will be developed which will have minimum size weight and power requirements and will provide reliable quantitative readings of strength of selected muscle groups.

(4) Blood Volume Determinations

Literature available from deconditioning research indicates that blood volume, having adjusted to experimental hypodynamic requirements, may be substantially decreased from control values and play a prominent role in the reduced stress tolerance resulting from such studies. Additional information suggests that such readjustment of blood volume is progressive with time at least up to several weeks before plateauing is evident. Although there are many factors to consider, a reduction in circulating blood volume has been evident in all astronauts to date (including Cosmonaut Titov)[4] in the immediate recovery phase.

The configuration of this test item is as described in the cardiovascular section. It has been considered in this discussion because of its important role in cardiovascular capability and general physical conditioning. High priority should be given this test item.

Blood volume determinations must be made periodically, at approximately weekly intervals, using Evan's blue dye or some operationally suitable modification of this technique. Inflight real time analysis must be done by the crew members and results recorded on tape and reported. Plasma expanders must be made available and administered prior to deorbit, if significant decrease in circulating blood volume is evident. This will insure optimization of astronaut physical capability.

(5) Measurements of Vascular Reactivity

The vascular system of the astronaut must be assessed periodically to evaluate the integrity of circulatory mechanisms having countergravity role such as venomotor tone, arteriolar responsiveness, and rate control reflexes. Such assessment can provide information about adequacy of astronaut support techniques and predict astronaut stress tolerance and possible deorbit support requirements.

Such measurements will include:

(a) Blood pressure and pulse rate response to calibrated exercises as described in cardiovascular section.

(b) Cardiac output determination before and during calibrated exercise as described in cardiovascular section.

(c) Blood pressure and pulse rate response to a calibrated Flack test.

Equipment for this test procedure will consist of an aneroid type pressure sensing device with the dial calibrated to read from zero to the equivalent of 40 mm Hg. This will be positioned in such a manner that the astronaut by blowing into a mouthpiece through tubing can visually maintain a programmed pressure value for a given number of seconds.

(d) Blood pressure and pulse rate response to a calibrated venous occlusion test.

Equipment for this will consist of quick-don extremity or abdominal tourniquets which, when inflated to a predetermined value, will reduce venous return to the heart simulating, in part, orthostatis. The aneroid type pressure sensing device used in the previous test may have application to this test as a monitor of inflation pressure.

(e) Blood pressure and pulse rate response to calibrated negative pressure applied to the lower half of the body.

This device can be designed into the "rest and test" area mentioned in item (1), muscle conditioning techniques. Equipment would consist of a rigid shell device which can be integrated with the sleeping platform, be designed to isolate the lower half of the astronaut's body. Calibrated negative pressure can then be applied causing significant body fluid trapping simulating orthostasis or even multiple $+G_z$. The amount of negative pressure required is yet to be determined, but should be minimal permitting the hard shell device to be very light-weight.

Such a device may find additional use as a sleep facility and also may prove to have some usefulness as a cardiovascular maintenance technique but this remains to be defined by ground-based studies.

(f) Some indication of venomotor responsiveness:

Existing direct techniques are not operationally feasible.

An attempt will be made to develop an indirect method of measuring venous tone using a tonometer -- closed venous segment technique. Such a device, if it can be developed within the time allowed, should be light-weight (50 gms), small in size and have minimal power requirement.

High priority should be given the development of this test item in an operational utilizable configuration because of the prominent role played by venomotor tone in cardiovascular responsiveness and the probability that the venous side has a significant role in cardiovascular deconditioning.

(6) Periodic Blood and Urine Aliquots

At this time it appears feasible to go for a 30-day mission with no real time analysis of blood and urine data providing reliable information has been obtained from preceding manned orbital experiments.

Blood must be drawn periodically and the plasma samples frozen and stored. Urine aliquots must also be taken periodically, frozen and stored. Total urinary outputs must be recorded on each test day.

The technique of sampling and aliquot preparation and storage is as described in genitourinary and gastrointestinal sections. Frequency of such measurements is not critical for this area and will depend upon priorities established by these sections.

In the later post deorbit analysis of these samples particular attention will be devoted to those determinations which reflect adequacy of astronaut inflight conditioning techniques and provide more basic information on tolerance of man for longer duration missions. Such considerations will include calcium, phosphorus, and nitrogen mobilization studies and catecholamine-vascular reactivity interrelationships.

(7) Additional Astronaut Support Considerations

Other techniques and devices for astronaut support are being actively considered for possible application and are de signed to attempt to compensate for lack of gravity without going to artificial gravity.

One such group of techniques is aimed at maintenance of cardiovascular adaptability:

(a) Intermittent positive pressure breathing.

(b) Periodic venous occlusion.

(c) Automatic conditioning.

Another device which appears promising is a whole body longitudinal vibrator to provide some measure of cardiovascular conditioning as well as musculoskeletal.

The potential of these various considerations remains to be established by ground based deconditioning studies. It may be that a deorbit counterpressure device used to compensate for anticipated deterioration of countergravity cardiovascular mechanisms may be effective and reliable enough to permit extended flight with no special cardiovascular maintenance techniques.

b. Test Support Equipment Required

(1) Spacecraft

(a) Negative pressure source capable of periodically reducing the pressure in a lower body rigid shell device for time durations of from 2-20 minutes. Optimum amount of negative pressure remains to be determined but expected to be minimal.

(b) Positive pressure source capable of periodically pressurizing various components of astronaut support equipment to pressure ranges of 10-60 mm Hg equivalent.

(c) A device for freeze-dehydrating urine and serum aliquots -- described in genitourinary and gastrointestinal sections.

(d) A technique and device for real time blood volume determination -- described in cardiovascular section.

(e) A device such as a centrifuge or microscope filter for separation of particulate constituents from body fluid samples.

(f) Power requirements are expected to be minimal and could be met by appropriate design of the exercise ergometer device to produce useful power.

(g) A positive pressure source for use during deorbit to pressurize astronaut support equipment. This requirement could be met by a small high pressure source carried out on the astronaut and possible integrated within his suit.

c. Test Procedure

(1) General: The tests involved in this astronaut support plan are designed to accomplish two intimately related goals. They can logically be classified into one group of tests designed to provide control of system deterioration and another group of tests designed to permit periodic evaluation of system deterioration. The first group consists of the muscle exercise device designed to maintain musculoskeletal effectiveness and the deorbit counterpressure device designed to compensate in part for possible cardiovascular deficiencies resulting from prolonged zero gravity exposure. The second group of tests include periodic muscle strength testing, vascular reactivity assessment, blood volume determinations, and collection of aliquots of serum and urine for later analysis. This group is designed to monitor the degree of system deconditioning, indicate adequacy of control measures, and permit valid predictions of astronaut deorbit stress tolerance and deorbit support requirements. The post flight analysis of serum and urine samples will further define adequacy of control measures and will provide additional information on tolerance of man for longer duration missions.

(2) Exercise: The exercise ergometer device will be operated on a programmed basis by both astronauts. The precise schedule remains to be established by ground based studies. Information from the Gemini and Apollo one and two-week missions will permit rational modifications of this test procedure. Particularly desirable would be an approach wherein only one astronaut would employ the exercise device, the other remaining as control. It remains to be determined if this can be done without compromising flight safety.

The ergometer will have been calibrated for a predetermined work rate so that to perform a programmed amount of work the astronaut need only to operate the device for a certain time period. Information available from ground based studies indicates that optimum work rates may be from 200 to 600 cal/hr with total work of from 100 to 200 cal/24 hrs. This approach to maintenance of musculoskeletal effectiveness has the flexibility to permit reprogramming of total work requirements at any time inflight in accordance with the results of periodic muscle strength testing.

It is probable that the exerciser will have to be operated at least once per 24 hours and possible twice, although the time periods and total time remain to be established.

(3) Deorbit Counterpressure: The counterpressure device will be inflated prior to deorbit as a prophylactic support measure based upon results from periodic assessment of cardiovascular responsiveness. It may also be feasible to initiate deorbit without counterpressure and pressurize only if necessary, in response to blood pressure, pulse rate and subjective evidence of inadequate venous return.

(4) Muscle Strength: For muscle strength measurements, the strength of preselected muscle groups will be assessed in a standardized manner on approximately a weekly basis using a dynamometer technique. Results will be read and recorded on tape. Existing methods for this type of testing are not suitable for operational use except for limited muscle groups. The device to be developed for MOL will be lightweight and small in size, will have minimal power requirement, and will permit rapid and reliable testing.

(5) Flack: The calibrated Flack test will be administered approximately weekly. This test is usually performed by holding the equivalent of 40 mm Hg pressure at expiratory apnea for a given number of seconds. It is suggested that lower pressures be used earlier in the mission until response profiles have been estalished and that the standard Flack be preceded by a preliminary "minimal Flack" at each test session. During each test blood pressure and heart rate will be recorded on tape.

(6) Venous Occlusion: The calibrated venous occlusion test will also be administered at approximately weekly intervals. It will consist of the astronaut applying to himself quick-don extremity or abdominal tourniquets and inflating them to a pressure equivalent of approximately 60 mm Hg for a programmed period of time. During this time blood pressure and heart rate will be recorded on tape.

(7) Negative Pressure: To test the response to negative pressure applied to the lower half of the body the astronaut will insert himself into the device which has been integrated into the "rest and test" area and may be doubling as a sleeping facility.[5] He will pressurize a waist seal which will permit calibrated

negative pressure to be applied to the lower half of his body for a programmed period of time. During this time blood pressure and heart rate will be recorded on tape. Evidence available from ground based studies indicate that this technique may be of much more effective cardiovascular stress test than the calibrated Flack and venous occlusion and may replace them.

(8) Venomotor Tone: Technique for venomotor tone remains to be determined.

(9) Others: The testing procedures for the remaining items (blood volume, cardiac output, blood pressure and heart rate response to calibrated work and serum and urine aliquot collection) is as described in cardiovascular, gastrointestinal and genitourinary sections.

(10) Sequence: The suggested testing sequence for those tests designed to periodically assess degree of system deconditioning is as follows:

(a) Blood volume determination (serum aliquot).

(b) Muscle strength testing.

(c) Calibrated exercise.

(d) Cardiac output.

(e) Venomotor tone.

(f) Flack.

(g) Venous occlusion.

(h) Negative pressure.

d. Category of Experiment

(1) Category a: The muscle exercise device appears to warrant this classification because it is a primary inflight astronaut support item and because it may involve elaborate equipment requirements. If adequate astronaut support for zero gravity deconditioning for 30-day MOL cannot be provided by such devices, artificial gravity appears to be the only remaining solution for support of man in this environment.

(2) Category b:

(a) Deorbit counterpressure garment.

(b) Muscle strength testing.

(c) Blood volume.

(d) Tests of cardiovascular responsiveness.

(e) Urine and serum aliquots.

e. Cost

It is expected that the development of the devices, procedures, and equipment required for this area can be met by in-house facilities and personnel.

f. Schedule

Development of an operationally suitable muscle exercise device has already been started. Validated design criteria and exercise regimens should be available June 1965.

A method for measuring the strength of selected muscle groups should be available by June 1965..

The deorbit counterpressure device is essentially optimization of an on-the-shelf item, the standard G-suit, and should be available as a separate item by March 1965 and as a pressure suit integrated item (if desired) by January 1966.

Techniques for assessment of cardiovascular responsiveness require minor modifications of existing equipment and procedures for the most part, and with the exception of venomotor tone measurement should be available by June 1965. An indirect simple and reliable venomotor tone technique should be available by June 1966.

IV. Participating Government Agencies:

Sponsor: Duane E. Graveline, Captain, USAF, MC, Aerospace Medical Division, Brooks AFB, Texas.

V. Additional Requirements:

A. Special Security

At this time there appears to be no justification for a special security classification of either the equipment or procedures which have been discussed. It is assumed that medical findings, preflight, inflight, and postflight, will be afforded the usual treatment of such data and be restricted to the medical community.

B. Manning Description Summary

1. Astronaut

The following test items for control and evaluation of system deterioration will be designed for one man operation with this man serving both as subject and technician:

a. Muscle exercise device.

b. Deorbit counterpressure.

c. Muscle strength testing.

d. Urine aliquot preparation.

e. Cardiovascular response to calibrated exercise.

f. Cardiovascular response to calibrated Flack.

g. Cardiovascular response to calibrated venous occisuion.

h. Cardiovascular response to calibrated lower body negative pressure.

The following test items will involve both astronauts, one as a subject and the other as technician:

a. Blood volume determination.

b. Serum aliquot preparation.

c. Venomotor tone testing.

d. Cardiac output determination during calibrated exercise.

The level of technical competence required of the astronaut for effective performance of the various test items discussed for this area should be easily within his capability with a minimum of training. The configuration and procedures of all test items will be optimized for operational use.

2. Ground Personnel

There are no foreseeable requirements for ground personnel to participate directly in the test items described for this area.

C. Logistics

Described in Annex (Approach to Ground Based R&D).

D. Facilities

Described in Annex (Approach to Ground Based R&D).

E. Simulation and Training

Described in Annex (Approach to Ground Test Simulation and Training).

VI. General

A. Reference Specific Attachments

1. Design Characteristics Test Equipment

For each test item in this astronaut support program the approximate equipment configuration, weight, volume and power requirements have been indicated under 7 a, b, and c. Addditional more definitive information is not available at this writing. Total heat output from the muscle exerciser may range 50-200 cal/24 hrs. and will come during the once or twice daily programmed exercise periods. The exercise ergometer will be mounted in the astronaut "rest and test" area as described in 7 a. The design configuration of this area remains to be established but will have special mounting requirements. Other items mentioned in the guidelines set down for this area are either not applicable or not definable at this time.

2. Test Support Equipment

Additional elaboration of support equipment requirements beyond that presented in 7 b is not possible at this time.

3. Test Operating Characteristics

An estimate of test duration, total number of test, test frequency and interval between test has been made in 7 a and c where appropriate. Other items referenced in the guidelines do not appear to be applicable at this state of planning.

4. Funding Summary

Ground based research and development requirement for the test experiments, procedures and equipment discussed in this section can be met with existing in-house personnel and facilities.

5. Manning Description

As described in V b. Further elaboration cannot be made validly at this time.

6. Communication and Data Handling

For all test items considered in this area of control and evaluation of system deterioration the information obtained from the various measurement techniques (i.e., muscle strength, blood volume, cardiovascular responsiveness) will be either read visually and recorded on tape or recorded directly on tape for subsequent fast playback during passage over selected stations.

7. Development Characteristics

Most of the items pertinent to this area have been discussed in 7 f and in Annex (Approach to Ground Based R&D).

B. Reference Annex VII, Study and Control of System Deterioration and Associated with MOL Mission.

SPACE RADIATION MEASUREMENTS OF SIGNIFICANCE TO MAN

I. Test Objectives:

The objectives of the radiation environment measurements or studies are to

A. Provide the necessary instrumentation for monitoring the intra- and extravehicular radiation environment of the MOL,

B. Update existing space radiation maps, at low orbital altitudes,

C. Validate or update computer programs and to provide more accurate predictions for future flights, and to

D. Establish inflight biological values which may be used as "biodosimeters" or indices or radiation dose in the event of accidental exposure.

II. Importance of the Test:

A. The test program is needed because:

1. For many years investigators have been active in studying the basic mechanisms of action of ionizing radiation as it interacts with biological tissue. From these studies, measurements have evolved which are relatively dose-dependent (biodosimeters). Although not entirely satisfactory, because of individual and even time-of-day variability, and because these same biological values may also be influenced by disease processes, they are accepted as valuable tools in diagnosis, prognosis, and therapy.

Now we are faced with the possibility that many of these biological values may change as the astronauts are subjected to conditions of weightlessness, altered atmospheric conditions, etc., encountered on a space mission. It is therefore necessary to a) establish new inflight values, b) test the validity of using "biodosimeters" as indices of radiation exposure, and c) provide biological endpoints for estimating radiation dose in case of accidental exposure to a solar flare, although it is anticipated that the radiation doses encountered in the MOL flights will be below the threshold of detection by current biological techniques

2. Evaluation of the radiation environment as related to the vehicluar configuration (crew compartments) and possible launch configurations including a 30-day launch from either the AMR or PMR, with and without unfriendly action (detonation of a high-altitude nuclear device) during flight, resulted in the formulation of the following basic physical dosimetry requirements: a) determination of dose, dose rate, etc., for extravehicular space (dosimetry of free space); b) determination of dose, dose rate, etc., in selected crew compartments or positions; and c) selected personnel dosimetry in space operations.

B. This test package must be included in the MOL program to provide crew safety and more accurate predictions of radiation environments for future space operations.

III. Description of the Experiment.

Studies designed for inclusion in the on-board MOL program fall into two general categories: 1) Biological and 2) Physical Dosimetry.

Requirements for biological observations will be minimal and consistent with a policy of establishing base-line data from which radiation damage may be assessed in the event of accidental exposure. Ground-bases support studies will be continued to study the basic mechanisms of action of ionizing radiation and to develop techniques for the detection and quantitation of doses below 25 to 50 rads.

Physical dosimeters will be provided in adequate numbers, types and location aboard the MOL to accomplish the objectives outlined in I above. Consideration is being given to a dosimetry package of minimal weight, volume, and astronaut time required for operation. It is anticipated or hoped that dosimetry measurements can continue to be made and telemetered to ground stations after completion of the programmed 30-day flights.

A. Configuration of Test Items:

1. Biological Observations: To be determined. It is assumed that these requirements will be consolidated with those of other test areas and that the data will be made available as required.

2. Physical Dosimetry:

a. Spectrometric Devices (Unmanned): (See atch 2)

(1) Two (2) Plastinauts instrumented with tissue equivalent ion chambers; one located in the living quarters and one in the laboratory compartment.

(2) Tissue equivalent ion chambers, and LET (Linear Energy Transfer) spectrometers, giving surface, 5 cm., and 10 cm. dose and LET spectrum; located in the laboratory and unpressured compartments.

(3) Externally mounted omni- and unidirectional proton, alpha, electron and heavy nuclei spectrometers located in the unpressurized compartment.

(4) Internally mounted omnidirectional proton and neutron spectrometer located in the laboratory compartment.

b. Spectrometric and Monitoring Devices (Manned): (See atch 3)

(1) Portable tissue equivalent ion chamber (TEIC); high level for emergency; visual readout; located in Gemini.

(2) Portable TEIC: low and high level; visual read-out; located in living quarters; to be operated continuously.

(3) Omni-directional proton, and electron, spectrometer; portable; adjustable; located in laboratory compartment.

(4) Portable TEIC, low level, visual read-out; to be operated continuously; located in laboratory compartment.

(5) Fixed TEIC: high resolution; in-flight calibration; located in laboratory compartment.

(6) LET spectrometer; located in laboratory compartment.

(7) Shields for depth-dose measurements. (for use with TEIC and LET Spectrometers).

(8) Fixed TEIC: shielded to provide inside space-suit dose rate; located in unpressurized compartment.

(9) Omni-directional proton, electron and alpha spectrometers for external environment measures; located in unpressurized compartment.

(10) Cosmic ray emulsions; to be sensitized and extended from the MOL.

c. Passive Dosimeters (Manned Flights):

(1) Personnel dosimeters: Up to five (5) packs in the space suit of each astronaut (film, thermoluminescent dosimeters, etc.) Locations to be determined. Doses received by each astronaut should be recorded accurately and become a permanent part of his medical record.

(2) Dosimeter packages or units: Five units each to contain pocket chambers, film, thermoluminescent dosimeters, glass rods, foils, etc. One unit to be located in the Gemini vehicle, and two each in the living quarters and laboratory compartment respectively.

B. Test Support Equipment Required:

1. Biological Observations: To be determined.

2. Physical Dosimetry:

a. Spectrometric Devices (Unmanned): Will require approximately 0.6 watt continuously, 5.6 watts intermittently.

b. Spectrometric and Monitoring Devices (Manned):

(1) Equipment listed in III. A.2.b. will require approximately 0.6 watt continuously and 6 watts intermittently.

(2) Tape recorder, telemetry, and voice communications required. Voice requirements will be minimal except in unanticipated emergency conditions (Occurrence of a solar flare or unfriendly action) or upon request after passage through the Cape Town anomaly.

c. Passive Dosimeters: No power requirement. Voice communication for reporting pocket chamber readings following extravehicular operations.

AGE

1. Biological Observations: N/A

2. Physical Dosimetry

a. Spectrometric Devices (Unmanned): Telemetry and power check only.

b. Spectrometric and Monitoring Devices (Manned): Telemetry and power check only. Cosmic ray emulsions must be sensitized, extended from the MOL for a pre-determined time and returned.

c. Passive Dosimeters: N/A

C. Test Procedure

1. Biological Observations: To be determined. A tentative list of requirements are listed below.

a. Hematocrit: *L-14 and L-7; bi-weekly during flight; upon return and as indicated thereafter. Use micropipette technique and small clinical centrifuge.

* L = Day of Launch

b. Blood Volume: Determinations on L-7 at weekly intervals during flight and upon return. Technique to be determined.

c. Reticulocyte and platelet counts: Determination on L-7 and L-1, and at weekly intervals during flight, assuming that insignificant radiation levels are encountered. Slides can be prepared and returned for evaluation. If high dose levels are measured, then determinations will be performed as directed by the ground monitoring station. If methods are available or can be developed for WBC determinations, counts should be performed at weekly intervals during flight, or as required, since this is one of the most sensitive indicators of radiation exposure.

d. Differential Counts: Preflight determinations will be made on L-7 and L-1. Slides can be prepared at weekly intervals during flight and returned for staining and evaluation. Post-flight determinations to be made upon return and as indicated thereafter.

e. Serum Electrolytes: Determinations at L-7 and L-1. Serum samples to be collected at weekly intervals and stored for analysis upon return.

f. Additional tests on serum and urine samples returned to ground laboratories are being considered.

2. Physical Dosimetry:

a. Spectrometric Devices (Unmanned): Data readout would be accomplished at specified intervals which are to be determined.

b. Spectrometric and Monitoring Devices (Manned): The majority of data obtained will be taped and transmitted without reference to the man. On a few orbits passing through the magnetic anomaly and during a solar flare the astronauts would be requested to move the portable spectrometry and dosimetry package to various preassigned positions within the space craft, and read out variations in cabin intensities. A series of dose rate measurements and LET spectral measurements through different thicknesses and kinds of shields would be requested as part of the experiment. During extravehicular operation the astronaut might be asked to relay dose rate information from an easily read portable dosimetric device.

c. Passive Dosimeters:

No single passive dosimeter, currently available, can adequately record the total radiation dose from the many types of particles and energy spectra encountered in space. Various types of dosimeters, having definite physical characteristics, will have to be calibrated against known ground sources--cyclotrons, x-ray units, etc.--and incorporated into a package to cover the radiations and energies expected. Any advances in the state-of-the art will be included in this package. Ideally, a pocket dosimeter capable of distinguishing between doses of protons, electrons, and electro-magnetic radiations would be desirable.

D. Category of Experiments: The tests outlined above fall within Category b.

E. Cost:

1. Biological Observations: To be determined.

2. Physical Dosimetry:

a. Spectrometric Devices (Unmanned): Approximately 830K Does not include integration costs, backup packages, or spare parts. (See atch 2 - Funding Summary)

b. Spectrometric and Monitoring Devices (Manned): Approximately 762K. Does not include integration costs, backup packages or spare parts. (See Atch 3 - Funding Summary)

c. Passive Dosimeters: To be determined

F. Schedule:

1. Biological Observations: To be determined.

2. Physical Dosimetry:

a. Spectrometric Devices (Unmanned): Items except neutron spectrometer are developed and flight worthy. The neutron spectrometer should be ready by July 1965.

b. Spectrometric and Monitoring Devices (Manned): Same as F.2.a.

c. Passive Dosimeters: As stated previously, many types of passive dosimeters are available but none is completely inadequate for space flights. A calibrated package containing the best available dosimeters should be ready by July 1965. Advances in the state-of-the-art will be incorporated as more reliable dosimeters become available.

IV. Participating Government Agencies:

A. Sponsor:

1. Biological Observations: AMD

2. Physical Dosimetry:

a. Spectrometric Devices (Unmanned): AMD

b. Spectrometric and Monitoring Devices (Manned): AMD

c. Passive Dosimeters: AMD

B. Test Equipment Acquisition:

1. Biological Observations: To be determined

2. Physical Dosimetry:

a. Spectrometric Devices (Unmanned): Air Force Weapons Laboratory.

b. Spectrometric and Monitoring Devices (Manned): Air Force Weapons Laboratory.

c. Passive Dosimetry: SAM and AFWL

V. Additional Requirements

A. Special Security: None

B. Manning Description Summary:

1. Biological Observations: Astronauts to alternate as subject and as testor.

2. Physical Dosimetry:

a. Spectrometric Devices (Unmanned): N/A

b. Spectrometric and Monitoring Devices (Manned): One man required ten minutes per orbit for 3 orbits/day at beginning of flight, with periodic check at 5 day intervals thereafter (unless more frequent checks are required by the ground station in the event of a solar flare) (See Atch 3) Specific details to be determined.

c. Passive Dosimeters: Prior to extravehicular operations pocket dosimeters must be set to "zero" and read upon completion of the extravehicular mission. This information should then be passed to the ground station via radio as soon as possible. During extravehicular operations, the astronaut remaining aboard the MOL should monitor the read-out of the external radiation environment spectrometer for necessary action in case of an emergency situation. The only additional requirement would be to recover five (5) dosimeter packages (two in the living quarters and the laboratory compartment, respectively and one in the Gemini capsule) near the end of the flight and return to the ground laboratory.

C. Logistics:

1. Biological Observations:

a. Manpower: 3 MY required during FY65.

b. Hardware Development: Off-the-shelf items with minor modifications.

c. Operation: N/A

d. Additional Support: None

2. Physical Dosimetry:

	CY 64	CY 65	CY 66	TOTAL
a. Manpower*	25 MY	24 MY	20.5MY	69.5MY
b. Hardware Dev.	0	0	0	0
c. Installation	0	1.0MY	4.5MY	5.5MY
d. Operation	0	0	0	0
e. Additional support	0	0	0	0
TOTAL	25MY	25MY	25 MY	75 MY

*Manpower figures furnished are AFWL scientists and technicians now directly engaged in space radiation and biophysics studies in support of Air Force requirements who could be diverted to this task. Will include ground support and associated sattelite programs.

f. Passive Dosimeters:

(1) Manpower: Two-man-years FY 65

(2) Hardware Development: Off-the-shelf items, with modifications to incorporate advances in state-of-the art.

(3) Installation: N/A

(4) Operation: N/A

(5) Additional Support: N/A

D. Facilities: No additional special facilities required.

E. Simulation and Training

1. Biological Observations:

a. Astronaut: Must be able to perform certain biological tests, which are to be determined, at a technician level. Training for this task will be incorporated with those of other test areas in the Biomedical Experiment.

b. Ground Personnel: None required.

c. Training Equipment: Equipment will be the same as planned or developed for MOL flights.

2. Physical Dosimetry:

a. Spectrometric Devices (Unmanned): N/A

b. Spectrometric and Monitoring Devices (Manned):

(1) Astronaut: No special skills or knowledge required not expected to be possessed by the typical astronaut. Technician level training is adequate. Simulation test run would be desirable. Check-out of instrumentation operation would require about one to two days for indoctrination.

(2) Ground Personnel: One or two highly skilled professional persons would be used to relay specific instructions during solar flare active periods or during magnetic anomoly experiments. These would be provided by the laboratory performing the experiment.

(3) Training equipment would consist of prototype models of scientific instruments and data display panel.

c. Passive Dosimeters:

(1) Astronaut: One to two manhours training required for reading and repair of dosimeters.

(2) Ground Personnel: None

(3) Equipment: Training to be accomplished through the use of equipment that will be used on MOL.

VI. General:

A. Biological Observations:

1. Communications and Data Handling Requirement: Lab note book and voice. (Data to be reported upon completion of required laboratory tests).

2. Development characteristics: N/A

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B. Physical Dosimetry

1. Spectrometric Devices (Unmanned):

a. Communication and Data Handling Requirements: Telemetering of data stored on magnetic tape would be required. (See Atch 2)

b. Development Characteristics: (See Atch 2)

2. Spectrometric and Monitoring Devices (Manned):

Communications and Data Handling Requirements: Telemetering of data stored on tape would be required. Some voice communication might be required on occasion. (See Atch 3)

Cosmic ray emulsions should be returned to the ground laboratory for evaluation only.

3. Passive Dosimeters:

a. Communications and Data Handling Requirement: Voice contact with ground station following completion of extravehicular operation. Return five dosimeter packages to ground at end of mission.

b. Development Characteristics: N/A

Atch 1 - BIOLOGICAL MEASUREMENTS

Design Characteristics Test Equipment -- To be supplied

Atch 2 - SPECTROMETRIC DEVICES (UNMANNED)

Test Support Equipment -- To be supplied

Atch 3 - SPECTROMETRIC DEVICES (MANNED)

Test Operating Characteristics -- To be supplied

Funding Summary -- N/A

Manning Description -- See V. b. and c.

Communications and Data Handling -- N/A

Development Characteristics -- Off the shelf

Atch 4 - GROUND-BASED EXPERIMENTS

Atch 5 - BACKGROUND INFORMATION ON THE SPACE RADIATION ENVIRONMENT ON THE BIOLOGICAL EFFECTS OF IONIZING RADIATION.

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ATTACHMENT 1

BIOLOGICAL MEASUREMENTS

a. Hematocrit: *L-14 and L-7; bi-weekly during flight; upon return and as indicated thereafter. Use micropipette technique and small clinical centrifuge.

b. Blood Volume: Determinations on L-7 at weekly intervals during flight and upon return. Technique to be determined.

c. Reticulocyte and platelet counts: Determination on L-7 and L-1, and at weekly intervals during flight, assuming that insignificant radiation levels are encountered. Slides can be prepared and returned for evaluation. If high dose levels are measured, then determinations will be performed as directed by the ground monitoring station. If methods are available or can be developed for WBC determinations, counts should be performed at weekly intervals during flight, or as required, since this is one of the most sensitive indicators of radiation exposure.

d. Differential Counts: Preflight determinations will be made on L-7 and L-1. Slides can be prepared at weekly intervals during flight and returned for staining and evaluation. Post-flight determinations to be made upon return and as indicated thereafter.

e. Serum Electrolytes: Determinations at L-7 and L-1. Serum samples to be collected at weekly intervals and stored for analysis upon return.

f. Additional tests on serum and urine samples returned to ground laboratories are being considered.

* L = Day of Launch

ATTACHMENT 2 Exp No. P-12

SPECTROMETRIC AND DOSE MEASURING DEVICES (UNMANNED FLIGHTS)

Location	Instrument	Weight (lbs)	Volume (ft.^{3})	Power (watts)	T.M. Points
Gemini	1. Tissue of equivalent ion chamber; low and high level	2.5	0.06	0.3	4
Living Quarters	2. TEIC, low and high level	2.5	0.06	0.3	4.
	3. Instrumented Tissue Equivalent Manikin	150.00	12.00	2.5	80
Laboratory	4. Omni-directional spectrometer; protons 10-200 Mev. electrons 0.5-2 Mev. neutrons-(thermal and fast)	4.5	0.10	1.5	12
	5. Fixed TEIC, high resolution	2.5	0.06	0.4	6
	6. LET Spectrometer	6.0	0.15	1.5	64
	7. Instrumented Tissue Equivalent Manikin	150.00	12.0	2.5	80
Unpressurized Compartment	8. Fixed TEIC, inside space suit dose-rate	2.5	0.06	0.4	4
	9. Omni-directional spectrometer. Protons 50-250 Mev; electrons 0.5-5 Mev and alphas	6.0	0.20	1.5	15
	10. Unidirectional charged particle spectrometer (Philco) (protons, electrons, alphas, and heavy nuclei	15.0	0.20	8.0	25
		341.5	24.89	18.9	294.

Equipment should operate 30 minutes per orbit for 3-6 orbits per day (1 1/2 - 3 hours total operating time per day)

ATTACHMENT 3

Exp No. P-12

SPECTROMETRIC AND DOSE MEASURING DEVICES (MANNED)

Location	Instrument	Weight (lbs)	Volume (ft^3)	Power (watts)	T.M. Points
Gemini	1. Portable TEIC*, high level for emergency. Visual read-out	2.5	0.06	0.3	3
Living Quarters	2. Portable TEIC, low and high level. Visual read-out	2.5	0.06	0.3	4
Laboratory	3. Omnidirectional Spectrometer. Protons 10-200 Mev; electrons 0.5-2 Mev	4.5	0.10	1.5	12
	4. TEIC, low level, high resolution, visual read-out. Portable option	2.5	0.06	0.3	4
	5. LET Spectrometer	6.0	0.15	1.5	64
	6. Shields for depth-dose measurements (TEIC and LET)	4.0	0.10	----	----
Unpressurized Compartment	7. Fixed TEIC-inside space suit dose-rate	2.5	0.06	0.4	4
	8. Omni-directional Spectrometer. Protons 50-250 Mev, electrons 0.5-5 Mev and alphas	6.0	0.20	1.5	15
Passive Dosimeters	1. High-level pocket chamber in Gemini 2. Personnel Dosimeters (up to 5 packs in space suit of each astronaut) 3. Dosimeter packages 1 in Gemini 2 in Living quarters 2 in Laboratory 5 at 0.2 lb	1.0	0.03	none	none
	Cosmic ray emulsions	10.0	0.20	none	none
		41.5	1.02	5.8	106.

* Tissue Equivalent Ion Chamber

Note: Only instruments Nos. 2 and 4 will be operated continuously, requiring 0.6 watt continuously, and 5.8 watts intermittently (1 1/2-3 hrs. per day)

ATTACHMENT 4

GROUND-BASED RADIATION EXPERIMENTS IN SUPPORT OF MOL

The ground or laboratory studies, outlined below, basically reflect on-going and/or planned investigations at the Air Force Weapons Laboratory, Kirtland, N.M., and the School of Aerospace Medicine, Brooks Air Force Base, Texas. It is anticipated that "inputs" or proposals from other DOD and NASA laboratories, will be considered along with the ones listed in this report and that the ground support studies will be revised to obtain a maximum amount of information for support of the MOL.

A. Experiments Needed (includes those in progress and/or required in support of MOL):

1. Biological

a. Proton Focal-Eye Studies:

The eyes of primates (Macaca mulatta) have been exposed to doses of radiation between 125 to 2000 rads of 14, 40, 185 and 730 Mev protons to determine the approximate threshold dose required to produce iridocyclitis, erythema, epilation, keratitis, desquamation, and cataracts. Animals are still being observed. Data accrued from this study should be of value in determining the critical or maximum permissable radiation dose to the eyes. This work has been partially funded by both the AF and NASA.

b. Proton Whole-Body Studies:

Groups of primates (Macaca mulatta) will be exposed to whole-body protons in the energy range between 14 and 730 Mev at cyclotron facilities in the United States and Europe. In addition to clinical and hematological observations and determination of the LD 50/30 Dose, depth-dose measurements will be made in a tissue equivalent phantom and correlated with pathological changes in the various organ systems. These data additionally will provide information on a depth-dose vs biological effects prediction model and can hopefully be used in the computer program for extrapolation of animal data to man. This work is also partially funded by the Air Force and NASA.

Studies are also being conducted by Dr. Cornelius A. Tobias, Univ. of California, in cooperation with NASA, utilizing a mixed proton energy spectrum, in contrast to studies planned by SAM in which monoenergetic energies will be used. In the latter, average energies which might be associated with solar flare activity are being simulated. Data from both studies will be complimentary.

c. Chromosome Abberations:

Studies are presently underway at the School of Aerospace Medicine, through an in-house and contractual effort, to study chromosomal changes in the peripheral blood and skin resulting from exposure to ionizing radiation. This work should provide information, not only on the mechanisms of action of radiation, but hopefully chromosomal abberations can be quantitated to provide a tool or "bio-dosimeter" for estimating dose in the event that an individual is exposed. Funds for this research are provided by the Air Force.

d. Altitude Chamber Studies:

Details concerning research in this area have not been determined, however, it is felt that the radio-sensitivity of laboratory animals should be tested as a function of time and atmospheric conditions expected in the MOL. Data from these studies also would serve to delineate any influence that other variables, such as weightlessness, might exert on the sensitivity of crew members to radiation in the event of exposure. Funding of this research to be determined.

e. Prophylaxis and Theraphy:

Laboratory studies in this area, although not specifically planned for the MOL program, could have a direct influence on the health and welfare of the crew in case of exposure to unanticipated high levels of radiation. Results, despite the man years of effort and the large sums of money expended, are still grossly inadequate. Much has been learned, but no tested radioprotectants are available for use in man. Investigations are continuing in many laboratories, using various chemical agents and transfused homologous and antologous bone marrow cells. Results of studies will be followed. Any major "break-through" in the state-of-the-art will be proposed for inclusion in the MOL program for emergency use.

2. Physical Dosimetry:

a. Spectrometric and Dose Measuring Devices:

Instruments will be calibrated with known radiation types, intensities, energies, etc., on the ground and flown aboard as many satellites (Programs 631A, 431, 162, and Saturn 10) as possible prior to the

MOL. This is an Air Force funded project.

b. Passive Dosimeters:

Many passive dosimetry devices are now available, however, as already mentioned, none are completely satisfactory in a space radiation environment. Ground studies are needed to select, calibrate, and assemble the best available dosimetry package from existing devices and to take advantage of any new or more efficient dosimeters which may be developed prior to MOL. Funding to be determined.

c. Computer Program:

Ground support for the MOL in the computer program will be to provide estimated doses, dose rates, etc., of radiation expected in the MOL flight profile. Information gained from other programmed flights (see 2.a. above) will provide data which will make the space radiation map more complete and further increase the reliability of predictions by the computer systems.

B. Schedule:

1. Biological Studies:

a. Proton Focal-Eye:

All animals in this study have been irradiated and are now 2 to 3 years post-exposure. It is anticipated that observations will be completed during FY64 and a final report written by early FY65.

b. Proton Whole-Body:

The exposure of animals in this study is scheduled to start in March, 1964. All exposures should be completed during FY65 or during the first half of FY66.

c. Chromosomal Abberations:

Studies are now in progress to investigate chromosomal abberations in the peripheral blood. Cells are being typed and an attempt being made to correlate observed changes with radiation dose. An additional study of the effects of radiation on the skin and corresponding chromosomal abberations is to be started in the near future. Data from this study should be available during the first quarter of FY66.

d. Altitude Chamber Studies:

The experimental design of studies in this area have not been determined. Both design and schedule will be determined in the near future.

c. Prophylaxis and Therapy:

No specific experimentation is planned for the MOL Program. Any major "break-through" in this area will be proposed for inclusion in the MOL Program as emergency procedures.

2. Physical Dosimetry

a. Spectrometric and Dose Measuring Devices:

All spectrometric devices will be available for flight during FY65.

b. Passive Dosimeters:

Selection and calibration of passive dosimeters will be a continuing process to take advantage of new and more efficient dosimeters which might become available.

c. Computer Program:

Already in existence at the Air Force Weapons Laboratory, Kirtland AFB, N. M. (Boeing) and at the Aerospace Medical Research Laboratory, Wright-Patterson AFB, Ohio (Northrup).

C. Where and How to be Accomplished and Contact.

1. Biological Studies:

a. Proton Focal Eye:

(1) School of Aerospace Medicine (SAM), Brooks AFB, Tex.

(2) In-House

(3) Lt. Col. Edwin R. Ballinger (SAM)

b. Proton Whole-Body:

(1) To be accomplished at the School of Aerospace Medicine as a cooperative effort with various cyclotron facilities in the United States and Europe.

(2) In-House and Contract

(3) Lt. Col. Edwin R. Ballinger (SAM)

c. Chromosomal Abberations:

(1) School of Aerospace Medicine

(2) In-House and Contract

(3) Dr. John Prince (SAM)

d. Altitude Chamber Studies:

(1) School of Aerospace Medicine. Additional inputs or proposals by other laboratories are suggested.

(2) SAM In-House and probably other laboratories not yet determined.

(3) Lt. Col. Edwin Ballinger (SAM)

e. Prophylaxis and Therapy:

This is a continuing program at the School of Aerospace Medicine with both in-house and contractual work being performed. Other DOD laboratories, universities, and private firms are also actively engaged in this research area.

The contact in this area is Capt. George Melville, SAM.

2. Physical Dosimetry:

a. Spectrometric and Dose Measuring Devices:

(1) Air Force Weapons Laboratory (AFWL), Kirtland AFB, N.M.

(2) In-House and contract

(3) Col. Irving Russell (AFWL)

b. Passive Dosimeters:

Responsibility for the selection, calibration, and packaging of the most efficient passive dosimetry package available is to be determined.

c. Computer Programs

(1) Air Force Weapons Laboratory, Kirtland AFB, N.M. Aerospace Medical Research Laboratory, Wright-Patterson AFB, Ohio

(2) In-House and Contract

AFWL - Boeing

AMRL - Northrop

(3) Col. Irving Russell (AFWL)

Lt. Col. Evan Coltra (AMRL)

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ATTACHMENT 5

BACKGROUND INFORMATION ON THE SPACE RADITION ENVIRONMENT ON THE BIOLOGICAL EFFECTS OF IONIZING RADIATION

Attachment 5 is currently being revised and will be distributed when completed.

ATTACHMENT 5

Exp No. P-12

BACKGROUND INFORMATION ON THE SPACE RADIATION ENVIRONMENT AND THE BIOLOGICAL EFFECTS OF IONIZING RADIATION

The purpose of this section of the experimental package is to provide additional information to support the radiation research or test requirements aboard the MOL.

I. Space Radiation Environment:

One of the areas of medical concern in a manned space flight is the radiation which might be encountered. A tremendous effort has gone into the mapping of this radiation environment through the use of dosimetric equipment aboard various space probes and/or satellites. The principal sources of radiation can be listed as (1) galactic cosmic radiation, (2) geomagnetically trapped corpuscular radiation, (3) solar flares, and (4) artifically injected fission products from high altitude nuclear detonations.

The galactic cosmic radiations mainly originate outside of the solar system and consist of atomic nuclei accelerated to very high velocities. Atomic nuclei of all elements in the periodic chart up to iron have been observed in these radiations (1).

The presence of trapped radiation particles in the earth's geomagnetic field were first discovered in 1958 by Van Allen (6) by means of equipment flown in U.S. Satellites Explorer I and II. These belts of trapped particles, known as the Van Allen Belts, and for descriptive purposes consist of two annular-or donut-shaped zones of radiation in the equatorial regions--the inner and outer belts--described by Van Allen as follows: "The inner zone of geomagnetically trapped particles occupies an annular region encircling the earth and lying approximately between altitudes 600 and 7,000 km and between latitudes 40°N and 40°S. The radiation comprises a sufficient intensity of protons of energies of the order of 100 Mev as to make effective shielding technically impractical for prolonged missions in this region (i.e., ones of more than a few hours duration). Beyond this region the earth is encircled by a second or outer radiation zone of much greater spatial dimensions, the maximum intensity of which occurs at a radial distance of about 3.6 earth radii (23,000 km) from the center of the earth." The radiation in this belt is primarily composed of electrons of energies up to a few hundred kev. X-rays (bremsstrahlung) will be produced when these electrons are stopped in the wall of the space ship, the magnitude of which will depend upon the weight, composition and design of the shield (1). The regions within these boundaries are not regular or even steady. It has been proposed that the major discontinuities in the outer radiation belt is the result of the Cape Town anomaly in the geomagnetic field. In the general area of Cape Town, Union of South Africa, the earth's magnetic field has a minimum value (7). In this region, relatively high intensities of electrons are found is close to the earth's atmosphere, creating a radiation hazard.

Solar flare radiations are related to sun-spot activity and number. Flare activity is a cyclic phenomenon, with the average cycle lasting an average of 11.2 years. Maximum activity in the current cycle is expected during the period 1968-1969. Typically in these solar events, the arrival of particles (principally protons) at the earth comes from about one to five hours after the optical flare is first observed (7). The duration of a solar flare may be on the order of a few hours to several days. At present it is impossible to predict the occurrence of a flare by more than a few minutes in advance (5); however, various methods are being investigated to give more accurate predictions in future operations.

Artifically injected fission particles from high altitude nuclear detonations is another source of radiation hazard in the space environment. It is estimated that a one megaton explosion at an altitude of 200 miles would cause an immense perturbation of the geomagnetic field to a distance of almost 700 miles from the point of detonation (5). The lifetime of the artifically injected particles seems to be on the order of months or years.

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II. Biological Dose vs. Effects

No attempt will be made to discuss the broad field of radiation biology, however, certain biological effects which could interfere with or seriously influence the outcome of the MOL mission will be discussed briefly.

Many factors influence the response of mammals to ionizing radiation, e.g., age, weight, sex, species (even individual within a species), type and energy of the radiation, dose rate, total dose, radiosensitivity of tissues exposed, and the exposure pattern - the latter referring to whole-body vs. partial-body exposure and to single exposure, fractionated, and/or low-level continuous irradiation.

Data from human radiation exposure cases, e.g., reactor accidents, Hiroshima and Nagasaki, cancer therapy, etc., have been studied in detail and documented; however, data are still insufficient to allow more than estimates of the dose required to produce certain biological responses. Results of animal studies serve as valuable guidelines in dose-effect predictions, however, extrapolation to man must be made with caution.

For purposes of this report only the acute radiation effects, i.e., clinical manifestations which might possibly interfere with the successful accomplishment of the MOL mission, will be discussed. It should be stressed, however, that certain effects may not be observed for months or even years. These long-term or latent effects may include but are not limited to life-span shortening, genetic effects, increased incidence of tumors (including leukemia), sterility, and cataracts. It is evident that certain risks are involved; however, with the doses or radiation predicted for the MOL flight profile, these risks in all probability are less than other risks associated with the mission.

A maximum of 10 m rad/hr or a total of 7.2 rad for a 30 day mission is predicted for the MOL flight profile by the Air Force Weapons Laboratory, Kirtland Air Firce Base, N. M. (4). Doses of radiation in this range are below the threshold of detection by current biomedical techniques and should produce no clinical signs and/or symptoms which would interfere with man's function in space. Except for the occurrence of a relativistic solar flare or the detonation of a high-altitude nuclear weapon during flight, no major problems are anticipated. Monitoring of the radiation environment by means of physical detectors is a requirement, regardless of the predicted dose, to assure safety for the crew.

In regard to the cosmic galactic radiations, the general consensus of opinion is in agreement with Langham (2) who states that "the expected infrequency of heavy cosmic ray interactions with vital areas of the body, dependence of their biological effect on volume of tissue affected, and the redundancy inherent in most body tissues and organs suggest that their potential hazard to manned space exploration is probably well within limits of an acceptable calculated risk."

Generally speaking, biological effects resulting from exposure to ionizing radiation may conveniently be divided into low, middle, and high dose responses. Dose estimates and discussions in the following paragraphs are based on whole-body x- or gamma radiations. Focal irradiation to the eye of the primate with 14, 39, 185, and 730 Mev protons indicate the RBE (relative biological effectiveness) for cataract formation, iridocyclitis, erythema, and epilation ranges between 1 and 2 when compared to Co 60. Preliminary whole body exposure of primates to 730 Mev protons yields on LD50/30 of 312 rad, suggesting an RBE of approximately 1.6. (6). Animal experimentation will be continued in an effort to relate particle type and energy, dose rate and dose to observed tissue effects.

Between zero and 100 r, single whole-body exposure, probably no clinical symptoms will be observed. A few minor hematological changes may be detected by laboratory techniques after exposure to doses of 25 to 50 r, however, as the radiation dose increases these changes are in general proportional to dose up to a point of maximum depression between approximately 600 and 800 r. Regeneration and recovery is expected in practically all persons exposed to doses below about 300 r. The minimum sickness dose (lethargy, nausea) of radiation in man has been estimated at 100 r to 225 r, when the dose is delivered at high dose rates. At low dose rates, the minimum sickness dose may be somewhat larger (1). The lower threshold doses, i.e., below approximately 150 r, may be influenced to a great extent by the individual's awareness that he has been subjected to radiation exposure. On a space mission, nausea and vomiting can result in serious consequences and is of little importance whether produced physchologically or from actual exposure. Glasstone's (1) discussion of the human response to acute whole-body ionizing radiation has been summarized (5) (Table I). In groups of persons exposed to approximately 100 r acute whole-body radiation, approximately 5 to 10% will show the same symptoms after exposure to 150, 200 and 300 r respectively.

Doses in the lethal range are not expected, however, for completeness a short discussion is included. The acute Ld 50/30 dose of x- or gamma radiation for man is not known but is variously estimated at from 300 to 700 r (1). Glasstone's estimate (table 1) is between 400 and 500 r. Approximately 450 r (delivered as a single dose) is a commonly accepted ID 50/30 dose. Beginning at about 300 r an occasional death may occur. The percentage of deaths increases as a function of dose, described by a sigmoid-curve, reaching 100% lethality at about 600 to 900 r.

Deaths in the dose range of about 300 to 600 r are commonly described as being caused by hematological damage and occur after a period of several weeks to months--depending upon dose. After exposure to doses of approximately 600 to 1500 r, the gastrointestinal form of death is evident. Deaths are relatively independent of dose and occur in about 1 to 2 weeks after exposure. After exposure to several thousand roentgens, central nervous system symptoms predominate and deaths are observed within hours to a few days, again depending upon dose.

III. Tolerance Limits

The following tolerance limits or criteria, based upon the rad as the unit of measurement, have been recommended by the Aerospace Medical Division:

A. Accumulated Whole-body exposure--

Total accumulated whole-body exposure to space radiation during a routine flight career should be limited to 150 rad, independent of dose rate and the manner in which the dose is reached.

B. Single Emergency Exposure--A single whole-body emergency exposure up to 250 rad can be permitted if the priority of the mission warrants it. This dose should be considered only in the event of a national emergency.

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Expected Effects of Acute Whole-Body Radiation Doses

Acute Dose (roentgens)	Probable Effect
0 to 50	No obvious effect, except possibly minor blood changes.
80 to 120	Vomiting and nausea for about 1 day in 5 to 10 percent of exposed personnel. Fatigue, but no serious disability.
130 to 170	Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 25 percent of personnel. No deaths anticipated.
180 to 220	Vomiting and nausea for about 1 day, followed by other symptoms of radiation sickness in about 50 percent of personnel. No deaths anticipated.
270 to 330	Vomiting and nausea in nearly all personnel on first day, followed by other symptoms of radiation sickness. About 20 percent deaths within 2 to 6 weeks after exposure; survivors convalescent for about 3 months.
400 to 500	Vomiting and nausea in all personnel on first day, followed by other symptoms of radiation sickness. About 50 percent deaths within 1 month; survivors convalescent for about 6 months.
550 to 750	Vomiting and nausea in all personnel within 4 hours from exposure, followed by other symptoms of radiation sickness. Up to 100 percent deaths; few survivors convalescent for about 6 months.
1000	Vomiting and nausea in all personnel within 1 to 2 hours. Probably no survivors from radiation sickness.
5000	Incapacitation almost immediately. All personnel will be fatalities within 1 week.

TABLE I

(From Space Radiation Guide Technical Documenting Report No. AMRL-TDR-62-86, Aerospace Medical Research Laboratories, Wright-Patterson AFB, Ohio. pg Aug 1962)

Flights aboard the MOL should be well below this level. Personnel who have received levels of 300 rad or more must be considered as not available for further crew duties.

Whole body tolerance levels have been established on the basis that genetic effects could be ignored and that the estimated life expectancy will be minimal, since risks associated with these factors are in all probability less than other risks associated with the mission.

C. Eyes - Tolerance dosage to the eyes is 250 rad. based upon 3 mm of shielding over the measuring device (tissue depth of lens). This level may cause lens changes in 3+ opacities within one to two years. These changes in the eyes are considered relatively acceptable because the changes will not interfere with the mission and is amenable to medical or surgical treatment.

D. Blood-Forming Organs - Tolerance dosage to the blood forming organs varies from 50 tl 150 rad. This level will cause changes in the bone marrow that are reversible, with several weeks required for recovery. Measurement of this dosage is based upon 8 mm shielding over the measuring device.

The USAF, NASA, and AEC have an extensive program underway to determine tolerance levels of radiation encountered in space. The dosages given above are tentative and will be changed to reflect recommendations resulting from this program.

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Exp No. P-12

(MISC, SECT 1)

TIME ANALYSIS OF ASTRONAUT DUTIES
IN BIOMEDICAL EXPERIMENT
FOR 30 DAY MISSION

SSTA-1-9
264

DAY

TIME

Exp No. P-12
24 March 1964

BIOMEDICAL AND PHYSIOLOGICAL PARAMENTERS -- SUMMARY OF EQUIPMENT

PARAMETER MEASURED	EQUIPMENT	WT. LBS.	VOL. FT^3	Power WATTS
Pulse (Monitored and/or recorded continuously)	Harness, Electrodes, Amplifier, Transmitters	0.2	<0.01	0.02
	Receiving Equipment	15.0	0.14	10.00
Electrocardiogram (3-Lead)	Attachable electrodes, amplifiers	0.5	<0.01	0.10
Blood Pressure	Cuff, Microphone, amplifier, inflator	8.0	0.30	4.00
Mechanical Events (Heart)	Microphone, accelerometers, Pressure transucer, amplifiers	3.8	0.03	0.5
Blood O_2 Content and Cardiac Output (T-1824 Dye)	Ear Oximeter, Power Supply Amplifier	7.0	0.05	6.0
Respiratory Flow, O_2 and CO_2 content of inspired and expired air	Flow Meter, amplifier, integrator, gas sensors	20.0	0.30	15.0
Electroencephalograms and electroculograms	Electrodes, amplifiers (4 channels)	1.3	0.01	0.2
Body Mass	Catapult, Accelerometer, amplifier	9.0	0.07	0.5
Physical condition and Deconditioning countermeasures	Ergometer, Tachometer, Power Meter, Dynamometers	40.0	0.40	Generates 30watt permin
Radiation--Electrons, protons, neutrons, heavy nuclei, alphas	Uni and Omni-Directional Spectrometers, TEICS	45.5	0.93	14.2
Blood and Urine Constituents, Volumes, and total body water	pH meter, Spectrophotometer, Centrifuge, Mass Spectrometer, and miscellaneous supplies	90.2	0.99	60.0
Astronaut General Status Visual Observation of work and movement in zero g	Voice Communication Equipment TV (During certain station passes)	(Included in Life Support Equipment)		
Biochemical Samples (for post-flight analysis	Centrifuge, Lyophilizer, Supplies	35.0	0.82	30.0
Data Storage	Magnetic Tape Recorder	60.0	1.30	60.0
	Total	335.5	5.41	200.5

Note: Weights and volumes do not include storage containers or mountings. Power represents average values for operating equipment.

SECONDARY EXPERIMENTS

NR	TITLE
S-1	VLF Communication/Propagation Experiment
S-2	Secure Communication Using Narrow Beam Widths
S-3	Laser Propagation
S-4	High Frequency Ionospheric-Ducting
S-5	Encapsulation and Recovery of Space Objects
S-6	Expandable Structures Techniques
S-7	Antanna Deployment, Alignment and Pointing
S-8	Space Rendezvous Radar
S-9	Manually Controlled TV and Orbital Inspection Photography
S-10	Mapping and Geodetic Survey
S-11	Determination of Mass of Orbiting Body
S-12	Hydrogen Reduction Atmospheric Regeneration System
S-13	Vapor Compression Distillation Water Purification System
S-14	Passive Propellant Settling System
S-15	Coherent EM Propagation and Antenna Loading
S-16	Solar X-Ray Monitoring
S-17	Materials Degradation and Malfunction Analysis
S-18	Astronomical Photography

VLF COMMUNICATION/PROPAGATION

I. TEST OBJECTIVE

The objective of the experiment is to determine if the propagation characteristics of the ionosphere will support VLF communications between MOL and globally distributed ground terminals on a continuous basis.

II. IMPORTANCE OF THE TEST

The potential operational application of a global VLF communication capability using a space-mission vehicle is the extension into space of the VLF global network. Such a capability would improve the global coverage of the VLF net and ensure alternate routing of traffic following the degradation or destruction of ground facilities. Communication VLF traffic normally transmitted from large ground antenna systems could be transmitted to a space vehicle at UHF or microwave frequencies and retransmitted from space at the VLF net frequency to the dependent weapon systems.

The current information on the propagation of VLF energy transmitted between space and the earth is inadequate to determine the full potential of this frequency range to provide global coverage. The propagation characteristics cannot be ascertained from simulated methods. The orbit of MOL will place it within the ionosphere, and many questions concerning the coupling of the VLF energy into the plasma and its subsequent propagation are still to be resolved.

III. DESCRIPTION OF THE EXPERIMENT

Basically the experiment will consist of transmitting VLF energy from the MOL during various locations of the MOL with respect to the diurnal variations of the ionosphere, and recording the received signal profile at a number of globally distributed earth based terminals, i.e. ground, ships. An adjustable length VLF antenna will be required, and it will be necessary to vary its length for maximum coupling to the ionosphere. The antenna extension need not be a problem since the Alouette Satellite has demonstrated the technique.

(a) Configuration of Test Items: { 1 1/2 cu. feet; 30 lbs.

(b) Test Support Equipment Required: Primary power 300-500 watts. Antenna to be shell mounted.

Items required for the test will consist of a VLF transmitter, variable-length antenna, test equipment for achieving maximum coupling (radiated power indicator) and recorder to coordinate time and antenna length. In addition, a preprogrammed modulation sequence unit will be required or incorporated into the TX.

The ground equipment will be standard VLF signal monitoring and recording. This equipment no doubt is in use now.

(c) Test Procedure:

The important variable in this experiment is the length of the antenna. Since the electrical length of the antenna will vary according to the plasma density, it will be necessary to continuously tune the antenna for maximum radiated power. The man's role in the test is to vary the length of the antenna to ensure optimum coupling at all times. The antenna tuning will be shown by maximum indication of the radiated power meter. The man's contribution will be measured by his ability to manipulate the antenna-length equipment by visual observation of the power meter. His coordination will be recorded on board by notebook or voice onto a tape.

Initially the test sequence will consist of radiating continuously for somewhat more than 1 orbit in order to obtain signal profiles corresponding to a complete diurnal variation of the ionosphere. Subsequently the test periods could be shortened to correspond to reception at particular ground terminals for different hours of the day.

Using the signal strength profiles, in conjunction with time-synchronization, it will be possible to estimate propagation time delay, absorption, and estimate propagation ray patterns. From the foregoing it should be possible to determine the feasibility of a space ground VLF link for operational traffic.

(d) Category of Experiment:

Category (b) - Minor structural accommodation for extending the VLF antenna.

(e) Cost:	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
	260 K	300 K	10 K	10 K	10 K	590 K

(f) Schedule:

1. FY 66 (12 months after issue of contract)

2. FY 66

IV. PARTICIPATING GOVERNMENT AGENCIES

Sponsor - NAVY; Participant: RTD and ESD

V. <u>ADDITIONAL REQUIREMENTS</u>

(a) Special Security: No

(b) Manning Description: See attached sheet

(c) Logistics: Not known

(d) Facilities: Existing facilities probably exist for ground monitoring and recording. Personnel would normally be trained in this operation.

(e) Simulation and Training:

1. Astronaut: Minimum technical skill. Familiarity with the purpose and his partcipation in the experiment would require a short prior briefing to become acquainted with the response of the antenna controls. On-board procedures will be provided.

2. Ground Personnel: Technician level.

3. Equipment: Nil.

VI. <u>GENERAL</u>

(a) Command and Data Requirements:

Telemetry data on status of the MOL's VLF transmitter, antenna extension and radiated power. Shared with on-board system.

VLF EXPERIMENT

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED: VLF Transmitter and Antenna Extensor-Tuner.

2. WEIGHT: 30 lb.

3. VOLUME: Stored 1.5 cu ft. In use 1.5 cu ft.

   CRITICAL DIMENSIONS - SHAPES - To be supplied to MOL designer during development of VLF equipment.

4. POWER

   a. Continuous: None

   b. Stand-by: None

   c. Average operating: 400 watts

   d. Peak: 400 watts

   e. Duty cycle: Continuous during test periods

5. SPARES: None required in flight.

   a. Volume

   b. Quantity

   c. Weight

6. TOOLS: None required in flight.

   a. Volume

   b. Quantity

   c. Weight

   d. Power

7. HEAT OUTPUT: 200 watts during test periods

DESIGN CHARACTERISTICS TEST EQUIPMENT (Cont'd)

8. STABILITY: No rapid rotations during test periods.

   a. Moving parts: Antenna extensions up to 150 feet from MOL in opposite directions.

9. VIBRATION LIMITS: Less than 0.1g during operation less than 20 g at other times.

10. SHOCK LIMITS: 20 g in any direction when not operating.

11. HAZARDS (fire, explosion, electrical, toxics, other): None.

12. TEMPERATURE LIMITATIONS: $0^{\circ}C$ to $50^{\circ}C$ ambient.

13. TYPE AND RANGE OF MEASUREMENT (definition of parameters to be measured while test is underway): See Section III C.

14. SPECIAL ENVIRONMENTAL REQUIREMENTS: Air circulation 25 cu ft. min.

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS:

    Station: Angle maintained within $\pm 3^{\circ}$ of equilibrium position/ angular rate not greater than 1° per min.

    Equipment: No accuracy requirement; must be accessible to operator.

16. EQUIPMENT OPERATING CYCLE

    Frequency: 2 per day

    Time Duration: Continuous during 1 or 2 early orbits.

17. EQUIPMENT LOCATION REQUIREMENT: Antennas extend in a straight line up to 150' from vehicle in two opposite directions. Transmitter accessible to operator.

18. SPECIAL MOUNTINGS REQUIREMENTS

    Apertures: See No 17.

    Booms: None

    Windows: None

    Antennae: See No. 17.

    Bracketry: None.

DESIGN CHARACTERISTICS TEST EQUIPMENT (Cont'd)

19. PRESSURE VESSELS - fluids, gasses, etc.: None required.

20. ELECTRO MAGNETIC INTERFERENCE (spurious generation, special shielding required, etc.): No special shielding required.

21. MAINTENANCE REQUIREMENTS

Ground: Ability to test, replace, repair transmitter and antenna extensor/tuner. Conventional Laboratory test equipment is sufficient.

Space: None required.

VLF EXPERIMENT

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA

   a. Tape: Conventional audio types at monitoring stations.

   b. Film: None Required.

   c. Other: Strip chart recorders for signal strength.

2. HANDLING (special equipment required to handle items being tested): None required.

3. PACKAGING: None required.

4. CALIBRATION - alignment, deployment: Conventional systems are available at monitoring locations.

5. JIGS AND FIXTURES: None required.

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION: None required.

7. SENSORS (TRANSDUCER - OUTPUT SIGNALS): None required.

8. TRAINERS/SIMULATORS: None required.

9. INSTRUMENTATION - cockpit and/or laboratory (note effect of time sharing instruments with other experiments). Laboratory only: Power on/off controls and pilot light. Indication that antenna is tuned, control of modulation cycle. Necessary metering of transmitter.

10. RELATED SUPPORT EQUIPMENT

    a. Targets: None required.

    b. Ground Stations: Will make use of existing VLF monitoring and receiving stations operated by Air Force, Navy, and Bureau of Standards.

    c. Tracking: None required.

    d. Handling Equipment: None required.

11. AGE: Conventional test equipment is sufficient.

12. ENVIRONMENTAL TEST EQUIPMENT: None required after acceptance tests.

13. FACILITIES: None required except as noted above.

VLF EXPERIMENT

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS (desired)
   a. Altitude: Any altitude between 100 and 250 miles is satisfactory.
   b. Inclination: 30° or greater is preferred, to increase time over the United States.
   c. Epoch: N/A
   d. Ellipticity: N/A
2. PLANE CHANGE: None required.
3. ALTITUDE CHANGE: None required.
4. TIME ON ORBIT: Full orbit (one or two per complete MOL operation).
5. TEST DURATION: 2 full orbits plus 60 10-minute tests.
6. TOTAL NUMBER OF TESTS: 62
7. TEST FREQUENCY: 2 per day
8. INTERVAL BETWEEN TESTS: 6-24 hours
9. CREW TASK LOADS - man hours: 13 man hours per MOL Mission.
10. CREW TASK FREQUENCY: 2 per day
11. FIELD OF VIEW REQUIREMENTS: Ability to determine antenna extension.
12. GROUND CONTROL LIAISON DURATION: From 5 min. before test until 5 min. after end of test.
13. GROUND CONTROL LIAISON FREQUENCY: Normal MOL voice Communication channels.
14. EXTERNAL TEST ITEMS:
    a. Launched from Station: None
    b. Launched from resupply: None
    c. Launched from ground: None

TEST OPERATING CHARACTERISTICS (Cont'd)

15. QUALIFICATION TESTS (other than space)

    a. Ground: Normal acceptance tests including simulated space enviornment

    b. Atmosphere: None

16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT: See Section III C.

17. HANDLING PROCEDURES: None required.

VLF EXPERIMENT

FUNDING SUMMARY
BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing		260 K	300 K				560 K
Integration & Installation	(1)						
AGE	(2)						
Simulators/Trainers	None required						
Data Reduction				10 K	10 K	10 K	30 K
Equipment Rework	None required						
Other	None required						
TOTAL		260 K	300 K	10 K	10 K	10 K	590 K

Source of Funds - Hitch Line Number

(1) Equipment will be GFE to MOL contractor and installed during manufacture.

(2) Conventional test equipment (dummy loads, receivers) readily available.

Atch 4

VLF EXPERIMENT

MANNING DESCRIPTION

1. ASTRONAUTS

   a. Number required: One; intermittent duties.

      (1) Man's function

         (a) As a part of test: Determining optimum antenna extension in cooperation with ground observers

         (b) As technician conducting test: turning equipment on and off, adjusting for optimum operations.

   b. Crew skill requirements: No special skills required.

   c. Manpower Profile: 2 full orbits early in flight plus two 10 minute tests per day.

   d. Critical Functions: See 1 (1), (a) above.

   e. Work Positions: In pressurized Module.

   f. Time Controlled Tasks: None.

   g. Human Performance Measures: Skill in cooperating with ground observers.

   h. Physiological and Psychological Measures: None.

   i. Selection Factors: None.

   j. Training Requirements: Brief instruction period - three half hour sessions.

2. GROUND PERSONNEL

   a. Number required: 3 to 60 (depending on monitoring statious involved)

      (1) Man's function

         (a) As part of test: monitoring received signals and directing astronaut in adjustments.

         (b) As technician conducting test: recording signal strength and quality.

MANNING DESCRIPTION (Cont'd)

b. Crew skill Requirements: Present crews of monitoring stations are satisfactory.

c. Manpower Profile: Same times as item 1-C above.

d. Critical Functions: Evaluation of signals.

e. Work Positions: In present monitoring stations.

f. Time Controlled Tasks: None.

g. Human Performance Measures: None.

h. Physiological and Psychological Measures: None.

i. Selection Factors: None; personnel now on the job for other purposes.

j. Training Requirements: None.

VLF EXPERIMENT

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE: Low. Summaries of data gathered on ground will be sent to mission headquarters by teletype. Detailed data may be collected by mail.

2. FUNCTIONS TO BE MEASURED: Strength and quality of the received signal.

3. TYPE OF ANALYSIS REQUIRED: Propagation attenuation and variation as a function of:

   a. Path length

   b. Location of MOL

   c. Ionospheric variations

   d. MOL transmitting antenna adjustments

4. PICTORIAL DATA REQUIRED: None, unless malfunction of MOL antenna can be documented by photographs taken by astronaut (recovered with Gemini capsule and log of trip).

5. REAL TIME MONITORING REQUIREMENT: None required.

6. DATA EDITING OR COMPRESSION: See Item 1 above.

7. READ-OUT TIME: Not pertinent. Data is gathered on the ground.

8. REQUIREMENTS FOR PERMANENT DATA RECORDS: None in MOL; data is gathered on the ground. Records include magnetic tape recording of audible sounds of received signals and pen tracings of signal strength, coordinated against time of reception.

9. MANUAL AND/OR AUTOMATIC CONTROL: MOL Equipment manually controlled. Ground equipment may be manual or automatic according to types of devices with which the ground recording stations are presently equipped.

10. SIMULTANEITY: No special requirements other than comman time reference accurate to approximately 0.1 second to permit correlating test records.

11. GROUND COMMANDS REQUIRED: None, except for brief periods of co-operative tests when astronaut must have voice contact with ground observer while he adjusts antenna tuning for optimum performance. This test only two to four ten-minute periods during a complete mission.

VLF EXPERIMENT

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME: 12 months
2. FINAL DEFINITIVE TEST DESIGN TIME: 18 months
3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED: None.
4. TYPE OF DEVELOPMENT TEST ITEMS:
   - a. Vacuum Chamber: Required.
   - b. Shaker: Required.
   - c. Thermal: Required.
   - d. Acoustic: Not required.
   - e. Simulators: Not required.
   - f. Aircraft: Not required.
5. SUPPORT EQUIPMENT DEVELOPMENT TIME: None required.
6. NUMBER OF TEST ARTICLES REQUIRED FOR:
   - a. Ground Test: One.
   - b. Atmospheric Test: None.
   - c. Space Test: Six
7. DATE AVAILABLE FOR TESTS: 12 months after award of order.
8. CURRENT DEVELOPMENT STATUS:
   - a. Proposed only: See below.
   - b. Project or program is approved and test item is under study, breadboard stage, etc.: Similar devices of comparable power and size have been manufactured in prototype quantities. Antenna tuner must be developed to meet impedance anticipated for this special antenna system.
   - c. Funds expended to date: None directly to this program.

Experiment No. S-2
3 Mar. 64

SECURE COMMUNICATION USING NARROW BEAM WIDTH

I. TEST OBJECTIVE:

It is required to determine the potential utility of narrow beam communication links for space-to-space and space-to-aircraft information transfer. The potential mission application is in the establishment of command and control links between space vehicles and between Airborne Command Posts and Space Command Posts.

II. IMPORTANCE OF THE TEST:

In order to provide a reliable and continuous command capability between ground command posts, airborne command posts and space command posts, the communications systems must be resistant to jamming and interception by the enemy. Narrow beam radiation responds to both these requirements and is particularly desirable between ABCPs and spacecraft.

The test is necessary in order to respond to questions relating to narrow beam communication link establishment. Because of the relative velocity of the terminals (i. e., space vehicle-to-space vehicle and space vehicle-to-aircraft) and the potentially high tracking rates involved, the initial antenna pointing angle represents an important system consideration.

In the initial feasibility experiment on the MOL, automatic link establishment will not be available and a space crew member will be required to point the antenna in the direction of the other terminal, i. e., another spacecraft, if available, or an aircraft. This experiment will provide a capability assessment of the potential contribution which man-in-space can make in a narrow-beam communication system. If this experiment shows a positive result, it would reduce the complexity (weight, power, space) which would otherwise be necessary in an automatic link establishment procedure when using narrow-beams.

III. DESCRIPTION OF THE EXPERIMENT:

The experiment will investigate the potential value of a narrow-beam communication link between the MOL and an aircraft flying at an altitude of the order of 40,000 feet and along the ground-track of the MOL. The experimental time duration will not be more than 5 minutes per contact. After a link has been established, a canned message sequence can be transmitted alternately from the MOL and from the aircraft. This will be a man-controlled experiment. Received-signal profiles will be recorded on both the MOL and aircraft for subsequent analysis.

(a) Configuration of Test Items:

The experiment would be carried out in the 75KMcs or higher frequency spectrum in order to provide a relatively narrow-beam with a small antenna and to reduce signal strength at ground level because of atmospheric attenuation. At this frequency, a 6-inch dish provides a beam-width of 22 or 40db gain; a 12-inch dish provides a beamwidth of 1° or 46 db gain. From a space vehicle at an altitude of 150 miles, the beamwidth at the aircraft altitude will be approximately 5.0 and 2.5 miles respectively.

Similar terminal equipment will be required in both the aircraft and the MOL, i. e., transmit, receive, record equipment. At 75Kmcs, the equipment will occupy about 1 1/2 cubic feet, weigh approximately 25 lbs. and require 25 watts during the test.

(b) Test Support Equipment:

The test support equipment in the MOL will consit mainly of signal-profile recording for permanent record and for transmission to the ground at an appropriate time. Provision will be made for a crew-member to listen to the received de-modulated signal for man-evaluation of the link for voice communications.

An aircraft will be required to be modified to provide a stabilized platform. The aircraft will contain essentially the same equipment as in the MOL.

(c) Test Procedure:

1. Establish communication between MOL and aircraft by conventional means (e. g., UHF) in order to conduct the experiment.

2. From a determination of the relative positions of MOL and aircraft, align antennas. MOL will transmit on frequency A and aircraft will transmit on frequency B to provide a capability to antenna-track on signal and remain aligned.

3. When the link has been established, a canned modulation sequence, i. e., voice, can be transmitted either simultaneously or alternatively between MOL and aircraft.

4. The received signal would be permanently recorded.

Man's role in the test will involve initial link establishment by pointing the antenna to locate the other terminal and to ensure that lock-on is sustained during the test. Continuous voice communication will be maintained between MOL and aircraft for the duration of the test. In addition, man will be required to initiate any canned sequences.

(d) Category of Experiment:

This experiment will be in category (a). In order to carry out the experiment, the antenna will need to be external to MOL to allow the required directional flexibility. This will be a significant design consideration in the structure of MOL since the antenna will probably be extended.

(e) Cost:	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
	420 K	520 K	75 K	275 K	200 K	1,490 K

This experiment needs to be performed in every MOL.

(f) Schedule:

1. Hardware and software available for test: Not now available.

2. Hardware and software flight readiness date - 1966.

IV. Participating Government Agencies:

Sponsor: SSPD/Aerospace

Participant: CRL-ESD

V. Additional Requirements:

(a) Special Security: No

(b) Manning Description Summary: See attached

(c) Logistics: Not known

(d) Facilities:

This test will require the modification of an aircraft to support a stabilized platform for the equipment, to accomodate a small randome on the top of fuselage, and to permit pointing of the antenna by a crew member.

(e) Simulation and Training:

1. Astronaut: The astronaut must be familiar with the sequence of the experiment and the response of the pointing angle system. Technician training only required. Details for operating experiment will be provided. Training would consist of operating the equipment on a simulated basis during training. It would not represent a long training period.

2. Aircraft personnel: Same as above

3. Equipment: No special equipment required for training

Exp. No. S-2

VI. General:

(a) Communication Data Handling Requirement:

Voice UHF contact will be maintained between the aircraft and MOL throughout the test. Simple telemetry of the MOL test equipment will be transmitted to the ground. Signal profile data obtained in the MOL will be transmitted to a ground terminal when opportune to do so.

NARROW BEAM COMMUNICATION EXPERIMENT

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED: Transmitter-Receiver and associated tracking antenna.

2. WEIGHT: 20 lbs.

3. VOLUME: Stored 1.5 cubic feet. In use 1.5 cubic feet.

   CRITICAL DIMENSIONS - SHAPES - Steerable Antenna 1-foot diameter. Dimensions of equipment to be supplied to MOL designer during development of millimetric wave equipment.

4. POWER:

   a. Continuous: None required

   b. Stand-by: None required

   c. Average operating: 25 watts

   d. Peak: 25 watts

   e. Duty Cycle: Continuous during test periods (6 minutes)

5. SPARES: None required in flight.

   a. Volume: N/A

   b. Quantity: N/A

   c. Weight: N/A

6. TOOLS: None required in flight

   a. Volume: N/A

   b. Quantity: N/A

   c. Weight: N/A

   d. Power: N/A

DESIGN CHARACTERISTICS TEST EQUIPMENT (Cont'd)

7. HEAT OUTPUT: 24 watts

8. STABILITY: See Item 15 below.

a. Moving Parts: Antenna and mount to track co-operating airborne terminal.

9. VIBRATION LIMITS: Can accept available environment by vibration mounting antenna assembly.

10. SHOCK LIMITS: 20 g in any direction, non-operating

11. HAZARDS (fire, explosion, electrical, toxics, other): None

12. TEMPERATURE LIMITATIONS: Transmitter: 10° - 40° C, air cooled

Antenna: Space Environment

13. TYPE AND RANGE OF MEASUREMENT (definition of parameters to be measured while test is underway). Measurements of strength and quality of received signal and antenna pointing angle.

14. SPECIAL ENVIRONMENTAL REQUIREMENTS: See item 12 above.

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS:

STATION: Angle maintained within $\pm 3^{\circ}$ of planned orientation to permit antenna to view the earth. Angular rate not greater than 1° per minute.

Equipment: Transmitter and receiver must be accessible to the operator.

16. EQUIPMENT OPERATING CYCLE:

Frequency: May be scheduled as convenient; total of ten tests per MOL mission.

Time Duration: Ten minutes.

17. EQUIPMENT LOCATION REQUIREMENTS: Antenna must be able to view substantially all visible areas of earth surface. Transmitter and receiver accessible to operator.

18. SPECIAL MOUNTINGS REQUIREMENTS

Apertures: See below

Booms: None required

DESIGN CHARACTERISTICS TEST EQUIPMENT (Cont'd)

Windows: Operator must see antenna when necessary

Antenna: See Item 17 above

Bracketry: Antenna support

19. PRESSURE VESSELS - fluids, gasses, etc.: None required

20. ELECTRO MAGNETIC INTERFERENCE (spurious generation, special shielding req., etc): No special shielding required.

21. MAINTENANCE REQUIREMENTS:

Ground: Ability to test, replace, or repair transmitter, receiver, and antenna. Conventional laboratory test equipment is sufficient.

Space: None required.

Exp. No. S-2

NARROW BEAM COMMUNICATION EXPERIMENT

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA

   a. Tape: For recording signal profile

   b. Film

   c. Other

2. HANDLING (special equipment required to handle items being tested): None required.

3. PACKAGING: None required

4. CALIBRATION - alignment, deployment: conventional test equipment may be used at ground installations.

5. JIGS AND FIXTURES: None required

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION: None required

7. SENSORS (TRANSDUCER -OUTPUT SIGNALS) - None required

8. TRAINERS/SIMULATORS: None required.

9. INSTRUMENTATION - cockpit and/or laboratory (note effect of time sharing instruments with other experiments): No instrumentation in cockpit. In the laboratory

   1. Indication of transmitter power
   2. Indication of received signal
   3. Modulation sequence activated

10. RELATED SUPPORT EQUIPMENT

    a. Targets: None required

    b. Ground Stations: Airborne terminal

TEST SUPPORT EQUIPMENT (Cont'd)

c. Tracking: Totally steerable tracking capability

d. Handling Equipment: None required

11. AGE: Conventional laboratory test equipment is satisfactory.

12. ENVIRONMENTAL TEST EQUIPMENT: None required after equipment acceptance tests.

13. FACILITIES: None required except as noted above.

NARROW BEAM COMMUNICATION EXPERIMENT

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS (DESIRED)
   a. Altitude: Not critical - 100 to 250 miles is satisfactory
   b. Inclination: Not critical
   c. Epoch: Not critical
   d. Ellipticity: Not critical
2. PLANE CHANGE: Not required
3. ALTITUDE CHANGE: Not required
4. TIME ON ORBIT: Not critical
5. TEST DURATION: 10 minutes per test
6. TOTAL NUMBER OF TESTS: 10 per MOL mission
7. TEST FREQUENCY: One per day preferred until 10 have been completed
8. INTERVAL BETWEEN TESTS: Approximately 1 day - not critical
9. CREW TASK LOADS - man hours: Approximately 4 hours per MOL mission
10. CREW TASK FREQUENCY: Approximately once per day
11. FIELD OF VIEW REQUIREMENTS: Antenna must be able to see substantially all the visible areas of the earth's surface.
12. GROUND CONTROL LIAISON DURATION: Continuous from 5 minutes before test until test completion.
13. GROUND CONTROL LIAISON FREQUENCY: Once per day
14. EXTERNAL TEST ITEMS:
   a. Launched from Station: None required
   b. Launched from resupply: None required

TEST OPERATING CHARACTERISTICS (Cont'd)

c. Launched from ground: None required

15. QUALIFICATION TESTS (other than space)

a. Ground: Acceptance of equipment in environment specified.

b. Atmosphere: Not required

16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT

1. Establish radio contact between MOL and aircraft
2. Power on transmitters
3. Attempt to align antennas
4. After align switch to auto-'track on signal'
5. Record received signal
6. Initiate modulation sequence
7. Transmit record to ground on first opportunity.

FUNDING SUMMARY

BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing		360 K	460 K	75 K			885 K
Integration & Installation			30 K				30 K
AGE		60 K	40 K				100 K
Simulators/Trainers							
Data Reduction					50 K	50 K	100 K
Equipment Rework					75 K		75 K
Other (Aircraft Operation)					150 K	150 K	300 K
TOTAL		420 K	520 K	75 K	275 K	200 K	1,490 K

Source of Funds - Hitch Line Number

NARROW BEAM COMMUNICATION EXPERIMENT

MANNING DESCRIPTION

1. ASTRONAUTS

   a. Number required: One

      (1) Man's Function

         (a) As part of test: To point antenna to establish link.

         (b) As technician conducting test: To activate sequence of experiment recording received signal and transmitting canned modulation. Transmit to ground.

   b. Crew Skill requirements: No special skills required

   c. Manpower Profile: Not more than 10 minutes per test

   d. Critical Functions: Antenna Pointing

   e. Work Positions: Seated

   f. Time Controlled Tasks: Not applicable

   g. Human Performance Measures: Ability to continuously monitor incoming signal.

   h. Physiological and Psychological Measures: N/A

   i. Selection Factors: N/A

   j. Training requirements: Familiarity with control response

2. GROUND PERSONNEL:

   a. Number required: Two; 1 engineer, 1 technician

      (1) Man's function: Same as (a) above

         (a) As Part of test: " "

         (b) As technician conducting test: Same as (a) above

Exp. No. S-2

MANNING DESCRIPTION (Cont'd)

b.	Crew Skill Requirements:	Same as Astronaut
c.	Manpower Profile	" " "
d.	Critical Functions	" " "
e.	Work Positions	" " "
f.	Time Controlled Tasks	" " "
g.	Human Performance Measures	" " "
h.	Physiological and Psychological Measures:	Same as Astronaut
i.	Selection Factors	" " "
j.	Training Requirements	" " "

NARROW BEAM COMMUNICATION EXPERIMENT

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE: 4 kc
2. FUNCTIONS TO BE MEASURED: ANTENNA POINTING ANGLE, received wave form, AGC voltage
3. TYPE OF ANALYSIS REQUIRED: Astronauts assessment of voice intelligibility
4. PICTORIAL DATA REQUIRED: No
5. REAL TIME MONITORING REQUIREMENT: No
6. DATA EDITING OR COMPRESSION: No
7. READ-OUT TIME: No
8. REQUIREMENTS FOR PERMANENT DATA RECORDS: Not required after transmission to ground
9. MANUAL AND/OR AUTOMATIC CONTROL: Manual control
10. SIMULTANEITY: No
11. GROUND COMMANDS REQUIRED: Radio contact between MOL and aircraft to start experiment.

Exp. No. S-2

NARROW BEAM COMMUNICATION EXPERIMENT

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME: 12 Months

2. FINAL DEFINITIVE TEST DESIGN TIME: 6 Months after development time

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED: 2

4. TYPE OF DEVELOPMENT TEST ITEMS: Space Acceptance Test Standards

SUPPORT EQUIPMENT DEVELOPMENT TIME: Will be developed with equipment

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

   a. Ground Test: 1 for aircraft installation

   b. Atmospheric Test: None

   c. Space Test: 6 for MOL series

7. DATE AVAILABLE FOR TESTS: Early 1966

8. CURRENT DEVELOPMENT STATUS

   a. Proposed only: Proposed only

   b. Project or program is approved and test item is under study, bread-board stage, etc.

   c. Funds expended to date.

Experiment No. S-3
3 March 64

LASER PROPAGATION

I. TEST OBJECTIVE:

It is required to determine the potential value for ground-to-space and space-to-ground of communication links using laser beams. The inherently wide bandwidths which can be supported by a laser carrier would be applicable to space missions involving transfer of wide band data, e.g., photographic. The use of a concentrated beam of a fraction of a degree with anti-intercept and anti-jam advantages would provide a reliable and secure information-transfer link between an orbiting command post and a ground command center.

II. IMPORTANCE OF THE TEST:

The test is necessary in order to be able to assess the propagation characteristics of the medium by recording the signal profiles, as the MOL passes from maximum slant range from the ground transmitter (minimum elevation angle) to minimum range (in the case of a zenith pass this corresponds to the orbital height of MOL). These include climatic conditions, cloud cover, turbulences, beam scintillation, and interfering signals, e.g., cloud reflections. Because of the randomness of the propagation medium it would not be possible to simulate its characteristics and thus obtain the required data for analysis. An astronaut will be required to adjust for maximum signal the lens system of the laser detector on board the MOL and continuously monitor its orientation during a test pass of not more than 5 minutes.

III. DESCRIPTION OF THE EXPERIMENT:

In this experiment the major complexity will be retained on the ground. The ground facility will consist primarily of a laser radar and the MOL will be equipped with a laser receiver only. A portion of the MOL surface will contain suitable reflectors for the laser radar in order to ensure track-on-signal. Initially the pointing angle for the pencil beam radar will be provided by slaving to a conventional radar. The receiver equipment on-board MOL will simply detect and record the signal from the LASER radar. Pointing of the LASER receiver lens system for maximum signal will be a critical part of the test since the angle of arrival of the signal will be an important parameter which will be recorded. The astronaut will point the lens system for maximum signal during a contact.

Exp No. S-3

a. Configuration of Test Items: The fundamental items for this test are a LASER detector with direction flexibility and a recording device of four channels to record time, angle of arrival, signal profile and a voice channel. The space, weight, characteristics are 1 cu ft., 20 lbs and 25 watts. The equipment will be located on the wall of MOL.

b. Test Support Equipment Required:

(1) Space craft: (as above)

(2) AGE: A ground based LASER radar (refer S-66 satellite program) and a recorder for returned-signal profile, azimuth, elevation, range, and time.

(3) A ground based tracking radar for back-up initial orientation of LASER beam.

c. Test Procedure: Voice contact between the ground terminal and MOL will be established prior to initiation of test. The ground LASER radar will illuminate MOL and the LASER receiver will be oriented by an astronaut to receive the maximum signal. As soon as tracking is confirmed the recorder on-board will be turned on and recording will continue for the duration of the pass.

(1) The astronauts role will be maintaining the LASER receiver pointed to receive maximum signal from the ground radar and his ability to do so will be a subjective opinion of the astronaut and so conveyed during voice contact with the ground terminal. A test will not exceed 5 minutes and could be repeated on any orbit which would allow not less than a 3 minute contact.

d. Category of Experiment: This experiment falls in category (b) since only a minor structural accommodation will be required to support the test. Provision must be made for unobstructed orientation of the receiver consistent with the attitude of MOL during the test, i.e., a look-through capability.

e. Cost:	FY 65	FY 66	FY 67	FY 68	TOTAL
	150 K	225 K	150 K	50 K	575 K

f. Schedule: Not determined.

IV. PARTICIPATING GOVERNMENT AGENCIES:

Sponsor: RTD

Participant: ESD-CRL

V. ADDITIONAL REQUIREMENTS:

a. Special Security - No.

b. Manning Description - See attachment.

c. Logistics: Not determined.

d. Facilities: A ground LASER radar has been developed for the S-66 satellite, however, it is expected that modifications and design improvements will be achievable for the MOL program. It would be desirable to have more than one such terminal and mountain locations would probably be necessary to reduce atmospheric attenuation.

e. Simulation and Training:

(1) Astronaut: Technician level will be adequate. Familiarity with the sequence of the test and the response of the receiver-pointing controls will be necessary. This would not require special simulation equipment. Procedures will be provided.

(2) Ground Personnel: Engineering level will be necessary and good knowledge of the operation of a LASER radar will be essential.

VI. GENERAL:

a. Communication and Data Handling Requirement: The data required to be sent from MOL to the ground would be equivalent to a low information rate 4 channel tape and would be sent when convenient.

b. Development Characteristics: See attached.

Exp No. S-3

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED: LASER Beam tracking and receiving equipment.

2. WEIGHT: 20 lbs (max)

3. VOLUME: Stored 1 cu. ft. In Use same.

   CRITICAL DIMENSIONS - SHAPES Ability to orient optical receiver (lens) through a 180° viewing angle.

4. POWER

   a. Continuous - 25 watts

   b. Stand-by - none

   c. Average operating - 25 watts

   d. Peak - 25 watts

   e. Duty cycle - continuous during experiment

5. SPARES

   a. Volume
   b. Quantity
   c. Weight

   none required

6. TOOLS

   a. Volume
   b. Quantity
   c. Weight
   d. Power

   none required

7. HEAT OUTPUT - 90 BTU/hr

8. STABILITY

   a. Moving parts - Lens system must be capable of movement through a 180° angle (±90° from vertical)

9. VIBRATION LIMITS - MIL SPEC as applied to other equipment in the MOL will be satisfactory.

10. SHOCK LIMITS - 20g

11. HAZARDS (fire, explosion, electrical, toxic, other) - none

12. TEMPERATURE LIMITATIONS - 80° C ambient

13. TYPE AND RANGE OF MEASUREMENT (definition of parameters to be measured while test is underway). Signal strength, fading rates, tracking angle error.

14. SPECIAL ENVIRONMENTAL REQUIREMENTS - none

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS:

    Station - angle should be maintained within 3.0° of planned position and drift rate should not exceed 1° per minute.

    Equipment: No position accuracy established. Will be furnished later; must be accessible to operator.

16. EQUIPMENT OPERATING CYCLE

    Frequency - 1 per day

    Time duration - 15 minutes

17. EQUIPMENT LOCATION REQUIREMENTS - not critical except for lens system which must be earth oriented.

18. SPECIAL MOUNTINGS REQUIREMENTS

    Apertures - sufficient to achieve desired positioning (See below)

    Booms - Boom is necessary for operation of lens system over a 180° angle

    Windows - none required

    Antennae - lens mount as above

    Bracketry - Brackets for extension and orientation of lens system

19. PRESSURE VESSELS - Fluids, gasses, etc. none required

20. ELECTRO MAGNETIC INTERFERENCE (spurious generation, special shielding req. etc) none

21. MAINTENANCE REQUIREMENTS

    Ground - standard radar tracking maintenance

    Space - none.

LASER PROPRAGATION EXPERIMENT

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA

   a. Tape: 4 channels 4 kc bandwidth

   b. Film: None

   c. Other: None

2. HANDLING (Special equipment required to handle items being tested). None

3. PACKING: Standard

4. CALIBRATION - alignment deployment: none required

5. JIGS AND FIXTURES: none required

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION: not applicable

7. SENSORS (TRANSDUCER - OUTPUT SIGNALS): not applicable

8. TRAINERS/SIMULATORS: LASER Transmitter

9. INSTRUMENTATION - cockpit and/or laboratory (note effect of time sharing instruments with other experiments). Indicator light; Tape recorder for recording data may be time shared.

10. RELATED SUPPORT EQUIPMENT

    a. Targets - none

    b. Ground stations: 1 ground station

    c. Tracking: LASER radar ground station with standard tracking radar as back-up.

    d. Handling Equipment: none required

Exp No. S-3

11. AGE: Standard laboratory test equipment will be sufficient.

12. ENVIRONMENTAL TEST EQUIPMENT: Vacuum chamber and temperature test chamber.

13. FACILITIES: None required except as noted above.

LASER PROPAGATION EXPERIMENT

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS (desired)
   a. Altitude: Not critical
   b. Inclination: Not critical
   c. Epoch: Not critical
   d. Ellipticity: Not critical
2. PLANE CHANGE: Not critical
3. ALTITUDE CHANGE: Not critical
4. TIME ON ORBIT: Within view of ZI
5. TEST DURATION: 10 minutes
6. TOTAL NUMBER OF TEST: 10
7. TEST FREQUENCY: 1 per day for 10 days
8. INTERVAL BETWEEN TESTS: 24 hours
9. CREW TASK LOADS - man hours: 100 mins/per 30 day MOL flight
10. CREW TASK FREQUENCY: 1 per day
11. FIELD OF VIEW REQUIREMENTS: 180°
12. GROUND CONTROL LIAISON DURATION: 5 minutes
13. GROUND CONTROL LIAISON FREQUENCY: 1 per day for 10 days
14. EXTERNAL TEST ITEMS:
    a. Launched from Station
    b. Launched from resupply — not applicable
    c. Launched from ground

Exp No. S-3

15. QUALIFICATION TESTS (other than space)

    a. Ground: Normal bench tests

    b. Atmosphere: Check operation from aircraft

16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT:

    1. Power on

    2. Recorder check

    3. Voice contact with ground

    4. Manual acquisition

    5. Switch to automatic track

    6. Close voice channel to ground

    7. Power off

17. HANDLING PROCEDURES: None

Exp. No. S-2

Atch 4

FUNDING SUMMARY

BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environment Testing		150 K	200 K				350 K
Integration & Installation				100 K			100 K
AGE							
SIMULATORS/Trainers							
Data Reduction					50 K		50 K
Equipment Rework				50 K			50 K
Other: A/C operation for check out			25 K				25 K
TOTAL		150 K	225 K	150 K	50 K		575 K

Source of Funds - Hitch Line Number

Exp No. S-3

LASER PROPAGATION EXPERIMENT

MANNING DESCRIPTION

1. ASTRONAUTS

   a. Number required: one

      (1) Man's function

         (a) As part of test: none

         (b) As technician conducting test: to operate equipment and orient antenna in manual mode

   b. Crew skill requirements: none

   c. Manpower profile: Not applicable

   d. Critical functions: adjustment of lens in manual acquisition mode

   e. Work Positions: Normal

   f. Time Controlled Tasks: None

   g. Human Performance Measures: Not applicable

   h. Physiological and Psychological Measures: Not applicable

   i. Selection Factors: No special

   j. Training Requirements: Training in operation of LASER equipment.

2. GROUND PERSONNEL

   a. Number required: 3

      (1) Man's Function

         (a) As part of test: none

         (b) As technician conducting test: To operate equipment.

   b. Crew Skill Requirements: Radar operation skills.

c. Manpower Profile: 1 Engineer, 2 technicians

d. Critical Functions: Operation of tracking equipment

e. Work Positions: Normal

f. Time Controlled Tasks: None

g. Human Performance Measures: Not applicable

h. Physiological and Psychological Measures: Not applicable

i. Selection Factors: No special

j. Training Requirements: Training in LASER equipment operation.

Exp No. S-3

LASER PROPAGATION EXPERIMENT

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE: Voice bandwidth - 4 kc.

2. FUNCTIONS TO BE MEASURED: Tracking error signal, signal strength, signal/noise ratio, acqusition time, time.

3. TYPE OF ANALYSIS REQUIRED: Correlation of tracking error, fades, and signal/noise ratios.

4. PICTORIAL DATA REQUIRED: None

5. REAL TIME MONITORING REQUIREMENT: 4 channel tape recorder voice bandwidth

6. DATA EDITING OR COMPRESSION: None

7. READ-OUT TIME: 5 minutes/pass

8. REQUIREMENTS FOR PERMANENT DATA RECORDS: Tape storage and punched card stores

9. MANUAL AND/OR AUTOMATIC CONTROL: Automatic level control. Start-stop manual.

10. SIMULTANEITY: All channels to be recorded simultaneously. Staggered recroding heads are permitted.

11. GROUND COMMANDS REQUIRED: Voice contact with astronaut for first 2 1/2 minutes and last 2 1/2 minutes.

LASER PROPAGATION EXPERIMENT

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME: 12 Months

2. FINAL DEFINITIVE TEST DESIGN TIME: 2 Months

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED: Bench tests for 30 days

4. TYPE OF DEVELOPMENT TEST ITEMS

   a. Vacuum chamber

   b. Shaker

   c. Thermal

   d. Acoustic

   e. Simulators

   f. Aircraft

5. SUPPORT EQUIPMENT DEVELOPMENT TIME: 12 Months

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

   a. Ground Test: 2

   b. Atmospheric Test: 2

   c. Space Test: 2

7. DATE AVAILABLE FOR TEST: 15 months after award of contract

8. CURRENT DEVELOPMENT STATUS

   a. Proposed Only

   b. Project or Program is approved and test item is under study, breadboard stage, etc.

   c. Funds expended to date.

Experiment No. S-4

HIGH FREQUENCY IONOSPHERIC-DUCTING COMMUNICATION

I. TEST OBJECTIVE

The purpose of this test is to determine the propagation of high frequency waves between points on the ground and the orbiting laboratory as it moves within and above the ionosphere. In particular, it is desired to determine to what degree it is possible to communicate with the orbiting laboratory by means of high frequency radio waves while the laboratory is beyond line-of-sight range of the ground communication point. Communication to and from high flying aircraft should also be examined. From this data it will be possible to decide how many ground stations are necessary to insure maintaining continuous contact with an orbiting space vehicle, and to predict the operating frequencies and power requirements for such communication. While such communication channels are likely to be limited in bandwidth, and may not serve the purpose of linking a command post to the ground for high rate data transmission, they still can form an extremely effective backup system for the essential elements of command and control.

II. IMPORTANCE OF THE TEST

To achieve the operational results indicated above, we must be able to forecast propagation conditions with accuracy and design an effective communication system. Although, a substantial amount of data has been obtained on the electron density in the ionosphere, and although some experiments with high frequency communication between an orbiting object and ground were made during Project Mercury flights, we still have insufficient information to indicate what may be expected of such a system or to measure the confidence factor with which it may be applied in military missions.

Such tests must be made in space because the propagation conditions cannot be accurately simulated in any other location. Tests of limited duration might be made from missiles, but the thorough examination of the propagation phenomena that are necessary require more time than can be easily allotted to missile investigations.

Conducting this experiment in the manner indicated below will directly help to assess man's ability and utility in space by determining his effectiveness in operating relatively conventional communication equipment to perform communication experiments and to record the results.

III. DESCRIPTION OF THE EXPERIMENT

The experiment may conveniently be planned in two major phases: (1) receiving in the orbiting laboratory and (2) two-way communication between the laboratory and a ground station. Extensions of these experiments to include aircraft stations in contact with the orbiting laboratory are possible, and will be encouraged.

a. Configuration of Test Items

The test equipment required in the spacecraft includes: receiver covering the H. F. frequency range, a high frequency transmitter, capable of keyed AM and singlesidedband voice modulation, the necessary antennas and antenna tuning equipment for effective operation over these ranges, a graphic recorder for receiver signal strength capable of being keyed with an accurate time reference, a twin track voice recorder capable of recording for the entire duration of the experimental period, and the necessary power supplies. Note that special power supplies might be shared with those used for the normal vehicle communications in the interest of weight conservation.

b. Test Support Equipment Required

The supporting equipment required outside the space vehicle consists of normally installed radio transmitters which exist in large numbers of around the globe and which will provide a variety of useful signals for observing in receiving tests at the spacecraft. Furthermore, selected ground stations must be able to transmit on appropriate frequencies for communication with the spacecraft when the spacecraft undertakes to transmit. All the necessary equipment for ground support already exists, with the possible exception of specialized recording equipment which may be necessary to preserve certain of the test results.

c. Test Procedure

At selected times during the mission, as it may be fitted in between other experiments, one of the spacecraft personnel will operate the receiving position in the spacecraft. After deploying the antennas as necessary, he will tune carefully over the frequency range assigned for the experiment, noting the call letters and other identification of signals observed. As he makes these observations the signal strength recording equipment will be activated and will provide a log of the signals received against time references obtained from the vehicle timing system. At the same time the twin channel voice recorder will be operative. One channel will record the output of the receiver to which the operator is listening; the other channel will be connected to a microphone used by the receiver operator, and will record his comments on what he hears and observes, and on what troubles he may have in performing the experiment. Tone impulses or other identification signals from the vehicle timing reference system will be imprinted on the channel on which the operators voice is recorded to enable correlating his observations and the received signals with the signal strength record.

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A program and schedule for the observations will be provided to the operator enabling him to make specific observations with regard to ground locations that are favorably situated, unfa vorably situated, or in a marginal location. From analysis of this data, it is expected that we will ba able to predict the attenuation between the spacecraft and ground locations beyond line-of-sight.

From time to time during the operation, it will be desirable for the operator to attempt to establish two-way contact with selected ground stations. This will be accomplished by single sideband voice, or if this proves impractical, by keying a tone in appropriate code.

To facilitate this two-way communication, it shall be possible for the transmitter to be synchronized with the receiver in the fashion normally known as "transceiving operation". This is an operation wherein the heterodyning oscillators are used in transmitting and receiving so that the transmission is necessarily on exactly the frequency to which the receiver is tuned. This insures maximum precision of tuning for reception on the ground, except for the corrections that may be necessary for doppler frequency.

It is desirable that the receiver be capable of continuous tuning throughout the range, rather than synthesized in descrete steps, to permit the following and tracking incoming frequency of ground stations despite the changes in apparent frequency due to doppler effect.

Summaries of significant observation may be transmitted to ground as part of the ships normal report through the appropriate data links, the recording comprising the entire set of observations made during the test will be returned with the capsule to the ground if necessary.

Development of compact recorders capable of functioning without attention for long periods of time will be necessary to instrument this activity.

The human operator plays a vital role in this experiment for many reasons. The skill of a human operator in extracting intelligence from a mixture of signal and noise has been noted in numerous experiments. The ability of the operator to scan, acquire, and track signals especially when these signals may be intermittent or fading, exceeds what can be successfully provided by automatic devices. To be useful for command and control purposes, it is vital that we know exactly what can be accomplished by a skilled operator in manipulating communication devices of a conventional type. The number and variety of experiments that can be carried out during a limited time by a human operator exceed what can be planned for an automated sequence. It would be difficult to devise command signals of sufficient complexity to permit a similar observation to be made on command from an unmanned satellite.

d. Category of Experiment

This experiment may be classified in category (a) because the ability to transmit and receive beyond line-of-sight contributes directly to the safe aspects of the orbiting laboratory program. Ability to remain continuously in contact with the vehicle for extended periods of time from a single ground point will enhance the ability of ground observers to determine the condition and status of the vehicle operators. The effect on crew moraleof having dependable long range communication from the vehicle is expected to be advantageous.

e. Cost

FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
$25,000	$129,000	$44,000	$16,000	$4,000	$218,000

f. Schedule

It is anticipated that suitable equipment can be prepared in time for inclusion within the manned orbiting laboratory without adversely effecting the schedule for these experiments.

IV. Participate in Government Agencies

Sponsor: RDT

Participant: ESD-RADC

V. Additional Requirements

a. Special Security

None.

b. Manning Description Summary

See attachment 5.

c. Logistics

Not yet determined.

d. Facilities

Ground station facilities with necessary equipment already exist. The stations must be able to transmit on frequencies compatible for communication with the spacecraft during periods of two-way transmission.

The spacecraft facilities consist of presently available receivers and transmitters which will require only modifications for installation in spacecraft.

e. Simulation and Training

(1) Astronaut; technician level will be adequate, familiarity with the sequence of tests and ability to adjust and tune receiver and transmitter should be adequate. There will be no requirement for special simulation equipment.

(2) Ground Personnel; technician level will be adequate during operation of global distributed VHF stations.

VI. General

a. Communications and Data Handling Requirement

The two-way voice transmissions from the MOL spacecraft to the ground would be equivalent to a low information rate and could be recorded on a four-channel tape recorder.

b. Development Characteristics

See attachment 7.

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DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED: VHF Communications Equipment

2. WEIGHT: 50 lbs.

3. VOLUME: Stored 4 cu. ft. In use Same

CRITICAL DIMENSIONS - SHAPES: None - deployable antenna required with tuning to be made by astronaut.

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4. POWER

a. Continuous - 100 watts

b. Stand-by - 10 watts

c. Average operating - 100 watts

d. Peak - 100 watts

e. Duty cycle - continuous during test

5. SPARES

a. Volume - none

b. Quantity - none

c. Weight - none

6. TOOLS

a. Volume - none

b. Quantity - none

c. Weight - none

d. Power - none

7. HEAT OUTPUT - 200 BTU average

8. STABILITY -

a. Moving parts - not critical

DESIGN CHARACTERISTICS TEST EQUIPMENT (Cont'd)

9. VIBRATION LIMITS - MIL SPEC as applied to other equipment in the MOL will be adequate.

10. SHOCK LIMITS - 20g

11. HAZARDS (fire, explosion, electrical, toxics, other) None

12. TEMPERATURE LIMITATIONS - 80° C ambient

13. TYPE AND RANGE OF MEASUREMENT (definition of parameters to be measured while test is underway). Tuning across frequency range, noting of station call letters, identification of signals, observation of signal strength, and logging of signals received.

14. SPECIAL ENVIRONMENTAL REQUIREMENTS - None

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS:

    Station: Not critical

    Equipment: No position accuracy established, must be accessible to astronaut.

16. EQUIPMENT OPERATING CYCLE

    Frequency - continuous during first six orbits by recording of stations received, other sequence of tests shall occur three times each day.

    Time Duration - 15 minutes per test

17. EQUIPMENT LOCATION REQUIREMENTS

    Not critical except for deployment of the antennas

18. SPECIAL MOUNTINGS REQUIREMENTS

    Apertures - not critical

    Booms - none required

    Windows - none required

    Antenna - Must be extendable from at least two sides of vehicle

    Bracketry - brackets must be provided for mounting of receiver and transmitter and for extension of the antennas.

DESIGN CHARACTERISTICS TEST EQUIPMENT (Cont'd)

19. PRESSURE VESSELS - fluids, gasses, etc. - none required

20. ELECTRO MAGNETIC INTERFERENCE (spurious generation, special shielding required etc.) None

21. MAINTENANCE REQUIREMENTS

    Ground - technician level adequate

    Spacecraft - none will be required

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA

   a. Tape - 2 channel with 4-kc bandwidth per channel; compact recorder capable of functioning for long periods will be required.

   b. Film - none

   c. Other - none

2. HANDLING (special equipment required to handle items being tested). None

3. PACKAGING - standard

4. CALIBRATION - alignment, deployment: none

5. JIGS AND FIXTURES: N/A

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION: N/A

7. SENSORS (TRANSDUCER - OUTPUT SIGNALS): Record output of receiver and connection to microphone used by astronaut.

8. TRAINERS/SIMULATORS: N/A

9. INSTRUMENTATION - cockpit and/or laboratory (note effect of time sharing instrument with other experiments). Indicator lights, astronaut observations, and tape recordings.

10. RELATED SUPPORT EQUIPMENT

    a. Targets - none

    b. Ground Stations - ground stations for two-way communication between astronaut and ground - also aircraft-to-MOL tests.

    c. Tracking - N/A

    d. Handling Equipment - standard equipment sufficient

11. AGE - standard test equipment sufficient

12. ENVIRONMENTAL TEST EQUIPMENT: Vacuum chamber and temperature test chamber.

13. FACILITIES: None required except as noted above.

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TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS (desired)
    a. Altitude - not critical
    b. Inclination - not critical
    c. Epoch - not critical
    d. Ellipticity - not critical
2. PLANE CHANGE - not critical
3. ALTITUDE CHANGE - not critical
4. TIME ON ORBIT - continuous during first six orbits for monitoring of receive signals; for voice communications within view of CONUS
5. TEST DURATION - continuous monitoring during first 6 orbits of receive signals 15 minutes required for voice communications test
6. TOTAL NUMBER OF TESTS - 30 tests
7. TEST FREQUENCY - 3 voice test per day for 10 days; continuous monitoring during first 6 orbits of receive signals
8. INTERVAL BETWEEN TESTS - not critical
9. CREW TASK LOADS - man hours: 1000 minutes per 30 day MOL orbit
10. CREW TASK FREQUENCY - 3 per day
11. FIELD OF VIEW REQUIREMENTS - not critical
12. GROUND CONTROL LIAISON DURATION - 3 times a day; 15 minute duration
13. GROUND CONTROL LIAISON FREQUENCY - same as above
14. EXTERNAL TEST ITEMS:
    a. Launched from Station - N/A
    b. Launched from resupply - N/A
    c. Launched from ground - N/A

TEST OPERATING CHARACTERISTICS (Cont'd)

15. QUALIFICATION TESTS (other than space)

    a. Ground - normal bench tests

    b. Atmosphere - can be tested in chambers

16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT -

    1. Power on
    2. Deploy antennas
    3. Recorder on
    4. Tune over frequency range of receiver
    5. Identify call letters and signals
    6. Observation of receive signal strength
    7. Log of signals received against time
    8. Switch-over to two-way communications
    9. Establish two-way contact with selected ground stations
    10. Describe observations during test to ground
    11. Power off

17. HANDLING PROCEDURES - N/A

FUNDING SUMMARY

BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing			$85,000	$10,000	$10,000		$105,000
Integration & Installation			$4,000	12,000	4,000	4,000	24,000
AGE	-	-	-	-	-	-	-
Simulators/Trainers	-	$25,000	30,000	20,000	-	-	$ 75,000
Data Reduction	-	-	$10,000	2,000	2,000	-	14,000
Equipment Rework	-	-	-	-	-	-	-
Other:							
TOTAL		$25,000	$129,000	$44,000	$16,000	$4,000	$218,000

MANNING DESCRIPTION

1. ASTRONAUTS

   a. Number required: two occasionally

      (1) Man's function:

         (a) as part of test: none

         (b) As technician conducting test: to operate continuous tuning receiver, adjust antenna, and provide voice communications to ground during tests

   b. Crew skill requirements: none

   c. Manpower Profile: N/A

   d. Critical Functions: adjustment of antenna and monitoring and logging of communications stations received

   e. Work Positions: normal

   f. Time Controlled Tasks: none

   g. Human Performance Measures: N/A

   h. Physiological and Psychological Measures: N/A

   i. Selection Factors: trained to technicians level to operate communications equipment

   j. Training Requirements: Trained to technicians level to operate communications equipment

2. GROUND PERSONNEL

   a. Number required: three

      (1) Man's function

         (a) As part of test: none

         (b) As technician conducting test: to operate HF equipment during two-way voice communications with astronaut

   b. Crew Skill Requirements: technicians level

   c. Manpower Profile: 1 engineer, 2 technicians

MANNING DESCRIPTION (Cont'd)

d. Critical Functions: none

e. Work Positions: normal

f. Time Controlled Tasks: N/A

g. Human Performance Measures: N/A

h. Physiological and Pyschological Measures: N/A

i. Selection Factors: not critical

j. Training Requirements: operation and maintenance of HF communications equipment

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE: voice bandwidth - two 4-kc channels

2. FUNCTIONS TO BE MEASURED: tuning across frequency range, noting of station call letters, identification of signals, observation of signal strength, logging of signals received, and two-way voice communications from spacecraft to ground

3. TYPE OF ANALYSIS REQUIRED: judgement of astronaut as to signals received, signal strength, location of stations, and voice reporting to ground

4. PICTORIAL DATA REQUIRED: none

5. REAL TIME MONITORING REQUIREMENT: two-channel tape recorder, 4-kc bandwidth per channel

6. DATA EDITING OR COMPRESSION: none

7. READ OUT TIME: N/A

8. REQUIREMENTS FOR PERMANENT DATA RECORDS: two-channel tape recorder

9. MANUAL AND/OR AUTOMATIC CONTROL: on HF transceiver, remote frequency control, and antenna tuning and steering control are automatic; stop/start of communication equipment, recorder and tuning across HF frequency band to be manual

10. SIMULTANEITY: two-voice channels to be recorded simultaneous

11. GROUND COMMANDS REQUIRED: voice communication with astronaut on scheduled test that will be determined at a later date

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DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME: no development time required; 12 months lead time for procurement

2. FINAL DEFINITIVE TEST DESIGN TIME: 6 months

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED: ground tests using chambers for 30 days; no flight tests required

4. TYPE OF DEVELOPMENT TEST ITEMS

   a. Vacuum Chamber: yes

   b. Shaker: yes

   c. Thermal: yes

   d. Acoustic: yes

   e. Simulators: no

   f. Aircraft: no

5. SUPPORT EQUIPMENT DEVELOPMENT TIME: no development time required, existing equipment available

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

   a. Ground Test: 2

   b. Atmospheric Test: none

   c. Space Test: 5

7. DATE AVAILABLE FOR TESTS: 12 months after award of contract

8. CURRENT DEVELOPMENT STATUS

   a. Proposed only: yes

   b. Project or program is approved and test item is under study, breadboard stage, etc. - existing equipment in HF band presently available

   c. Funds expended to date: none

ENCAPSULATION AND RECOVERY OF SPACE OBJECTS

I. TEST OBJECTIVES

The objectives of this test are three-fold; determine man's ability to apply polyurethane or other plastic ablators to an object (such as an enemy satellite), determine the effects of the space environment on the free flowing, foaming, and setting characteristics of these ablators, and finally, to determine the feasibility of deorbiting and recovering this object from space. The successful execution of this experiment will provide the USAF with the capabiliy of recovering either previously launched U.S. satellites, or more important, recovery for ground inspection of enemy or foreign satellites.

II. IMPORTANCE OF THE TEST

The inspection and ultimate recovery of foreign enemy satellites is one of the potential military missions for USAF. Also inspection and recovery of previously launched U.S. satellites would provide invaluable data on materials degradation, and causes of failures of satellites.

The only way available to test man's ability to utilize encapsulated foam recovery satellites is to conduct a small scale experiment in space. Since man is in the experiment, a piggyback shot experiment is not feasible. Hence, this experiment should be conducted on the MOL. Zero g aircraft tests will not provide sufficient test durations; also they do not provide a vacuum environment.

This will definitely assess man's ability and utility in the area of recovering enemy satellites.

III. DESCRIPTION OF THE EXPERIMENT

A small scale satellite, containing recovery aids, will be stowed in the unpressurized area of MOL. An astronaut will enter this area and apply the polyurethane foam to the test article. The foam will expand by a factor of 20 and form a rigidized ablative coating over the satellite's surface. (The space available in MOL will determine the size of the target. The techniques and methods of applying the foam are to be determined by further study.) Following application of the foam, the astronaut will conduct an inspection of the test article and will determine the effects of zero "g" and hard vacuum on the free flowing characteristics of polyurethane foam. This portion of the experiment will determine man's ability and utility in applying polyurethane foam coatings to satellites or data capsules for eventual recovery. The next phase of this experiment is contingent on the previously outlined phase being completed successfully. This second phase will deal with the deorbiting and re-entry of the foam-encased satellite. Several techniques are available for this phase of the experiment. Retro recovery pack or piggy back re-entry on Gemini. The selection as to which approach to follow will be made during the early stages of R&D. Man's ability to recover unfriendly or previously launched U.S. satellites will be the final determination of this experiment.

a. Configuration of Test Items

The key items of this experiment are mock up small enemy satellites, capsulated foam reactants, and possibly retro recovery pack. Total experiment weight 45-50 lb. and 3 cu ft. package volume. This experiment will be stored in unpressurized module of MOL. See Attachment 1.

b. Test Support Equipment Required

(1) Spacecraft - None

(2) AGE - None

c. Test Procedure

The test satellite will be stowed in unpressurized module of MOL. Astronaut will photograph and inspect satellite, astronaut will encase satellite in a ball or casing of polyurethane foam, astronaut will attach retro recovery package, and finally command deorbit at direction of ground control of satellite. Alternate possible deorbit re-entry piggyback on Gemini.

Man's role will be a key portion of this mission, he is directly involved in all atests. Man will apply foam to satellite, observe its reaction in total space environment, and finally command deorbit. The success or failure of this experiment will be very dependent on man.

d. Category of Experiment

This experiment to determine the one aspect of military capability of man in space, but requires no modification to MOL vehicle. Category B.

e. Cost

Total - $1,800K. See Attachment 4. If Gemini piggy back recovery is utilized, reduce funds by $600K-700K.

f. Schedule

(1) Hardware and software avilable for qualification tests, late 1965.

(2) Hardware and software available for flight readiness, 1966.

IV. PARTICIPATING GOVERNMENT AGENCIES

Sponsor: AF Aero Propulsion Laboratory, RTD, (APFT), and SSD.

Test Equipment Acquisition: Same and SSD

V. ADDITIONAL REQUIREMENTS

a. Special Security

Mission objective and success of mission classified SECRET, because of military implications.

b. Manning Description Summary

See Attachment 5. One astronaut required for 70 minutes for test. No special skills required.

c. Logistics - N/A

d. Facilities

Existing facilities such as vacuum chamber, zero "g" flights, shake-rattle-roll, etc. are in existence and are available to APFT, sponsor.

e. Simulation and Training

(1) Astronaut: Astronaut would be required to learn techniques for applying and triggering encapsulated foam reactants. Astronaut would be required to learn how to apply retro recovery package to satellite. This training would last approximately four (4) working days.

(2) Ground Personnel: A Discover recovery team would be utilized for recovery of satellite. No additional training would be required. Alternate Gemini piggy back reentry would require no additional recovery forces.

(3) Equipment: All necessary facilities, etc. are available to sponsor.

VI. GENERAL

a. Communication and Data Handling Requirement - See Attachment 6.

b. Development Characteristics - See Attachment 7

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS:

    a. Station - N/A

    b. Equipment - Must be stable, not tumbling during deorbiting sequences.

16. EQUIPMENT OPERATING CYCLE

    The test items will be operated once during the experiment. Total time duration of items 45-60 minutes... . Maximum, possibly less.

17. EQUIPMENT LOCATION REQUIREMENTS - Unpressurized compartment for all experiment items.

18. SPECIAL MOUNTINGS REQUIREMENTS - Bracketry for launching enemy target satellite, and stowage bracketry or tie down fittings.

19. PRESSURE VESSELS - Small nitrogen pressure bottle for pressurizing foam reactants. This may be an unnecessary item if micro encapsulated foam reactants are utilized.

20. ELECTRO MAGNETIC INTERFERENCE - N/A

21. MAINTENANCE REQUIREMENTS - N/A

Attachment 2

Recovery of Satellites via the Utilization of Man and Encapsulated Foam Coatings

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA
   a. Possibly tape record astronaut's comments on experiment
   b. Film - 16-35mm still photo coverage
2. HANDLING - N/A
3. PACKAGING - N/A
4. CALIBRATION -N/A
5. JIGS AND FIXTURE - N/A
6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE VEHICLE - None
7. SENSORS - None
8. TRAINERS/SIMULATORS - N/A
9. INSTRUMENTATION - N/A
10. RELATED SUPPORT EQUIPMENT
    a. Target - 20 lb., satellite 1.2 cu. ft. volume
    b. Ground Stations - Tracking stations
    c. Tracking - should be available for tracing reentry path of satellite
    d. Handling equipment - N/A
11. AGE - N/A
12. ENVIRONMENTAL TEST EQUIPMENT - N/A
13. FACILITIES - Vacuum chamber for testing foam reactants over satellite, shock, vibration, thermal limit, and reentry simulator required; however, all of these facilities are available or are directly under auspices of APFT sponsor.

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS - Any orbit selected for MOL will be satisfactory for this experiment.

2. PLANE CHANGE - None.

3. ALTITUDE CHANGE - None.

4. TIME ON ORBIT - Prefer to conduct retrieval of object on daylight portion of orbit.

5. TEST DURATION - 70 minutes.

6. TOTAL NUMBER OF TESTS - One (1).

7. TEST FREQUENCY - N/A.

8. INTERVAL BETWEEN TESTS - N/A.

9. CREW TASK LOADS - One astronaut required. 1.2 manhours.

10. CREW TASK FREQUENCY - N/A.

11. FIELD OF VIEW REQUIREMENTS - Field of view afforded by space helmet is adequate.

12. GROUND CONTROL LIAISON DURATION - 30-40 minutes.

13. GROUND CONTROL LIAISON FREQUENCY - 10 minutes intervals.

14. EXTERNAL TEST ITEMS -
    a. Launched from Station - 20 lb enemy target satellite

15. QUALIFICATION TESTS:
    a. Ground - Coating and Foaming of satellite in vacuum chamber, shake-rattle-roll, thermal limits, re-entry simulation.
    b. Atmosphere - Aircraft dropping of satellite with recovery package.

16. SEQUENCE OF EVENTS ASTHEY OCCUR DURING FLIGHT:

    T = 0 Astronaut dons space suit.

    T = 8 Astronaut enters unpressurized module of MOL.

T = 9 Astronaut inspects satellite in MOL unpressurized compartment.

T = 10 Astronaut photographs and inspects satellite.

T = 16 Astronaut places encapsulated dry reactants over satellite and initiates foam reaction.

T = 22 Astronaut attaches recovery retro package to satellite.

T = 25 Astronaut places foam coated satellite outside vehicle. Alternate piggyback Gemini re-entry may be utilized.

T = ? At proper time in orbit determine via ground contact satellite is deorbited.

17. HANDLING PROCEDURES - The astronaut would place encapsulated foam reactants coating over entire satellite. Nothing else critical involved.

Attachment 4

FUNDING SUMMARY

BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY66	FY67	FY68	FY69	TOTAL
Engineering, Developmental Environmental Testing	0	300K	300K	400K	400K	225K	1725K
Integration & Installation	0	0	0	0	75K		75K
AGE	0	0	0	0	0	0	0
Simulators/Trainers	0	0	0	0	0	0	0
Data Reduction	0	0	0	0	0	0	0
Equipment Rework	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0
TOTAL	0	300K	300K	400K	475K	225K	1800K

Hitch Number 62405336
* If Gemini piggy back reentry is utilized reduce overall funding by $600K to $700K

MANNING DESCRIPTION

1. ASTRONAUTS

a. Number Required - One (1)

(1) Man's function - Man will photograph satellite, apply foam reactants to satellite, and finally deorbit satellite.

b. Crew skill requirements - Normal skills possessed by astronauts is adequate. Astronaut will be shown how to apply foam reactants and retro recovery pack.

c. Manpower Profile - Require no more 1.2 manhours per MOL mission.

d. Critical Functions: - Placing foam reactants over satellite, proper deorbiting sequence for landing satellite in desired recovery area.

e. Work Positions - During inspection - application of foam - de-orbit cycle, inside unpressurized module of MOL.

f. Time Control Task - Only deorbit sequence

g. Human Performance Measures - Ability of man to place encapsulated foam covering and retro recovery pack over a satellite.

h. Physiological and Psychological Measures - N/A

i. Selection Factors - Normal factors required for astronauts.

j. Training Requirements - Astronaut to be trained how to cover satellite with foam reactants, and how to fire retro recovery pack.

2. GROUND PERSONNEL - Typical Discover team would be required for recovery of reentering satellite unless alternate piggy back reentry undertaken.

Attachment 6

COMMUNICATIONS AND DATA
HANDLING

1. DATA RATE - N/A
2. FUNCTIONS TO BE MEASURED - N/A
3. TYPE OF ANALYSIS REQUIRED - N/A
4. PICTORIAL DATA REQUIRED - Still photographs required 16mm or 35mm.
5. REAL TIME MONITORING REQUIREMENTS - N/A
6. DATA EDITING OR COMPRESSION - N/A
7. READ-OUT TIME - N/A
8. REQUIREMENTS FOR PERMANENT DATA RECORDS - N/A
9. MANUAL AND/or AUTOMATIC CONTROL - N/A
10. SIMULTANEITY - N/A
11. GROUND COMMANDS REQUIRED - Ground control would give commands for specific de-orbit time.

Attachment 7

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME - 1.5 years to qualification testing. .5 - .8 year for testing.
2. FINAL DEFINITIVE TEST DESIGN TIME - .8 - 1 year.
3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED - six (6).
4. TYPE OF DEVELOPMENT TEST ITEMS:
   a. Vacuum Chamber - 4 ea.
   b. Shaker - 2 ea.
   d. Acoustic - 0
   e. Simulators 0
   f. Aircraft Zero "g" - 2
5. SUPPORT EQUIPMENT DEVELOPMENT TIME
6. NUMBER TEST ARTICLES REQUIRED FOR:
   a. Ground Test - 4 ea.
   b. Atmospheric - 2 ea.
   c. Space Test - 3 ea.
7. DATA AVAILABLE FOR TESTS:
   a. Ground and Atmospheric Test Mid 1965
   b. Space Test on MOL - 1966
8. CURRENT DEVELOPMENT STATUS:
   a. Proposed only - N/A
   b. Project is approved
   c. Funds expended to date - $800K

EXPANDABLE STRUCTURES TECHNIQUES

I. Test Objective

This experiment will provide the USAF with the capability of boosting into orbit minimum package-size structures which can be expanded into useful larger MOL's and space structures. The results of this experiment will have a direct bearing on whether or not any portion of a relatively large future space system, which of necessity must be partially formed and erected in space, can be so designed.

II. Importance of the Test

This kind of experiment is needed to determine which of several types of expandable structures show potential for space application. The most important reason to conduct these tests in space by man is to observe the expanding process, resulting stability and deformation characteristics in a zero "g" environment. Further, it is desirable to utilize man's observations on the long term effects of exposing these structures to the space environment. The following future space systems data can be obtained from these tests.

a. Complete Space Stations and Components

Numerous expandable space station configurations have been proposed. Some of the design problem areas which lend themselves to solution through model tests using a manned space station are:

(1) Deployment characteristics of inflated configurations including stability.

(2) Effects of complete space environment of rigidization processes.

(3) Methods of deploying rigid module systems (telescoping systems).

(4) Gas retention of gas stabilized structures.

(5) Long term effects of structural exposure to space environment. Man will be needed to make these periodic observations.

b. Solar Collectors and Antenna Applications

An experiment designed to determine the applicability of a particular expandable concept to solar collector and antenna construction would consist of deploying a dynamically scaled structural replica of a solar collector in the space environment and conducting tests in which signal pattern and intensity are recorded along with measurements of local reflective surface deformation. The principal objective of the experiment is the measurement of deformation tolerance control to structure size. Man would play an invaluable role in determining surface imperfections of the rigidized solar collectors, which is of paramount importance.

Scaling of collector-antenna results to full scale is straightforward. The principal problem area in this experiment is the extrapolation of structural data to full scale. MOL will afford the earliest possible platform from which these experiments can effectively be conducted.

III. Description of the Experiment

Four small expandable structure cylinders would be deployed early in a MIL mission. One cylinder would be constructed of airmat, one of expandable self-rigidizing honeycomb, one of a foamed-in-place structure and, finally, a telescoping structure. Each one of these types of expandable structures has the most potential in the areas of minimum package volume and strength fro weight, except the telescoping structure. Each cylinder will be pressurized to the cabin pressure of the MOL. An astronaut will periodically inspect the exterior of the structures, and will possibly cut a small segment of each structure out to be returned to earth for laboratory analysis. No major problems are anticipated in this experiment.

Two small expandable solar collectors will also be expanded and rigidized in this experiment to determine the ability to form useful solar energy conversion devices in space. These solar collectors will also provide sufficient test data to determine the feasibility of utilizing these types of structures for antennae systems. One solar collector will be an expandable honeycomb type, while the other collector will be either a metal unfurlable or a foamed-in-place type. Such types of structures are now ready, or are nearly ready for space testing. It is proposed to make each item of the experiment a module in order that the over-all weight and package volume can be trimmed to meet MOL flight requirements. The priority of structures to be tested would be one expandable honeycomb cylinder and one expandable honeycomb or foam rigidized solar collector.

a. Configuration of Test Items

The four unexpanded cylinders will have a package volume of 4 to 5 cu. ft. total, while the four expanded cylinders will have an expanded volume of 400 cu. ft. However, minimum of one honeycomb expandable cylinder and one expandable solar collector experiment can be conducted with a maximum weight of 35 pounds and 1.7 cu. ft. package volume. The total experiment weight will be 80 to 100 pounds. The experiment can be stowed in the unpressurized module of MOL. Experiment requires no power except for instrumentation.

b. Test Support Equipment Required

(1) Spacecraft - None

(2) AGE - None

c. Test Procedure

Man will be utilized to monitor periodically instrumentation, photograph structures during deployment and rigidization and, finally, to inspect exterior of structures exposed to space environment. He may also be utilized to remove a small piece of each structure, and bring it back to earth for laboratory analysis.

Testing Sequence

T = 0 Airmat cylinder is deployed.

T = 10 Foamed-in-place structure deployed.

T = 20 Foamed-in-place structure fully cured.

T = 21 Expandable honeycomb structure deployed.

T = 30 Telescoping structures deployed.

T = 80 Honeycomb structure fully rigidized.

T = 90 All three structures pressurized to cabin pressure.

Instrumentation

1. Temperature profile across structure every hour.
2. Strain gage data recorded hourly.
3. Leak rate recorded hourly.
4. Number of leads required from inside to outside = 30. (This number of leads may possibly be reduced.)

d. Category of Experiment

Category "c", although man will be utilized considerably in the experiment.

e. Cost

	Prior	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering Development	0	200 K	300 K	300 K	300 K	300 K	1,400 K
Installation	0	0	0	30 K	70 K	0	100 K
Ground Support	0	0	0	0	0	0	0
Total	0	200 K	300 K	330 K	370 K	300 K	1,500 K*

Hitch Number: 62405334

*Cost can be reduced if only minimum previously mentioned experiment is utilized.

f. Schedule

(1) Hardware and software available for qualification testing, 1965.

(2) Hardware and software flight readiness date 1966 (mid to late).

IV. Participating Government Agencies

Sponsor: AF Aero Propulsion Laboratory, RTD
APFT

Test Equipment Acquisition: APFT, WPAFB, Ohio

V. Additional Requirements

a. Special Security - Unclassified

b. Manning Description Summary

One astronaut will be required to initiate deployment of all structures, periodically monitor instrumentation, and to inspect exterior of structures with AMU. The astronaut will require no special skills or qualifications. His normal work position will be inside of MOL. Total man hours involved over a thirty day mission is 3 hours. Frequency of AMU inspection missions - 10 day intervals - 12 minutes each.

c. Logistics - N/A

d. Facilities

The following qualification tests are considered essential to the over-all success of this experiment; vacuum deployment, thermal limit, structural testing, shake-rattle-roll, and centrifuge tests. The sponsor, APFT, has under it auspices all facilities necessary to conduct above tests. This experiment does not require man rating.

e. Simulation and Training

(1) Astronaut: Astronaut will require no additional training, except for a one or two day briefing on sequence of experiment.
(2) Ground Personnel: None required.
(3) Equipment: None

VI. General

a. Communication and Data Handling Requirements

Thermocouple monitors, strain gage monitors, and pressure leak rate required for instrumentation. Would prefer to time-share all instrumentation. Require data taking once/hour. Require 16mm movie or stop motion pictures of deployment and rigidization sequence.

b. Development Characteristics

(1) Development time - 1.2 years
(2) Final Definition Test Design Time - 8 years
(3) Number of Ground or Flight Tests - 36
(4) Type of Development Test Items

a) Vacuum chamber; 3 each type = total 9
b) Shaker - 3 total
c) Thermal - 3 total
d) Acoustic - 0
e) Simulators - 0
f) Aircraft - 3 (Zero "g" deployment)
f) Static Testing - 3 each

(5) Support Equipment Development Time - None
(6) Number of Test Articles Required for:
a) Ground test - 18
b) Atmospheric - 0
c) Space tests - 3 units for MOL readiness

(7) Data Available for Test - 1965

(8) Current Development Status:

a) Project approved

b) Funds expended to date - $900K

ANTENNA DEPLOYMENT, ALIGNMENT AND POINTING

I. OBJECTIVE: To deploy, align and point as necessary an antenna typical of those that may be employed in spaceborne high resolution radar equipments.

II. DESCRIPTION: The astronaut will deploy (unfold or unfurl) an antenna of approximately 25 ft. in length. Studies have indicated that this is a minimum length antenna for even experimental spaceborne radar equipments. After deployment, the astronaut will check the alignment of the antenna and adjust as necessary to maintain a phase relationship of 1/8 - 1/10 wave of the antenna is designed for operation at X band the alignment must be maintained to with in .5-1 cm along the entire 25 ft. length. The alignment must be maintained inspite of the severe temperature variations that will be encountered as the MOL moves in and out of the earth's shadow. After alignment and at an appropriate time the astronaut will position the vehicle so that the antenna will point at a calibrated ground target range. Coherent R/F energy will be transmitted and the reflected energy recorded and stored aboard the MOL vehicle. If suitable equipments exist, data processing and signal analysis may be done aboard the MOL and the astronaut may adjust equipments as necessary to optimize or measure performance of various system components.

III. IMPORTANCE OF TEST:

The application of high resolution radar techniques in space reconnaissance is a tremendously complicated problem in which there are many scientific phenomenological and engineering unknowns. One of the chief problem areas is the antenna with many specific problem areas such as: construction, deployment, alighment, the transmission of r-f energy to the antenna segments, etc. It is extremely doubtful if these problem areas can be overcome in space without a man performing a vital role.

IV. VEHICLE REQUIREMENTS:

Power:	1 kw (short periods only)
Volume:	20 cu ft in spacecraft
Weight:	1000 lbs (includes extra batteries)
Stabilization:	05 °/Sec
Aperture:	Small viewing ports for astronaut to observe antenna and to assess antenna adjustments

V. SIMULATION PROGRAM:

Pre-Phase I - None
Phase II - Astronaut Familiarity and Practice only

VI. EXPERIMENT DEFINITION:

Pre-Phase I - Contractor study to determine what antenna configurations and construction techniques appear feasible for future system application.

Phase I: The Phase I contractors will be asked to recommend and bid upon antennas whose general characteristics had been determined in the pre-phase I study.

VII. FUNDING REQUIRED:

Pre-Phase I	$ 150 k
Phase I	$ 300 k

VIII. PARTICIPATING AGENCIES:

Sponsor:	AFSSD/Aerospace
Participant:	RDT

RENDEZVOUS RADAR

I. Test Objective

The objective of this experiment can be broken down into the following basic subcategories:

a. To evaluate the components and overall performance of precision radars designed for spaceborne operation in both cooperative and non-cooperative modes.

b. To measure the effects of target motion and scintillation during close-in tracking. These measurements will establish a requirement on or for terminal guidance in vehicles designed to station-keep or dock with uncooperative or inoperative satellites.

c. To test and evaluate the radar as an auxiliary or emergency space navigation sensor using the radar as an altimeter and in conjunction with earth transponder beacons.

d. To test and evaluate the radar as an emergency communication device for space/ground or space/space communications.

e. Test and evaluate the role of man during terminal acquisition and homing and determine his advantages, disadvantages or best role as a controlling device during the terminal rendezvous maneuver.

II. Importance of the Test

Presently there exists no space qualified radars that will operate in the cooperative and non-cooperative modes. Since this system will become a primary development and test item for any future space mission requiring rendezvous (inspection, resupply, rescue, etc.) the present experiment will not only carefully define the radars capabilities, with or without man, but will also cut down future costs or lead times in operational hardware development. Furthermore, the MOL offers the unique advantages of man/unmanned operation and maneuverable targets like Gemini or the GTV which can operate in the cooperative or noncooperative modes. Since the MOL is also a precisely tracked test vehicle having man aboard, the full capability of the precision radar as a self-contained navigation and emergency communication/command device can be determined.

III. Description of the Experiment

a. Configuration of Test Items:

(1) Radar: Characteristics of this equipment will depend on the selected design, but the basic radar should have the capability to provide range and angle data (with associated rates) from 100 nm to 30 feet or less against an uncooperative target of 1 or 2 square meters in cross section. Electrical characteristics (PRF, frequency, wave form, etc.) should be tailored to optimize the MOL mission after definition studies. The radar should include provisions to operate with a matched transponder for cooperative tracking of ground and satellite beacons and be capable of complete manual or automatic control by the astronaut. A secondary mode should be provided for tracking at ranges below 2000 ft.

For planning purposes the following physical characteristics should be considered representative:

(a) Weight - 300 lbs
(b) Input power - 1800 watts primary mode, 50 watts secondary mode
(c) Antenna - 5 ft parabolic
(d) Volume - 4 ft^3 stowed - 20 ft^3 with antenna erected.

(2) Target: The target should be either a Gemini vehicle or a GTV, so that cooperative and non-cooperative operation can be tested and compared. Target and/or MOL maneuverability will be required to complete the rendezvous maneuvers.

(3) Associated Flight Equipment: A control and display console will be required for complete manual control and adjustment by the astronaut. Beacons and radar matched communications electronics will be required at the MOL tracking sites for the navigation and communications tests.

(4) AGE: Standard functional check equipment will be required for factory and launch facility installation.

b. Once the MOL is manned, all aspects of the experiment can be started in an order that best suits the planned mission profile. The following test series indicates the test content only and not an established priority.

During the first several orbits, the radar is warmed up and interrogates known ground transponders providing range, range rate, line-of-sight, LOS rate, and orbit altitude data to both man and computer. The results of the on-board computer calculations are then compared with ground ephemeris. Mans calculations, along with attitude references gained from computed position and sequential transponder readings, could also establish the applicability of using the radar as an emergency positioning and re-entry system.

The next sequence will be established during the first rendezvous. If the target is a Gemini vehicle or or GTV, tracking should be established alternately in the cooperative and uncooperative modes. down to a distance of 5000 feet. At this time tracking should be switched to the uncooperative mode and rendezvous (to docking if possible) completed. The effects of scintillation can be ascertained and corrected for during the latter terminal stages. The results of this sequence will definitely establish the value of man for rendezvous and/or docking, and will establish the feasibility, limits and/or penalties to be expected by automatic operation.

At a time compatible with crew duty and mission profile the emergency communications experiment can be completed. For purposes of this experiment space/ground communications should suffice. The astronaut should place the radar in the manual search mode and attempt to orient the antenna toward the known ground site. Continuous antenna reorientation will be required during the length of the transmissions. The manually controlled radar transmitter then transmits the required information in a mode most adaptable to wave form characteristics and design. Changes in PRF, frequency, and duty cycle, or amplitude modulation are possibilities to be considered in coding the communication. Reception can be obtained by manual control over the nominal transmit-receive sequence, causing continuous receiver operation. Auxiliary electronics will convert the received signal to audio or visual displays required by the astronaut.

c. Category of Experiment: The radar and associated controls are category "a" equipment and will dictate part of the MOL vehicle design. Allowances will have to be made for the large weight, and the large stowable antenna. The antenna should be placed to give maximum view, both in azimuth and elevation when erected, and allowances made for the antenna dynamics, inertias, and alignment accuracies.

From an operational standpoint remote control is acceptable but in-flight maintenance may be required on the electronics making accessability advisable.

d. Cost (for 4 units and AGE)

	Prior	FY 65	FY 66	FY 67	FY 68	TOTAL
1. Engr & Dev	Unk	1.0	3.4	2.6	-	7.0
2. Installation		-	.3	.5	.3	1.1
3. Ground Support		0.05	.15	-	-	.20

e. Schedule: (Assuming 1 Jul 64 start)

Hardware available for test - July 1966

Hardware flight readiness date - August 1967

IV. Participating Government Agencies

SSD/Aerospace

Participant: RTD

V. Additional Requirements:

a. Special Security - None.

b. Manning Description Summary - Only one man will be necessary for the space operations. He should be completely familiar with the equipment and its operation so that in-flight maintenance can be performed. Ground test support forces should be supplied mainly from contractor resources. Operational ground support for beacon tracking and communications should be satisfied by the manpower of existing tracking facilities.

c. Logistics - No special logistics requirements exist since the contractor will supply all hardware for flight, test and maintenance. The addition of this experiment will not impose additional logistics requirements to those already existing for tracking and communicating with the MOL vehicle.

d. Facilities - No special facilities will be required.

e. Simulation and Training -

(1) Astronaut

The astronaut should have a background in electronics and OJT at the contractor's plant for at least four months. Complete knowledge of the operation, adjustment and maintenance of the system is mandatory.

(2) Ground Personnel -

No special requirements exist as this support should come from contractor resources.

(3) Equipment

No special equipment will be needed for flight or ground personnel.

VI General

Development Characteristics: Once the MOL mission profile, target type, and this experiment are defined, a normal development cycle should lead to hardware tailored to fit the job. No particular problems are to be expected unless ranges of over 100 NM are required in the non-cooperative mode.

ATTACHMENT A

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED: Spaceborne radar detection and tracking system.

2. WEIGHT: 300 lbs

3. VOLUME: Stored - 4 ft^3. In use - 20 ft^3 (antenna erected externally).

4. CRITICAL DIMENSIONS - SHAPES - 5 ft parabolic antenna in both stowed and extended configuration.

4. POWER:
Continuous - N/A
Standby - 300 watts
Average Operating - 1800 watts primary; 50 watts secondary
Peak - N/A
Duty Cycle - N/A

5. SPARES:
Volume - To be determined
Quantity - To be determined
Weight - To be determined

6. TOOLS:
Volume - To be determined
Quantity - To be determined
Weight - To be determined
Power - To be determined

7. HEAT OUTPUT - approximately 1300 watts during primary mode operation

8. STABILITY:

Moving parts - Massive antenna will be in motion during search mode producing torques on host vehicle

9. VIBRATION LIMITS: None - can be built to stand expected environment

10. SHOCK LIMITS: None - can be built to stand expected environment

11. HAZARDS - Hi voltage

12. TEMPERATURE LIMITATIONS: Will require active cooling if operated for more than 30-45 minutes in primary mode without a 3 or 4 hour cooling period.

13. TYPE AND RANGE OF MEASUREMENT: Range and angle to target from 100 NM to 30 ft. Range and angle rate can also be obtained if required.

14. SPECIAL ENVIRONMENTAL REQUIREMENTS: Extreme precautions against RFI/EMI should be taken during design and integration.

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS:

    Precise alignment of antenna is required in all three axis.

16. EQUIPMENT OPERATING CYCLE:

    Frequency - To be determined

    Time Duration - To be determined

17. EQUIPMENT LOCATION REQUIREMENTS - Antenna should be positioned to provide minimum obstruction to view in both azimuth and elevation.

18. SPECIAL MOUNTINGS REQUIREMENTS:

    Antenna - May require extendable or foldable boom to position antenna to the operating configuration. Mountings, brackets, and etc will have to handle a dynamic 5 ft diameter parabolic antenna and still maintain precise alignment accuracies.

19. PRESSURE VESSELS - fluids, gasses, etc. N/A

20. ELECTRO MAGNETIC INTERFERENCE (spurious generation, special shielding req, etc.)

    Special shielding, isolation and all other precautions are required to prevent EMI emanations.

21. MAINTENANCE REQUIREMENTS:

    Ground - Factory only. Calibration, alignment and checkout can be done in the field.
    Space - Modular change of electronics and calibration only.

ATTACHMENT B

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA:

   a. Tape - To be determined
   b. Film - To be determined
   c. Other - N/A

2. HANDLING: Special dolly required for ease in handling.

3. PACKAGING: Standard MIL Spec requirements are sufficient.

4. CALIBRATION - alignment, deployment: Flight control console should contain controls for in-flight calibration; AGE and factory test equipment for ground operations.

5. JIGS AND FIXTURES: None

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION: Approximately 6

7. SENSORS (Transducer - Output Signals): To be determined

8. TRAINERS/SIMULATORS: N/A

9. INSTRUMENTATION - cockpit and/or laboratory (note effect of time sharing instruments with other experiments.): A full control console should be provided to allow monitoring in the automatic mode, and operation in the manual mode.

10. RELATED SUPPORT EQUIPMENT:

    a. Targets - Anechoic chambers required for ground test in active mode. A Gemini or GTV is required for flight tests.
    b. Ground Stations - Should be equipped with transponders and receivers/transmitters compatible with the radar system.
    c. Tracking - N/A
    d. Handling Equipment - N/A

11. AGE: Standard contractor supplied AGE will be required for ground check-out and maintenance.

12. ENVIRONMENTAL TEST EQUIPMENT: Standard chambers and shakers available at contractors facilities are sufficient.

13. FACILITIES: No special facilities required.

ATTACHMENT C

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS (desired):

   a. Altitude - To be determined
   b. Inclincation - To be determined
   c. Epoch - To be determined
   d. Ellipticity - To be determined

2. PLANE CHANGE - N/A

3. ALTITUDE CHANGE - N/A

4. TIME ON ORBIT - To be determined

5. TEST DURATION - To be determined

6. TOTAL NUMBER OF TESTS - To be determined

7. TEST FREQUENCY - N/A

8. INTERVAL BETWEEN TESTS - To be determined

9. CREW TASK LOADS - man hours - To be determined

10. CREW TASK FREQUENCY - To be determined

11. FIELD OF VIEW REQUIREMENTS - Antenna should be mounted to provide minimum obstruction to view in both azimuth and elevation.

12. GROUND CONTROL LIAISON DURATION - To be determined

13. GROUND CONTROL LIAISON FREQUENCY - To be determined

14. EXTERNAL TEST ITEMS:

   a. Launched from station - None
   b. Launched from Resupply - None
   c. Launched from ground - Gemini or GTV targets

15. QUALIFICATION TESTS (other than space)

   a. Ground - To be determined
   b. Atmosphere - N/A

16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT - To be determined

17. HANDLING PROCEDURES - To be determined

SECRET

ATTACHMENT D

FUNDING SUMMARY

BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	PHASE I FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing	Unk	.82	3.4	5.4	1.5	- -	11.12
Integration & Installation			.35	.35	.35		1.05
AGE			.2	1.0			1.2
Simulators/Trainers							
Data Reduction							
Equipment Rework							
Other (Ground beacons, etc)				1.0	1.0		2.0
TOTAL		.82	3.95	7.75	2.85		15.4

Source of Funds - Hitch Line Number

SECRET

ATTACHMENT E

MANNING DESCRIPTION

1. ASTRONAUTS

a. Number required: One required

(1) Man's function

(a) As part of test: Operates system in manual control during space positioning, emergency communication, and rendezvous sequences.

(b) As technician conducting test: Monitors automatic control and provides maintenance.

b. Crew skill requirements: Background in electronics and 4 months OJT at contractor's plant required.

c. Manpower profile: To be determined

d. Critical functions: to be determined

e. Work positions: Remote control is acceptable except for maintenance which requires accessibility to electronics.

f. Time controlled tasks: to be determined

g. Human performance measures: Comparisons of manual and automatic performance during rendezvous. Parameters are time and velocity required for completion

h. Physiological and psychological measures: To be determined

i. Selection factors: See 1b above

j. Training requirements: See 1b above

2. GROUND PERSONNEL

Number required: To be determined

ATTACHMENT F

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE: To be determined
2. FUNCTIONS TO BE MEASURED: To be determined
3. TYPE OF ANALYSIS REQUIRED: To be determined
4. PICTORIAL DATA REQUIRED: Target position versus time at ranges of 2,000 feet to rendezvous.
5. REAL TIME MONITORING REQUIREMENT: N/A
6. DATA EDITING OR COMPRESSION: N/A
7. READ-OUT TIME: To be determined
8. REQUIREMENTS FOR PERMANENT DATA RECORDS: To be determined
9. MANUAL AND/OR AUTOMATIC CONTROL: To be determined
10. SIMULTANEITY: N/A
11. GROUND COMMANDS REQUIRED: To be determined

ATTACHMENT G

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME: 37 months from start

2. FINAL DEFINITIVE TEST DESIGN TIME: To be determined

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED: Two units should be ground tested and one flight tested.

4. TYPE OF DEVELOPMENT TEST ITEMS:

   a. Vacuum Chamber
   b. Shaker
   c. Thermal
   d. Acoustic

   To be determined - Standard contractor test facility now in existence should suffice.

   e. Simulators - N/A

   f. Aircraft - N/A

5. SUPPORT EQUIPMENT DEVELOPMENT TIME: 12 months from start

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

   a. Ground Test: Two

   b. Atmospheric Test: N/A

   c. Space Test: Two (one as flight back up)

7. DATE AVAILABLE FOR TESTS: August, 1967

8. CURRENT DEVELOPMENT STATUS: All components and techniques have been previously developed.

Experiment No. S-9

MANUALLY CONTROLLED TV AND ORBITAL INSPECTION PHOTOGRAPHY OF EXTRAVEHICULAR OBJECTS

I. Test Objectives:

Primary: a. Evaluation of man's ability to select and control in space photographic conditions to obtain best photographs of all target aspects under varying orbital lighting conditions without use of artificial illumination, (i.e., obtain target details in deep sun shadow areas utilizing available earth shine).

b. Evaluation of man's ability to make on the spot evaluations of electronically displayed photographic results for selection of best photographs for electronic transmission to ground stations and/or reprogramming of camera controls and photographic geometry for optimum natural illumination conditions.

Secondary: a. Evaluation of the relationships between the electronic transmission of photographs to a central control station for further interpretation and the ability of a central control station to direct and/or control photographic conditions of either manned or unmanned rendezvous inspections.

b. The collection of both space taken photographs and their electronic transmitted reproductions as intelligence background data for use in either the interpretation of future satellite inspection photographs or to refine future photographic equipment and transmission performance specifications to satisfy image quality needs for intelligence interpretation.

c. The evaluation and/or use of a prototype rendezvous inspection photographic sensor as supplementary MOL equipment for the permanent photographic recording of extravehicular experiments, rendezvous operations, and man's extravehicular activity with nearby or tether experimental objects.

II. Importance of Test:

This test will provide the data required to establish the operational and equipment limitations of unmanned versus manned rendezvous inspection photography. The dual lens camera concept with simultaneous image recording on alternate frames of the same roll of film is intended to provide maximum operational capability in a minimum equipment package. It also contains in the same unit film development and electronic readout of the developed film. Camera coverage consists of a 40° field of view with [redacted] target resolution at 2,000 ft. and a central 8.5° field of view with [redacted] resolution at 2,000 ft. Intended to work with this unit is a TV camera utilizing a sec-vidicon in conjunction with a turret lens and an 0.6 microsecond pulse illumination unit for nighttime operation. Manual control of actual picture taking is accomplished by means of viewing the TV monitor. However, the resolution capability of the TV monitor is much less resulting in less intelligence detail than that obtained with the photographic unit. The full operational significance and limitations of this capability will be established by this experiment. In addition, it will provide experimental evidence of man's capability to receive, process, and evaluate information and then make command decisions during satellite inspection on what courses of action to take while in a space environment. This experiment will also provide actual data to determine the required in-space performance necessary to produce photographs containing significant detail for use in intelligence interpretation. As a result this experiment will be simultaneously accumulating intelligence background data on satellite inspection activities.

III. Description of the Experiment:

Normally, in an actual inspection vehicle this combination of photographic unit and TV camera-illuminator would be in a body fixed mounting located in an unpressurized area with aperatures for the required fields of view. This experiment, however, contemplates the use of prototype inspection equipment as a supplemental TV monitor and photographic recorder for other extra-vehicular experiments. As such it requires consideration of a more flexible mounting within MOL. The devices could be stored in the work area during ascent to orbit. Once in orbit the devices could then be mounted on an extension protruding from the MOL vehicle. The desirability of manual assembly or automatic self-erection of the extension as an expanding boom is yet to be determined. The extension would hold the TV camera and photographic unit away from the vehicle and allow orientation of its field of view toward the experimental area of interest. Electrical control of mounting platforms orientation in elevation and azimuth with respect to the MOL vehicle is desirable. Controls and visual display equipment would be located in the pressurized area. Direct viewing for visual monitoring from the pressurized vehicle is desirable to allow simultaneous visual observation of both the equipment and the extravehicular experimental area.

The equipment would be first checked out operationally by taking photographs of the MOL vehicular extremities and viewing the processed film frames on the electronic readout display. Fifteen minutes of film processing time is required after picture taking before photographic readout can be initiated. This experiment would then be conducted in conjunction with other extravehicular experiments and consist of an astronaut utilizing the equipment to monitor and record the experiments. Prime interest lies in photographic recording of the following experiments: (1) decoy deployment, (2) experiments and activities with a remote maneuvering unit, (3) MOL rendezvous experiments concerning simulated or actual resupply, fuel transfer, space rescue, and/or docking, (4) an inspection oriented MOL rendezvous experiment with either another in-space operating MOL or previously expended MOL section. These other experiments would be partially modified in procedure to allow favorable orientation of the camera, experimental objects, sun, and earth shine to effect inspection simulation while monitoring and recording the conduct of the experiments. Provisions will have to be made to allow in-orbit realignment of the geometric relationships between the camera, experimental objects, and natural illumination. The determination of the required in-orbit realignment would be made by the MOL crew in conjunction with the ground control station after evaluation of the electronic displays of the photographic images. Continual analysis by the ground control station would provide the MOL crew with instructions for appropriate realignment and/or procedure modification of succeeding tests. This would effect minimum interference with the conduct of the extravehicular experiments and yet provide maximum data for this experiment. It is recognized that it is possible to adapt existing off-the-shelf photographic units, TV cameras, and illuminator units to accomplish the experiment observation function for a particular MOL station. However, although these equipments with their limited performance may fill MOL's immediate observation requirements, they generally would be heavy, unreliable and too limited in performance capability for ensuing military space missions. Since the development lead time requirements of this proposed equipment is timely to MOL, it is proposed that, to achieve the maximum return on our investment, preference be given to the development and utilization of this equipment on MOL.

a. Configuration of Test Items

The nature of this experiment is such that the equipment items can serve a dual function, i.e., obtain data for this experiment and also provide photographic coverage of other extravehicular MOL experiments. Consequently, the ascent storage location in MOL as well as the assembled external location will be of prime concern in the design of a particular MOL station. Known data regarding the equipment elements is included in Attachment A. However, a study will be required to determine which MOL flights the equipment would go on, its impact upon and relationship with the other planned experiments, which flights require the extension platform versus simple exterior mounting, and/or the advisability of rendezvous with a previously expended MOL section for removal and utilization of equipments such as this photographic unit, TV camera unit and boom extension.

b. Test Support Equipment Required

Known details are included in Attachment B.

c. Test Procedure

Since this experiment is dependent on other on-board extravehicular experiments, detailed procedures cannot be described until it is decided to include and integrate it into a particular MOL flight. Then the procedures for other planned experiments can be reviewed and appropriately modified to meet the objectives of this experiment. The desired results will evolve from ground analysis of the transmitted images, in-flight photographic conditions, and the recovered film. As a consequence, the desired results do not depend upon the specific procedures employed to obtain pictures but depend upon the objects within camera fields of view and the geometric relationships of the natural illumination at the time of photography. It is anticipated that the required equipment for this experiment will become part of MOL crews experiment observation and recording equipment. Therefore, experience of the crew in taking and reviewing the on-board photographs may dictate modifications in planned procedures and timing of the other experiments in order to obtain the best photographic recording and observation conditioning for the experiments.

d. Category of Experiment

This experiment is considered to be in Category A. It affects the capability of MOL's photographic recording and monitoring of extra-vehicular experiments. It requires the MOL vehicle design to include provisions for internal storage during ascent of exterior mounted equipment elements which are later assembled in orbit by the MOL crew and attached to the MOL. Particular attention to the electrical connectors for vacuum plug in as well as methods of applying power to exterior plugs will be required.

e. Costs and Schedules

Engineering development of the inspection photographic unit and the associated inspection TV camera with its nighttime illuminator requires a forty (40) month lead time for both items. If go-ahead is given by August 1964, then the first flight units could be delivered for installation on a MOL station by April 1967 for the TV camera and illuminator and by July 1967 for the photographic unit. Available data on costs and schedules: (6 flight units)

Photographic Unit	FY 65	FY 66	FY 67	FY 68
Eng & Devel				
Installation		See Attachment D		
Ground Support				

TV Camera and Illuminator	FY 65	FY 66	FY 67	FY 68
Eng & Development	$375,000	$555,000	$849,000	$75,000
Installation	To be determined in relation to MOL.			
Ground Support	To be determined in relation to MOL, 3 sets of aerospace ground equipment are included in the engineering and development cost figures.			

IV. Participating Government Agencies:

Sponsor - SSD
Participant: RTD
Test Equipment Acquisition - SSD

V. Additional Requirements:

a. Special Security - To be specified.

b. Manning Description Summary - To be specified.

c. Logistics - To be determined.

d. Facilities - To be determined.

e. Simulation and Training -

(1) Astronaut: Should be trained as technicien to operate the equipment but must be given scientific training in photography and illumination effects as well as photo interpretation. Simulation of equipment control and extra-vehicular experiment control in a MOL simulator will be highly desirable. Need to develop astronaut skills in his ability to simultaneously observe, record, and control planned extra-vehicular experiments, when conceivable malfunctions and erratic experiment conditions occur, such as drifting equipment, meteorite impacts, sunlight to earth shadow traversals, and/or miscellaneous power fluctuations or failures.

(2) Ground Personnel: Training in equipment checkout, photo-interpretation of transmitted results, ground command of automatic equipment operation, i.e., for advising astronaut and simulating ground command control of unmanned rendezvous inspection conditions.

(3) Equipment: To be determined.

VI. General:

a. Communications and Data Handling - To be determined for maximum evaluation of the control of manned and unmanned rendezvous inspection capabilities.

b. Development Characteristics - To be determined to establish compatibility between MOL and the rendezvous inspection sensor package Advance Technology Development Program.

ATTACHMENT A

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED: Dual lens rendezvous inspection camera with electronic film readout and inspection TV camera with illuminator.

2. WEIGHT:

Photographic unit	-	175 lbs
TV camera	-	35 lbs
TV illuminator	-	75 lbs
Extension platform	-	80 lbs
Display and controls	-	30 lbs
Total	-	395 lbs

3. VOLUME:

	Stored	In Use	
		Interior	Exterior
Photographic unit	5.0 ft^3	- - -	5.0 ft^3
TV camera	0.2 ft^3	- - -	0.2 ft^3
TV illuminator	1.6 ft^3	- - -	1.6 ft^3
Extension platform	3.0 ft^3	- - -	3.0 ft^3
Display and Controls	1.5 ft^3	1.5 ft^3	- - -
Total	11.3 ft^3	1.5 ft^3	9.8 ft^3

4. POWER:

a. Continuous - To be determined for temperature control requirements.
b. Standby - To be determined.
c. Average operating - 285 watts.
d. Peak - 380 watts.
e. Duty cycle - To be determined, may depend primarily on operator control and related extra-vehicular experiments or objects to be photographed.

5. SPARES:

a. 4 film refills: Volume 2 ft^3
Weight 60 lbs
b. Miscellaneous: Volume 1 ft^3
Weight 30 lbs

6. TOOLS:

Assembly, film refill and minor repair: Volume ½ ft^3
Weight 30 lbs

7. HEAT OUTPUT: To be determined.

8. STABILITY: Requirements for controllable platform to be determined.

9. VIBRATION LIMITS: To be determined.

10. SHOCK LIMITS: To be determined.

11. HAZARDS: To be determined concerning film processing unit and its refill as well as external inflight electrical connections.

12. TEMPERATURE LIMITATIONS: To be determined.

13. TYPE AND RANGE OF MEASUREMENT: Photographic unit-temperatures, pressure, and processing chamber humidity; go no-go indicators on shutter mechanisms, film advance and take-up, readout mechanisms, and readout section BIMAT sticking or jam. The interior film readout display is the primary use item for photographic quality evaluation.

14. SPECIAL ENVIRONMENT REQUIREMENTS: To be determined, none expected.

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS:

    a. Station - .016 radian/sec max. tolerable angular velocity during picture taking.
    b. Equipment - Astronaut control of field-of-view pointing.

16. EQUIPMENT OPERATING CYCLE: As determined by operator control.

17. EQUIPMENT LOCATION REQUIREMENTS:

The external mounting plate or extension boom and platform should be located such that (1) direct viewing of both the equipment and extra-vehicular experiment area is possible from the pressurized control area, (2) the MOL's TV monitoring camera can be also mounted on same platform, (3) at least one extremity of MOL vehicle can be photographed.

18. Special mountings requirements: A specially designed equipment and/or boom extension mounting plate on MOL's exterior is required to allow in orbit assembly and electrical connection.

19. PRESSURE VESSELS: To be determined, none expected.

20. ELECTRO MAGNETIC INTERFERENCE: To be determined.

21. MAINTENANCE REQUIREMENTS: Ground - To be determined; Space - To be determined.

ATTACHMENT B

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA:

   a. Tape - Video tape for temporary storage of several frames of both the electronic film readout pictures and selected TV imaging. Capability of transmission from tape to ground stations is required in the event of photographic unit malfunction or BIMAT sticking to film prevents recycling of picture readout. Temporary storage of units temperature and pressure reading is desirable.
   b. Film - To be determined, possibly film recording of TV images.
   c. Other -

2. HANDLING - To be determined.

3. PACKAGING - To be determined, expect special tie down and possible shock absorption pad for ascent to orbit.

4. CALIBRATION - Field-of-view alignment with adjacent TV monitoring camera may be required.

5. JIGS AND FIXTURES - To be determined.

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION - To be determined.

7. SENSORS - To be determined.

8. TRAINERS/SIMULATORS - To be determined.

9. INSTRUMENTATION - To be determined.

10. RELATED SUPPORT EQUIPMENT:

    a. Targets - 1 decoy minimum, others to consist of planned extra-vehicular experiments, plus a photographic test target consisting of a corner reflector with detailed designs on it.
    b. Ground station - To be determined, none expected.
    c. Tracking - Line-of-sight and range information needed from MOL on-board equipment.
    d. Handling Equipment - To be determined, as concerns resupplying film to the photographic unit, and recovery of film at the termination of the MOL flight.

11. AGE - To be determined.

12. ENVIRONMENTAL TEST - A space simulation chamber for operational ground test of assembled extension boom, platform, visible TV camera unit and photographic unit. Primary concern is vacuum and thermal effects on photographic unit and the controllable platform.

13. FACILITIES - To be determined.

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Exp No. S-9

ATTACHMENT D (Revised)

Funding Summary (Photography - TV Manually Controlled for Flights #3, #4, #5 and #6)

Budget Requirements by Fiscal Year (K = $1,000.00)

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Development Environmental Testing (1 Flt Unit)							
Dual Lens Camera with Readout		1,200K	2,510K	3,245K	805K		7,760K
TV Camera with Pulsed Illuminator		585K	825K	760K	180K		2,350K
In-flight Display & Control Console		150K	680K	870K	120K		1,820K
TOTAL		1,935K	4,015K	4,875K	1,105K		11,930K
Integration & Installation				740K	2,745K	1,690K	5,175K
AGE (3 sets)		70K	806K	844K			1,720K
Simulators/Trainers			1,200K	2,500K	1,800K		5,500K
Data Reduction					700K	1,050K	1,750K
Equipment Rework							
Other							
TOTAL		2,005K	6,021K	8,959K	6,350K	2,740K	26,075K

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Exp No. S-9

ATTACHMENT D (Revised)

(Photography - TV Manually Controlled)

Cost Data

Dual Lens Camera with Readout

(K = $1,000.00)

	FY 65	FY 66	FY 67	FY 68
Phase I	275K			
Phase II				
RTDE	1,200K	2,510K	1,540K	
AGE	70K	690K	760K	
1st flight unit			830K	
	1,545K	3,200K	3,130K	
Additional Flt Units				
2nd			500K	60K
			3,630K	60K
3rd				
4th			375K	185K
			4,005K	245K
5th				560K
				805K
6th				560K
				1,365K

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Exp No. S-9

ATTACHMENT D (Revised)

(Photography - TV Manually Controlled)

Cost Data

SEC Vidicon TV and Pulsed TV Illuminator

(K = $1,000.00)

	FY 65	FY 66	FY 67	FY 68
Phase I	300K			
Phase II				
RTDE	285K	825K	415K	
AGE		116K	84K	
1st flight unit			150K	
	585K	941K	649K	
2nd			125K	
			774K	
3rd			70K	55K
			844K	55K
4th				125K
				180K
5th				125K
				305K
6th				125K
				430K

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Exp No. S-9

ATTACHMENT D (Revised)

COST DATA

FLIGHT CONTROL CONSOLE FOR TV CONTROLLED PHOTOGRAPHY

(K = $1,000.00)

	FY 65	FY 66	FY 67	FY 68
Phase I	150K			
Phase II				
RTDE		680K	420K	
1st flight unit			170K	
TOTAL	150K	680K	690K	
2nd			100K 790K	
3rd			60K 850K	40K 40K
4th			20K 870K	80K 120K
5th				100K 220K
6th				100K 320K

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ATTACHMENT D (Revised)

Funding Summary (Photography - TV Manually Controlled)

Integration & Installation Cost Estimates for Flights #3, #4, #5 and #6

(K = $1,000.00)

	FY 67	FY 68	FY 69	TOTAL
Coordinate Integration	100K	100K	100K	300K
Interfacing and Layout Designs (2 vehicles)	400K	275K		675K
Special Studies & Experiments	240K	160K		400K
Vehicle Interfacing Fabrication		1,850K	750K	2,600K
Equipment Installation & Checkout	___	360K	840K	1,200K
TOTAL	740K	2,745K	1,690K	5,175K

Data Processing Cost Estimates

	FY 68	FY 69	TOTAL
Analysis & Evaluation of Ground Control, Simulator & Astronaut Training for Data Handling	500K	500K	1,000K
Initial Photo Set Ups and Trial Runs	200K		200K
Flight & Post Flight Data Processing & Analysis		550K	550K
TOTAL	700K	1,050K	1,750K

Experiment No. S-10

MAPPING AND GEODETIC SURVEY FOR IDENTIFIED POINTS

I. Test Objective

This experiment will achieve a great improvement in the knowledge of the ties between the various major continental data. The results will contribute directly to a more precise knowledge of the location of positions on the earth's surface.

II. Importance of the Test

Present estimates of the uncertainty of positional errors of some of the unmapped areas of the earth's surface are as large as 2000 to 5000 ft. In some special cases the errors noted are as large as 10,000 ft. These errors are greater than acceptable for intermediate range ballistic missiles and constitute a problem for intercontinental range ballistic missiles. Because of the difficulty of flying over portions of the earth's surface in an airplane or balloon, only a satellite is acceptable for accurately mapping these unknown regions. The ANNA satellite which was successful in mapping areas with an extensive cooperative ground based observing system, considerably improved geodetic knowledge. However, in large areas, such as the Soviet Union and China, where such cooperation is not probable, good positional accuracy has not been realized.

For a manned spacecraft such as MOL, whose ephemeris is accurately known and where the principal errors contributing to a mapping operation are of the order of a few hundred ft., one can conduct a complete mapping of any region.

The uncertainty in such a map will be the uncertainties in the spacecraft ephemeris and the ability of a man to accurately point a camera and laser radar at a well identified point on the ground. The experiment described here will satisfy an immediate military requirement of locating positions on the earth to within a few hundred ft. It will provide a secondary scintific purpose by accurately relating major datums of the continents and improving the present knowledge of geodesy. It will greatly assist in assessing man's capability of performing an experiment in space.

III. Description of the Experiment

The experiment will determine the position of permanent land marks such as rivers, lakes, continental boundaries, and distinguishing terrain, by measuring their absolute position and the separation distance between bench marks. These measurements are obtained from an accurately determined ephemeris of the spacecraft and devices for measuring the range from the spacecraft to the point of interest and the angle of the spacecraft with the radius from the center of coordinates. This will determine the angle and radius of the point with respect to a primary datum which is already established. The uncertainties in the ephemeris and in the range and angle measuring devices are such that the positional accuracy can be made as low as several hundred ft.

The experiment consists of a special camera which photographs a point on the ground and simultaneously the star field along the line of sight. The range from the spacecraft to the point is determined by means of a giant pulse ruby laser and counter. This determines the absolute position of a point with respect to the spacecraft ephemeris. Points of separation between two objects can be determined with the camera and a crystal clock which determines the transit time between the two points. This will permit an extensive mapping of a region with high internal precision and with accurate reference to an external datum point. The most significant problem that is expected to be encountered in this measurement is that of identifying the targets on the ground with sufficient accuracy for mapping purposes. However, with the aid of an auxiliary optical system which will be a part of the spacecraft, it is expected that this problem will be resolved.

a. Configuration of Test Items

The principal items of test equipment to be used for the geodetic experiment are: (1) a camera which will simultaneously photograph a position on the ground with sufficient resolution to identify the object photographed on which is superimposed the star field on the optical axis, (2) a laser range device which consists of a capacitor, high voltage power supply, electronic circuitry, and ruby laser will determine the range from the spacecraft to the ground, and (3) a 50 megacycle counter to measure the transit time of the light pulse from the spacecraft to the ground and back. In addition, the separation distance between two points on the ground can be accurately determined by using the camera and a precision crystal clock to determine the transit time between the points. Since the camera is required to observe the earth, it will be necessary to locate this item and the laser head on the MOL in such a fashion as to permit it to view simultaneously the ground and the star field. Attachment I gives the design characteristic details.

Physical dimensions of the equipment are as follows:

Item	Dimensions	Wt.	Power	Volume
Camera	6" x 12" x 12"	25 lbs.	1 watt	0.5 cu ft
Capacitor	8" x 8" x 8"	36 "	None	0.3 " "
Power Supply & Electronics	2" x 4" x 6"	2 "	2 watt	0.03 " "
Laser Head & Mirror	4" x 4" x 5"	1 "	None	0.05 " "
Counter & Clock	5" x 17" x 19"	43 "	100 watt	0.93 " "

These items may be placed at any convenient spot on the vehicle where the camera and laser head have a view of the ground.

b. Test Support Equipment Required

(1) Spacecraft

In addition to the equipment described, the support of an auxiliary optical system to identify objects on the ground and to point the camera and laser at the same point is required.

(2) AGE

Range support to accurately establish an ephemeris for the vehicle and checks on the crystal clock on board to maintain time accuracies to 1 millisecond are required. Attachment II describes the test support equipment in detail.

c. Test Procedure

It is planned to observe a large network of identified objects on the ground to establish a map which is internally accurate from the clock measurements and to relate one or more points of the map to one of the major datums in the

United States. To accomplish this, the astronaut will have to identify major and minor land marks which are permanent such as large lakes, rivers, cities, or other distinguishing terrain. Attachment III describes the test operating factors. Man's contribution to the experiment is in the identification of and selection of significant areas and objects to be mapped. He will be utilized to the maximum extent possible in making decisions on the importance of the objects he identifies for mapping and the care with which he makes the measurement. His contribution will be measured by the quality of the map he produces.

d. Category of Experiment

This experiment is expected to be a Category A1 experiment in that it contributes to the MOL objectives, but does not exert a significant influence on the design characteristics of the laboratory.

e. Cost

	FY65	FY66	FY67	FY68	FY69	Total
(1) Engineering and Development	150K	150K	150K	100K	100K	650K
(2) Installation	25K	25K	100K	100K	100K	350K
(3) Ground Support					100K	100K

f. Schedule

(1) Hardware and Software Available for Test

Prototype hardware will be constructed during FY65 and available for test during FY66.

(2) Hardware and Software Flight Readiness Date

Flight ready equipment will be available beginning with FY67, tested and flight qualified.

IV. <u>Participating Government Agencies</u> Sponsor: SSD/Aerospace

It is expected that the agencies concerned with geodesy and mapping such as were utilized in the ANNA satellite will be active participants in conducting, monitoring, and evaluating the experiment. Since the information obtained will be of interest to all agencies, agency responsibility similar to ANNA will be required. Test equipment should be acquired by a single agency with a concurrence of all participating agencies.

V. <u>Additional Requirements</u>

a. <u>Special Security</u>

Special processing of the data will be required in view of its importance to identification of possible target areas in the Soviet Union and China land areas.

b. <u>Logistics</u>

No special requirements.

c. <u>Facilities</u>

Existing facilities can be used for the experiment integration. Coordination with the national range, and SSD satellite network will be required to obtain an accurate ephemeris. It is expected that training of the astronaut will require use of a flight simulator, but only for the purposes of instructing the astronaut in the use of the quipment.

d. Simulation and Training

(1) Astronaut

The astronaut must be trained to the level of a technician in order to achieve full effectiveness in this experiment. It is expected that a few weeks training in photoreconnaisance work and in astronomical observation techniques will be adequate to develop a capability necessary for the experiment.

(2) Ground Personnel

No requirement.

(3) Equipment

The equipment to be used in the experiment will be utilized in training the astronaut.

VI. General

a. Communications will be limited to discussions with specially informed ground based personnel on particular areas to be observed. This will involve someone with knowledge of the land mass expected to be surveyed. Data will be recorded on film and magnetic tape and will be required to be recovered with the re-entry vehicle.

b. Development Characteristics

No additional requirements.

Exp. No. S-10

ATTACHMENT I

1. LASER RADAR AND GEODETIC CAMERA

2. WEIGHT: 107 LBS.

3. VOLUME: Stored 1.81 cu ft In use 1.81 cu ft

4. CRITICAL DIMENSIONS

Item	Dimensions
Camera	6" x 12" x 12"
Capacitor	8" x 8" x 8"
Power Supply & Electronics	2" x 4" x 6"
Laser Head & Mirror	4" x 4" x 5"
Counter & Clock	5" x 17" x 19"

5. SPARES

a. Volume: 3.62 cu ft

b. Quantity: 2

c. Weight: 200 lbs.

6. TOOLS

No requirement

7. HEAT OUTPUT

100 watts with 1/10 duty cycle

8. STABILITY

No requirement

9. VIBRATION LIMITS

20 g's

10. SHOCK LIMITS

30 g's

ATTACHMENT I (cont'd.)

11. HAZARDS

Electrical, 10 kv power supply

12. TEMPERATURE LIMITATIONS

No requirement

13. TYPE AND RANGE OF MEASUREMENT

Ground based photographically and laser radar ranging

14. SPECIAL ENVIRONMENTAL REQUIREMENTS

No requirements

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS

Accurate ephemeris and accurate time evaluation

16. EQUIPMENT OPERATING CYCLE

Several times daily -- Time duration: 15 min.

17. EQUIPMENT LOCATION REQUIREMENTS

Camera requires access to ground and stellar background

18. SPECIAL MOUNTING REQUIREMENTS

Apertures: Clear view of ground and stars

Pulse: None

Windows: None

Antennae: None

Bracketry: Mountings for camera, laser and power supply

19. PRESSURE VESSELS

No requirements

20. ELECTROMAGNETIC INTERFERENCE

No requirement

21. MAINTENANCE REQUIREMENTS

No requirement

Exp. No. S-10

ATTACHMENT II

1. RECORDING MEDIA

   a. Tape recorder required to store laser range data.

   b. Film required to obtain ground and stellar photographs.

2. HANDLING

   No requirement

3. PACKAGING

   No requirement

4. CALIBRATION

   Accurate crystal clock with comparison with ground clock.

5. JIGS AND FIXTURES

   Mounting jig for camera and telescope

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION

   None

7. SENSORS

   One photomultiplier for laser radar

8. TRAINERS/SIMULATORS

   Flight training program for astronaut on airplane or balloon

9. INSTRUMENTATION

   Telescope for guiding camera and identifying ground based objects; may be time shared with other experiments

10. RELATED SUPPORT EQUIPMENT

   a. Simulated ground based target

   b. Communication with specialists on ground

   c. Accurate tracking to establish very good ephemeris

   d. Film recovery and processing required

ATTACHMENT II (cont'd.)

11. AGE

Time calibration and position indicating equipment

12. ENVIRONMENTAL TEST EQUIPMENT

No requirement

13. FACILITIES

No requirement

Exp. No. S-10

ATTACHMENT III

1. ORBITAL PARAMETERS

   a. Altitude: 200 mi

   b. Inclination: Polar desired or high latitude equitorial

   c. Epoch: No requirement

   d. Ellipticity: Circular preferred

2. PLANE CHANGE

   No requirement

3. ALTITUDE CHANGE

   No requirement

4. TIME ON ORBIT

   30 days desired

5. TEST DURATION

   3 days

6. TOTAL NUMBER OF TESTS

   100

7. TEST FREQUENCY

   Daily

8. INTERVAL BETWEEN TESTS

   When orbit permits survey of area to be mapped

9. CREW TASK LOADS

   .3 of a man month

10. CREW TASK FREQUENCY

   Daily

11. FIELD OF VIEW REQUIREMENTS

   2 degrees view of earth and stars

ATTACHMENT III (cont'd.)

12. GROUND CONTROL LIAISON DURATION

10 minutes

13. GROUND CONTROL LIAISON FREQUENCY

Each orbit

14. EXTERNAL TEST ITEMS

No requirement

15. QUALIFICATION TESTS

a. Shock and vibration for launch. Life test for laser and power supply.

b. No requirement

16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT

Photographs taken of terrain during passage over territory to be mapped. Check of clock and ephemeris on each orbit to maintain precise ephemeris. Removal and return of film at conclusion of flight.

17. HANDLING PROCEDURES

Recovery of film and magnetic tape record and special processing.

Exp. No. S-10

ATTACHMENT IV

FUNDING SUMMARY
BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing		150K	150K	150K	100K	100K	650K
Integration and Installation		25K	25K	100K	100K	100K	350K
AGE					100K	100K	200K
Simulators/Trainers				100K			100K
Data Reduction					100K	100K	200K
Equipment Rework					100K		100K
Other							--
TOTAL							1,600K

Source of Funds - Hitch Line Number

ATTACHMENT VI

1. DATA RATE

   Ten photographs recorded each orbit. Transit time between ten points recorded each orbit.

2. FUNCTIONS TO BE MEASURED

   Time, position, and aspect angles.

3. TYPE OF ANALYSIS REQUIRED

   Photoreconnaissance photographs of geographic terrain.

4. PICTORIAL DATA REQUIRED

   Reconnaissance photographs of geographic terrain.

5. REAL TIME MONITORING REQUIREMENT

   Crystal clock and ephemeris monitoring required.

6. DATA EDITING OR COMPRESSION

   Data edited to correlate ephemeris, photographs, and stellar aspects.

7. READ-OUT TIME

   Data read-out on passage over ground support station.

8. REQUIREMENTS FOR PERMANENT DATA RECORDS

   Photograph and aspect records permanently recorded.

9. MANUAL AND/OR AUTOMATIC CONTROL

   Manual control of camera; automatic control of time.

10. SIMULTANEITY

    All events require correlation in time.

11. GROUND COMMANDS REQUIRED

    Identification of proper targets to be photographed; correlated with ground.

Exp. No. S-10

ATTACHMENT VII

1. DEVELOPMENT TIME

Development time required to design and build camera and laser radar; approximately two years.

2. FINAL DEFINITIVE TEST DESIGN TIME

One year required for final flight model.

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED

Several ground and flight tests to familiarize astronaut with operation of equipment.

4. TYPE OF DEVELOPMENT TEST ITEMS

a. Vacuum test required if camera operates outside of spacecraft.

b. Shock and vibration test for booster.

c. Thermal cycling dependent on location of camera on spacecraft.

d. Normal vibration during boost to orbit.

e. Star field and terrain radiance simulation for ground based training of astronaut.

f. Aircraft flights to familiarize astronaut with equipment and flight condition.

5. SUPPORT EQUIPMENT DEVELOPMENT TIME

One year to develop stellar/terrain simulator.

6. NUMBER OF TEST ARTICLES REQUIRED

a. One ground test instrument required.

b. One instrument for aircraft test.

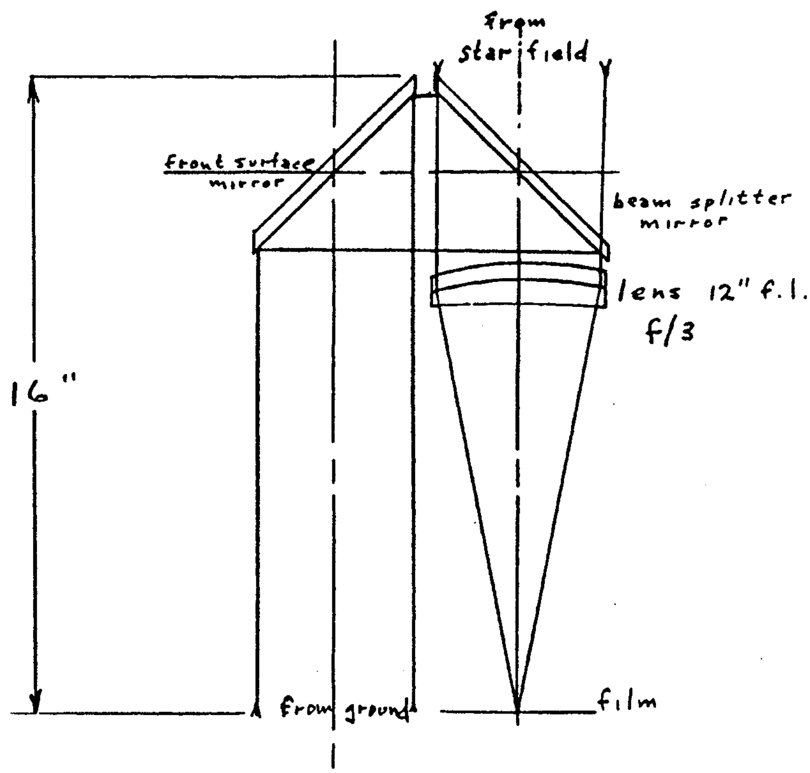
c. Four instruments required for flight qualification, prototype installation, flight instrument and back-up.

7. DATE AVAILABLE FOR TESTS

FY67

8. CURRENT DEVELOPMENT STATUS

Proposed only.



Camera

Additional instruments are rectangular boxes whose dimensions are given on page 4. These instruments can be made to conform with available racks.

DETERMINATION OF MASS OF ORBITING BODIES
PART 1

I. Test Objective

This experiment is directed towards the proving of a system of mass measurement under a Zero G condition. It will allow man to perform the aiming and firing functions and will allow his assessment of the results as indicated by spaceborne equipment.

II. Importance of the Test

This test is required in order to demonstrate under operational conditions, i.e., space environment, the performance and accuracy of the rocket propelled net as a method of mass measurement. The size of the expanded net, aiming accuracy requirements and atmospheric interferences make it necessary to do this test in space. This test will demonstrate man's abilities to meet the required aiming accuracy and to perform the translation of range rate into mass.

III. Description of the Experiment

The test will be the firing of a rocket-propelled net which will expand once it has left the parent vehicle and will proceed to the target approximately 2000' per second and will impart its momentum to the target by wrapping itself around. It has been determined that this method of mass measurement will give an accurate measurement of the target mass to 10% with targets weighing up to 10,000 pounds. The only foreseeable problem is that the exhaust from the rocket may obscure the photographic equipment utilized to record the experiment. This obscuration should be fairly short.

a. Configuration of Test Items

The net to be utilized will weigh approximately 5 pounds and the case and solid propellant an additional 1½ pounds. It is expected that the launch tube will not weigh in excess of an additional 5 pounds, giving a total system weight of 11½ pounds. (See Attachment A.)

b. Test Support Equipment Required

Use of the radar system aboard the MOL will be required to measure the change in relative velocities between the MOL and target. Use of available camera equipment will also be required to record the net impact on the target vehicle. No specific AGE requirements have been determined. (See Attachment B.)

c. Test Procedure

At the beginning of the test the man may be required to load the rocket device into the launcher. He will then aim the launcher with the use of an optical aiming device having at least one degree accuracy and electrically fire the rocket. The aiming and firing will most likely be done in the environmentally controlled section of MOL. The net will impinge on the target in approximately $\frac{1}{4}$ to $\frac{1}{2}$ second after firing. At this time the man will be required to consult range rate displays available to him and correlate the change in range rate from before the experiment to after the experiment to a chart indicating approximate mass. It would be desirable to have the camera available on the MOL aligned at the same time with the optical aiming device and have the camera start filming the experiment electrically simultaneously with the rocket firing. Since the target mass will be known a check can be made after the experiment is over on the accuracies attained by this method of mass measurement.

d. Category of Experiment

This experiment falls in Category B as defined in the sample format.

e. Cost (Budget Requirements by Fiscal Year)

	Prior	FY 65	FY 66	FY 67	TOTAL
(1) Engineering & Development; (2) Installation; (3) Ground Support	.15	.158	.472	.12	.9
TOTAL	.15	.158	.472	.12	.9
	Phase I	Phase II			

f. Schedule

(1) The first prototype equipment should be available in early 1966 with the first flight article available in October of the same year. These dates are predicated upon an April 1965 go-ahead for Phase II.

IV. Participating Government Agencies

Sponsor: SSD/Aerospace

Test Equipment Acquisition: To be acquired as part of the system.

V. Additional Requirements

a. Special Security - None.

b. Manning Description Summary - See Attachment E.

c. Logistics - To be determined.

d. Facilities

A vertical test facility fairly simple in nature will be required to test net deployment. It appears all other tests can be conducted with the existing facilities.

e. Simulation and Training

Familiarization with the optical aiming device will be required for the astronaut.

VI. General

a. Communications and Data Handling Requirement - See Attachment F.

b. Development Characteristics - See Attachment G.

ATTACHMENT A

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. Equipment to be Tested - Rocket Propelled Net Device

2. Weight - 6.5 lbs and a small rocket launcher - less than 5 lbs

3. Volume - Stored - small to be determined

   Critical Dimensions - None

4. Power - Requires use of existing radar - negligible power required for firing circuit

5. Spares -

   a. Volume - small to be determined

   b. Quantity - 1 or 2 extra net cartridges may be carried

   c. Weight - 13 lbs if spares are carried

6. Tools - No requirement

7. Heat Output - Negligible - fired outside MOL

8. Stability - Required to permit aiming to 1 degree

   a. Moving Parts - Barrel to cartridge

9. Vibration Limits - to be determined - not considered critical

10. Shock Limits - to be determined

11. Hazards (Those Normally Associated With Solid Rocket Firing)

12. Temperature Limitations - to be determined

13. Type and Range of Measurement - Net is fired when MOL is 500-1000 feet from target. Radar range measurements will indicate momentum transferred to target. Range rate change is required to 1 ft/second

14. Special Environmental Requirements - None

15. Orientation and Position Accuracy Requirements -

Station - Stabilized

Equipment - Aiming to 1 degree accuracy

16. Equipment Operating Cycle - that of the radar

17. Equipment Location Requirements - may require storage within MOL prior to use

18. Special Mountings Requirements - Rocket tube should be mounted externally. The location should be such that the astronaut can load it if necessary.

19. Pressure Vessels - None

20. Electro Magnetic Interference - None

21. Maintenance Requirements -

Ground - Maintenance and care of firing circuit

Space - None identifiable

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ATTACHMENT B

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA -

    a. Tape - may be required to record range rate data

    b. Film - should be used to record experiment

    c. Other - astronaut will be required to record results

2. HANDLING (SPECIAL EQUIPMENT REQUIRED TO HANDLE ITEMS BEING TESTED -

    None

3. PACKAGING -

4. CALIBRATION - must be boresighted with aiming device

5. JIGS AND FIXTURES - to be determined

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION - to be determined. Will concern electrical firing circuits.

7. SENSORS (Transducer - Output Signals)

8. TRAINERS/SIMULATORS - to be determined

9. INSTRUMENTATION - Laboratory. Radar range rate during short duration of the test must be displayed to the astronaut.

10. RELATED SUPPORT EQUIPMENT -

    a. Targets - A target of known mass must be available at a range between 500 and 1000 feet.

    b. Ground Stations - no requirement

    c. Tracking - Must be accomplished by MOL ATE to 1 ft/second

    d. Handling Equipment - No special requirement

11. AGE - to be determined. However, the lack of equipment complexity will make the requirement small.

~~SECRET~~

12. ENVIRONMENTAL TEST/EQUIPMENT - Will require scale model vac chamber firing tests.

13. FACILITIES - A vertical test facility will be required during development for net deployment and impact tests.

ATTACHMENT C

TEST OPERATING CHARACTERISTICS

1. Orbital Parameters (Desired) - No special requirements

2. Plane Change - No requirement

3. Altitude Change - No requirement

4. Time On Orbit - No special requirement

5. Test Duration - Less than 1 minute

6. Total Number of Tests - 1 required - more may be possible and desirable

7. Test Frequency - no set frequency

8. Interval Between Tests - Not critical

9. Crew Task Loads - man hours not to exceed 1 man-hour

10. Crew Task Frequency - to be determined

11. Field of View Requirements - Astronaut must see target through optical aiming device

12. Ground Control Liaison Duration - Not required

13. Ground Control Liaison Frequency - Not required

14. External Test Items -

    a. Launched From Station - Net will be launched from MOL against any available target

15. Qualification Tests (Other Than Space) -

    a. Ground - Launch rocket must be tested for spin and firing. Net deployment tests are also required.

16. Sequence of Events as They Occur During Flight - Exact sequence to be determined

17. Handling Procedures - Those associated with solid rocket handling

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ATTACHMENT D

FUNDING SUMMARY

BUDGET REQUIREMENTS BY FISCAL YEAR

	PHASE I FY 65	PHASE II FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing	.450	.203	1.082	.765			2.500
Integration & Installation	.050	.075	.150	.025			.250
AGE		.100	.250	.150			.500
Simulators/Trainers							
Data Reduction							
Equipment Rework							
Other		.100	.100	.050			.250
TOTAL	.500	.478	1.582	.990			3.500

Source of Funds - Hitch Line Number

~~SECRET~~

ATTACHMENT E

MANNING DESCRIPTION

1. ASTRONAUTS

a. Number required - One astronaut will be required to aim the rocket tube at the target to within one degree of accuracy.

(1) Man's function - In addition to the aiming requirement, the astronaut will be required to interpret the range rate data available concerning the target and relate this information to the target measured mass. Since the mass of the target will most likely be known, the astronaut may also be able to determine the accuracy of the test conducted.

b. Crew skill requirements - The astronaut will require sufficient skill with the aiming device to meet the one degree requirement.

c. Manpower profile - One astronaut for a period of approximately 5 minutes.

d. Critical functions - aiming to within one degree and determincation of range rate to one foot per second.

e. Work positions - The astronaut will most probably work in the environmentally controlled section. He may, however, be required to leave this section in order to load or reload the rocket launcher.

f. Time controlled tasks - to be determined.

g. Human performance measures - to be determined.

h. Physiological and Psychological measures - to be determined.

i. Selection factors - no special requirements.

j. Training requirements - familiarization with the equipment involved.

2. GROUND PERSONNEL

No ground personnel requirements are directly relatable to the test.

ATTACHMENT F

COMMUNICATIONS AND DATA HANDLING

1. Data Rate - Range rate measurements are required during the period of the test.

2. Functions to be Measured - Range rate.

3. Type of Analysis Required - Correlation of range rate to mass and analysis of the determined mass with the known mass of the target.

4. Pictorial Data Required - Film records are required of the experiment to show net impact.

5. Real Time Monitoring Requirement - No requirement.

6. Data Editing or Compression - No requirement.

7. Read-Out Time - No requirement.

8. Requirements For Permanent Data Records - See 4. above.

9. Manual and/or Automatic Control - Both methods of operation should be available to the astronaut.

10. Simultaneity - Not required.

11. Ground Commands Required - Not required.

ATTACHMENT G

DEVELOPMENT CHARACTERISTICS

1. Development Time - On a three-time estimate system a total of 24 months is the most likely development time. The most pessimistic time is approximately 30 months and the most optimistic time is 18 months. These times include both Phases I and II. In all cases Phase I will require 5 months.

2. Final Definitive Test Design Time - To be determined.

3. Number of Ground or Flight Tests Required - To be determined.

4. Type of Development Test Items -

a. Vacuum Chamber - Scale model fired will be required to verify rocket and meet performances in a vacuum.

5. Support Equipment Development Time - To be determined.

6. Number of Test Articles Required For:

a. Ground Test - To be determined.

b. Atmospheric Test - To be determined.

c. Space Test - One.

7. Date Available For Tests - Prototype will be available in early 1966 with the first flight model available in late 1966. These figures are based on a Phase II go-ahead in April 1965.

8. Current Development Status - This system was studied during the Phase 0 of Program 706. To date approximately $100,000 has been expended on mass measurement. During 706 Phase 0 this expenditure included preliminary designs on this and other systems.

DETERMINATION OF MASS OF ORBITING BODIES
PART 2

I. Test Objective

This experiment is directed towards the proving of a system of mass measurement under a Zero G condition. It will allow man to perform the aiming and firing functions and will allow his assessment of the results as indicated by spaceborne equipment.

II. Importance of the Test

This test is required in order to demonstrate under operational conditions, i.e. space environment, the performance and accuracy of an automatic shotgun as a mass measurement device. Atmospheric conditions will affect the velocity of the pellets at the point of impact on the target. Space testing is necessary in order to eliminate this and in order to verify man's capability to aim. In addition, disposal of spent cartridges under a Zero G environment could be a problem. These cartridges must be collected from the immediate vicinity of the spacecraft and deposited so as not to affect this or other systems. Similarly, the operation of the repeating shotgun under the prolonged extremes of the space environment is not determinable without a spaceborne experiment. This test will demonstrate man's abilities to meet the required aiming accuracy and to perform the translation of range rate into mass.

III. Description of the Experiment

The test will be the firing of an automatic shotgun loaded with small nylon pellets which will impact the target and transfer momentum to it. The number of rounds to be fired is dependent upon the size of the target and the ability of the radar to determine changes in range rate. For extremely light targets, this method is capable of adding sufficient momentum to de-orbit them.

a. Configuration of Test Items

The automatic shotgun will be a gas operated device capable of firing up to 200 rounds. The total weight of the gun and ammunition is approximately 27 pounds. (See Attachment A.)

b. Test Support Equipment Required

Use of the radar system aboard the MOL will be required to measure the change in relative velocities between the MOL and target. Use of available camera equipment will also be required to record the pellet impact on the target vehicle. No specific AGE requirements have been determined. (See Attachment B.)

c. Test Procedure

At the beginning of the test, the man may be required to load the shotgun. He will then aim the shotgun with the use of an optical aiming device and will electrically fire it. The aiming and firing will most likely be done from the environmentally controlled section of MOL. At this time, the man will be required to consult range rate displays available to him and correlate the change in range rate from before the experiment to after the experiment to a chart indicating approximate mass. Firing may be stopped when sufficient momentum has been imparted to give a measurable change in range rate. It would be desirable to have the camera available on the MOL aligned at the same time with the optical aiming device and have the camera start filming the experiment electrically simultaneously with the firing. Since the target mass will be known, a check can be made after the experiment is over on the accuracies attained by this method of mass measurement.

d. Category of Experiment

This experiment falls in Category B.

e. Cost (Budget Requirements by Fiscal Year)

	Prior	FY 65	FY 66	FY 67	TOTAL
(1) Engineering & Development					
(2) Installation	.300	.320	.960	.72	2.3
(3) Ground Support					
TOTAL	.300	.320	.960	.72	2.3
	Phase I	Phase II------------------			

f. Schedule

(1) The first prototype equipment should be available in early 1966 with the first flight article available in April or May of 1967. These dates are predicated upon an April 1965 go-ahead for Phase II.

IV. Participating Government Agencies

Sponsor: SSD/Aerospace

Test Equipment Acquisition: To be acquired as part of the system.

V. Additional Requirements

a. Special Security

None.

b. Manning Description Summary

See Attachment E.

c. Logistics

To be determined.

d. Facilities

It appears all tests can be conducted with the existing facilities.

e. Simulation and Training

Familiarization with the optical aiming device will be required for the astronaut.

VI. General

a. Communications and Data Handling Requirement

See Attachment F.

b. Development Characteristics

See Attachment G.

ATTACHMENT A

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. Equipment to be Tested: Automatic Shot Gun

2. Weight: 27 lbs. including 200 rounds

3. Volume: Stored - To be determined In Use - To be determined

4. Power for Firing Circuits only: Negligible

5. Spares: To be determined. Some maintenance may be done for repair or practice

6. Tools: To be determined. No planned requirements have been identified

7. Heat Output: Not determined

8. Stability: This device is recoil loaded. The effects of this recoil on the MOL will be determined

   a. Moving Parts

9. Vibration Limits: None critical to the sensor system

10. Shock Limits: N/A

11. Hazards: No critical hazards should be present since the gun is fired outside of The Mol

12. Temperature Limitations: Gun must be stored inside environmentally area until used

13. Type and Range of Measurement: Range rate measurement is required to 1 ft/sec during Test period

14. Special Environmental Requirements: Environmentally controlled storage for Shotgun prior to use

15. Orientation and Position Accuracy Requirements:

    Station: The MOL must be stabilized. The degree required will be determined

    Equipment: Aiming accuracy is a function of shotgun barrel choke and must be determined during development

16. Equipment Operating Cycle:

    Frequency: Up to 200 firing cycles - dependant on target mass

    Time Duration: Less than 1 minute

17. Equipment Location Requirements: Aiming device may be in environmentally controlled area. Gun will be fired outside

18. Special Mountings Requirements:

    Bracketry: To be determined

19. Pressure Vessels: Fluids, gasses, etc. None.

20. Electro Magnetic Interference (spurious generation, special shielding req, etc): None

21. Maintenance Requirements:

    Ground: To be determined

    Space: Maintenance demonstration may be incorporated as part of the Test

ATTACHMENT B

TEST SUPPORT EQUIPMENT

1. Recording Media

    a. Tape

    b. Film

    c. Other

2. Handling: None

3. Packaging: To be determined

4. Calibration: Gun and sight must be boresighted on the ground

5. Jigs and Fixtures: None

6. Number of Leads from Outside to Inside Station: Only those concerned with firing circuit

7. Sensors: None

8. Trainers/Simulators: To be determined

9. Instrumentation - cockpit and/or laboratory (note effect of time sharing instruments with other experiments): Range Rate data must be available within The MOL and displayed to the astronaut during the Test

10. Related Support Equipment:

    a. Targets: A Targer of known mass must be available to a range of approximately 150 ft.

    b. Ground Stations: None

    c. Tracking: Radar must Track the target from The MOL

    d. Handling Equipment: No special equipment required

11. AGE: To be determined

12. Environmental Test Equipment: To be determined

13. Facilities: Test firing facilities are required during development. It may be necessary to fire in a vacuum chamber during pellet Tests.

ATTACHMENT C

TEST OPERATING CHARACTERISTICS

1. Orbital Parameters (desired): Not critical
2. Plane Change: Not required
3. Altitude Change: Not required
4. Time on Orbit: 10 minutes
5. Test duration: 10 minutes maximum
6. Total Number of Tests: 1
7. Test Frequency: N/A
8. Interval Between Tests: N/A
9. Crew Task Loads: To be determined. For practice.
10. Crew Task Frequency: To be determined. For practice.
11. Field of View Requirements: Sufficient to aim shotgun with remote device
12. Ground Control Liaison Duration: Not required
13. Ground Control Liaison Frequency: Not required
14. External Test Items: Target must be available
15. Qualification Tests Ground: Testing is required to determine shotgun characteristics and pellet performance during development.
16. Sequence of Events as They Occur During Flight: Exact sequence to be determined.
17. Handling Procedures: To be determined if required.

ATTACHMENT D

A combined Attachment D is included for both systems of mass measurement.

ATTACHMENT E

MANNING DESCRIPTION

1. ASTRONAUTS

a. Number required - One astronaut will be required to aim the shotgun at the target to an accuracy to be determined during development tests.

(1) Man's function - In addition to the aiming requirement, the astronaut will be required to interpret the range rate data available concerning the target and relate this information to the target measured mass. Since the mass of the target will most likely be known, the astronaut may also be able to determine the accuracy of the test conducted.

b. Crew skill requirements - The astronaut will require sufficient skill with the aiming device.

c. Manpower profile - One astronaut for a period of approximately 10 minutes.

d. Critical functions - aiming to the accuracy required and determination of range rate to one foot per second.

e. Work positions - The astronaut will most probably work in the environmentally controlled section. He may, however, be required to leave this section in order to load or reload the rocket launcher. He may also be required to maintain the shotgun.

f. Time controlled tasks - to be determined.

g. Human performance measures - to be determined.

h. Physiological and Psychological measures - to be determined.

i. Selection factors - no special requirements.

j. Training requirements - familiarization with the equipment involved.

2. GROUND PERSONNEL

No ground personnel requirements are directly relateable to the test.

ATTACHMENT F

COMMUNICATIONS AND DATA HANDLING

1. Data Rate - Range rate measurements are required during the period of the test.

2. Functions to be Measured - Range rate.

3. Type of Analysis Required - Correlation of range rate to mass and analysis of the determined mass with the known mass of the target.

4. Pictorial Data Required - Film records are required of the experiment to show pellet impact and affect on the target.

5. Real Time Monitoring Requirement - No requirement.

6. Data Editing or Compression - No requirement.

7. Read-Out Time - No requirement.

8. Requirements for Permanent Data Records - See 4 above.

9. Manual and/or Automatic Control - Both methods of operation should be available to the astronaut for aiming and firing.

10. Simultaneity - Not required.

11. Ground Commands Required - Not required.

ATTACHMENT G

DEVELOPMENT CHARACTERISTICS

1. Development Time - On a three-time estimate system a total of 30 months is the most likely development time. The most pessimistic time is approximately 35 months and the most optimistic time is 21 months. These times include both Phases I and II. In all cases Phase I will require 5 months.

2. Final Definitive Test Design Time - To be determined.

3. Number of Ground or Flight Tests Required - To be determined.

4. Type of Development Test Items -

   Vacuum Chamber - Scale model firing will be required to verify shotgun and pellet performances in a vacuum.

5. Support Equipment Development Time - To be determined.

6. Number of Test Articles Required For:

a. Ground Test - To be determined.
b. Atmospheric Test - To be determined.
c. Space Test - One.

7. Date Available for Tests - Prototype will be available in early 1966 with the first flight model available in early 1967. These figures are based on a Phase II go-ahead in April 1965.

8. Current Development Status - This system was studied during the Phase 0 of Program 706. To date approximately $100,000 has been expended on mass measurement. During 706 Phase 0 this expenditure included preliminary designs on this and other systems.

Experiment No. S-12

HYDROGEN REDUCTION ATMOSPHERIC REGENERATION SYSTEM

I. Test Objective

Evaluate component and system performance of a chemically regenerative atmospheric control system as an integral part of a life support system. An adjunct part of this experiment will be periodic monitoring of the contaminants within the cabin atmosphere.

II. Importance of Test

This test is needed for the development of life support equipment for long duration manned space missions. Operation of the equipment requires verification in a manned system in a zero gravity field, and the use of a space vehicle, such as MOL, is essential.

As mission times and the complement of manned spacecraft increase, a point will be reached in the not-too-distant future where the penalties for the use of expendable or open cycle atmospheric control systems will be excessive. Reliable high performance atmospheric regeneration systems will have to be developed for these long duration manned space missions. The most promising systems consist of reducing CO_2 to H_2O with hydrogen and subsequent electrolysis of the water to provide breathing oxygen. Two-phase operation exists in the water condenser and electrolysis cell which requires verification in a zero gravity field. The basic system will consist of a reactor subsystem and an electrolysis subsystem which may be operated separately to conserve power.

III. Description of the Experiment

The systems consists of a water and CO_2 removal subsystem, a reactor subsystem in which CO_2 is reduced with hydrogen to water and methane (possibly carbon), and an electrolysis subsystem in which water is dissociated into hydrogen and oxygen.

Assuming that the MOL consists of two pressurized compartments, it is proposed that the system be used to purify the atmosphere for one of the compartments as long as the system functions properly. The vehicle life support system should be capable of complete atmospheric control in the event of failure of the reduction system.

a. Configuration of Test Items (See Attachment A)

b. Test Support Equipment Required (See Attachment B)

(1) Spacecraft. Miscellaneous vehicle maintenance tools

(2) AGE. None

c. Test Procedures (See also Attachment C)

The system should be operated continuously to obtain operating experience. A 30 day test of this nature would be a big help in developing long duration atmospheric control systems for space vehicles. Temperatures, pressures, flow rates and power consumption should be measured, and samples of the gas stream should be periodically analyzed. A gas chromatograph or mass spectrometer should be used to monitor all trace contaminants in the cabin atmosphere during the entire mission.

(1) Man's Role. Man's role primarily consists of providing the "used" air (by normal breathing) for the system. In addition, the crew must monitor the system operation.

(2) Man's Utilization. As mentioned in paragraph 1 above, man is utilized primarily for the purpose of loading the test system.

(3) Testing Sequence. There is no special testing sequence. The system should be operated continuously with regularly scheduled monitoring and data recording chores.

d. Category of Equipment (Omit)

e. Cost (See Attachment D)

f. Schedule

(1) Hardware could be made available for test in 1965.

(2) A flight readiness date of 1967 is feasible.

IV. Participating Government Agencies

Interested agencies are the Aerospace Medical Research Laboratory and the School of Aviation Medicine, both of the Aerospace Medical Division, AFSC; the Flight Dynamics Laboratory of the Research and Technology Division, AFSC; and the NASA Laboratories at Houston, Langley and Lewis.

V. Additional Requirements

a. Special Security None

b. Manning Description Summary (See Attachment E)

c. Logistics (Omit)

d. Facilities

Prior ground testing is required for system development and for astronaut training. This is a man-rated system and should be thoroughly evaluated in a space station atmospheric control simulator.

e. Simulation and Training

(1) Astronaut. Training as a technician should be sufficient for this experiment. The astronaut should be trained to start-up the apparatus and take data, including operation of the gas chromatograph and/or mass spectrometer.

(2) Ground Personnel. None

(3) Equipment. The atmospheric reduction system should be evaluated in a simulator mentioned in paragraph (d) above.

VI. General

a. Communications and Data Handling Requirement. (See Attachment F)

b. Development Characteristics. (See Attachment G)

Exp No. S-12

ATTACHMENT A

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED HYDROGEN REDUCTION ATMOSPHERIC REGENERATION SYSTEM

2. WEIGHT: 150 lbs

3. VOLUME: Stored 4.4 In use 4.4

   CRITICAL DIMENSIONS - SHAPES Cube 1.64 ft on each side

4. POWER (watts)

   a. Continuous 550

   b. Stand-by Not known

   c. Average operating 550 (molecular sieve subsystem included)

   d. Peak 700

   e. Duty cycle Continuous at 550 watts, 700 for start-up

5. SPARES None required

   a. Volume

   b. Quantity

   c. Weight

6. TOOLS No unique requirements - use spacecraft maintenance tools

   a. Volume

   b. Quantity

   c. Weight

   d. Power

7. HEAT OUTPUT 550 watts

8. STABILITY Not available

   a. Moving parts

9. VIBRATION LIMITS Not available

10. SHOCK LIMITS Not available

11. HAZARDS (fire, explosion, electrical, toxics, other) Possible hydrogen fire in event of reactor leak

12. TEMPERATURE LIMITATIONS None

13. TYPE AND RANGE OF MEASUREMENT (definition of parameters to be measured while test is underway). Gas pressure, temperature, flow rate and composition. Also system power consumption.

14. SPECIAL ENVIRONMENTAL REQUIREMENTS None

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS: None

    Station

    Equipment

16. EQUIPMENT OPERATING CYCLE Continuous

    Frequency

    Time Duration

17. EQUIPMENT LOCATION REQUIREMENTS Pressurized compartment

18. SPECIAL MOUNTINGS REQUIREMENTS None

    Apertures

    Booms

    Windows

    Antennae

    Bracketry

19. PRESSURE VESSELS - fluids, gases, etc. Gaseous hydrogen

20. ELECTRO MAGNETIC INTERFERENCE (spurious generation, special shielding required, etc.) None

21. MAINTENANCE REQUIREMENTS

    Ground None

    Space None

Exp No. S-12

ATTACHMENT B

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA

   a. Tape None

   b. Film None

   c. Other Chart paper

2. HANDLING (special equipment required to handle items being tested). None

3. PACKAGING None

4. CALIBRATION - alignment, deployment None

5. JIGS AND FIXTURES None

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION None

7. SENSORS (TRANSDUCER - OUTPUT SIGNALS) Self contained

8. TRAINERS/SIMULATORS Ground atmospheric control chamber simulator

9. INSTRUMENTATION - cockpit and/or laboratory (note effect of time sharing instruments with other experiments). Built into system

10. RELATED SUPPORT EQUIPMENT

   a. Targets None

   b. Ground Stations None

   c. Tracking None

   d. Handling Equipment None

11. AGE None

12. ENVIRONMENTAL TEST EQUIPMENT Gas chromatograph or mass spectrometer

13. FACILITIES None

ATTACHMENT C

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS (desired)

   a. Altitude
   b. Inclination
   c. Epoch
   d. Ellipticity

   No requirements

2. PLANE CHANGE None
3. ALTITUDE CHANGE None
4. TIME ON ORBIT 30 days
5. TEST DURATION Continuous
6. TOTAL NUMBER OF TESTS One
7. TEST FREQUENCY Continuous
8. INTERVAL BETWEEN TESTS None
9. CREW TASK LOADS - man hours 15
10. CREW TASK FREQUENCY Monitor equipment and record data every 4 hours
11. FIELD OF VIEW REQUIREMENTS None
12. GROUND CONTROL LIAISON DURATION Not known
13. GROUND CONTROL LIAISON FREQUENCY Not known
14. EXTERNAL TEST ITEMS: None

    a. Launched from Station
    b. Launched from resupply
    c. Launched from ground

ATTACHMENT C (Cont'd)

TEST OPERATING CHARACTERISTICS

15. QUALIFICATION TESTS (other than space)

a. Ground Complete qualification required

b. Atmosphere None

16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT No rigid requirement except periodic monitoring

17. HANDLING PROCEDURES No special procedures

ATTACHMENT D

FUNDING SUMMARY

BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing		100,000	75000	50000			225000
Integration & Installation							
AGE							
Simulators/Trainers			25000	25000			50000
Data Reduction							
Equipment Rework							
Other Astronaut Training				25000			25000
TOTAL		100,000	100,000	100,000			300,000

Source of Funds - Hitch Line Number

Exp No. S-12

ATTACHMENT E

MANNING DESCRIPTION

1. ASTRONAUTS

a. Number required One

(1) Man's function

(a) As part of test Provides "used" air for system

(b) As technician conducting test Monitor and record data

b. Crew skill requirements. Trained as technicians

c. Manpower Profile 4 man hours total per week for periodic (every 4 hours) monitoring and data recording

d. Critical Functions None

e. Work Positions Anywhere in pressurized compartment

f. Time Controlled Tasks None

g. Human Performance Measures None

h. Physiological and Psychological Measures None

i. Selection Factors None

j. Training Requirements Astronauts must be thoroughly familiar with operation of equipment

2. GROUND PERSONNEL None

a. Number required

(1) Man's function

(a) As part of test

(b) As technician conducting test

b. Crew Skill Requirements

c. Manpower Profile

ATTACHMENT E (Cont'd)

MANNING DESCRIPTION

d. Critical Functions

e. Work Positions

f. Time Controlled Tasks

g. Human Performance Measures

h. Physiological and Psychological Measures

i. Selection Factors

j. Training Requirements

Exp No. S-12

ATTACHMENT F

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE Periodic and very slow

2. FUNCTIONS TO BE MEASURED Gas pressure, temperature, flow rate and composition. Also power consumption.

3. TYPE OF ANALYSIS REQUIRED Gas composition via gas chromatograph

4. PICTORIAL DATA REQUIRED None

5. REAL TIME MONITORING REQUIREMENT None

6. DATA EDITING OR COMPRESSION None

7. READ-OUT TIME Not known

8. REQUIREMENTS FOR PERMANENT DATA RECORDS Record data on chart paper or telemeter to ground

9. MANUAL AND/OR AUTOMATIC CONTROL Manual

10. SIMULTANEITY None

11. GROUND COMMANDS REQUIRED None

Exp No. S-12

ATTACHMENT G

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME 3 years

2. FINAL DEFINITIVE TEST DESIGN TIME One year

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED Not known

4. TYPE OF DEVELOPMENT TEST ITEMS

 a. Vacuum Chamber None

 b. Shaker Yes

 c. Thermal None

 d. Acoustic None

 e. Simulators Atmospheric control system chamber require long duration evaluation

 f. Aircraft None

5. SUPPORT EQUIPMENT DEVELOPMENT TIME One year

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

 a. Ground Test Three

 b. Atmospheric Test None

 c. Space Test Three

7. DATE AVAILABLE FOR TESTS Test 1965, flight test 1967

8. CURRENT DEVELOPMENT STATUS

 a. Proposed only

 b. Project or program is approved and test item is under study, breadboard stage, etc. Breadboard units are now under study and development

 c. Funds expended to date.

Experiment No. S-13

VAPOR COMPRESSION DISTILLATION WATER PURIFICATION SYSTEM

I. Test Objective

Verify and evaluate operation of the system. Conduct a time study of the test operator.

II. Importance of the Test

This test is needed for the development of water recovery systems. Testing in a space vehicle, such as MOL, is required because of the gravity sensitive heat transfer mechanisms involved in the reclamation process.

Waste water reclamation may be necessary for manned space vehicles having a mission greater than two weeks and which use a power supply other than a fuel cell (which produces excess water). Vapor compression distillation is attractive for military applications since it can be made compact. The operation involves boiling and condensing which will require a zero gravity test of the system. This system will provide potable water for the vehicle.

III. Description of the Experiment

The basic elements of the system are an evaporator, a vapor compressor and a condenser in which the condensation occurs at a slightly higher pressure and temperature than the boiling. The higher temperature which results from the vapor compression, together with the heat released by the condensation process, provides the heat for boiling. Impurities are collected on a liner in the evaporator which can be replaced from time to time because the system operates on a batch process method. Liner replacement will be required about once in two weeks.

a. Configuration of Test Items (See Attachment A)

b. Test Support Equipment Required (See Attachment B)

(1) Spacecraft. None

(2) AGE. None

c. Test Procedure (See also Attachment C)

The purpose of the test is to operate and verify the performance of the system. The system must be set up and supplied with waste water. The quantities of both waste water input and purified water output should be measured, and a chemical analysis of the purified water must be made to verify the performance.

(1) Man's Role. The working fluid (waste water and urine) will be provided by the astronauts during the mission. Under these conditions the fluid will be produced in space under the actual diet, environmental and zero gravity conditions.

(2) Man's Utilization. Monitor the performance of the system and provide for the working fluid as noted above.

(3) Testing Sequence. No special testing sequence is required. The system is tested in a batch manner whenever a sufficient supply of waste water has accumulated.

d. Category of Experiment (Omit)

e. Cost (See Attachment D)

f. Schedule

(1) Hardware could be made available for test in 1965

(2) A hardware flight readiness date of 1966 is reasonable

IV. Participating Government Agencies

Interested government agencies are the Aerospace Medical Research Laboratory, and the USAF School of Aviation Medicine, both of the Aerospace Medical Division, AFSC; the Flight Dynamics Laboratory of the Research and Technology Division, AFSC; and NASA laboratories at Houston and Langley.

V. Additional Requirements

a. Special Security. None

b. Manning Description Summary (See Attachment E)

c. Logistics. (Omit)

d. Facilities

Existing facilities can be used to develop and test this water purification system. No special facilities are required, but the system should be thoroughly checked out on the ground.

e. Simulation and Training

(1) Astronaut. A minimum of training will be required and no simulation is needed.

(2) Ground Personnel. None

(3) Equipment. None

VI. General

a. Communications and Data Handling Requirements. (See Attachment F)

b. Development Characteristics. (See Attachment G)

ATTACHMENT A

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED VAPOR COMPRESSION DISTILLATION WATER PURIFICATION SYSTEM

2. WEIGHT: 40 lbs

3. VOLUME: Stored 3 In use 3

CRITICAL DIMENSIONS - SHAPES Cube 1.44 ft on each side

4. POWER (watts)

a. Continuous

b. Stand-by

c. Average operating 50

d. Peak 100 (start up only)

e. Duty cycle 4 to 12 hours per day

5. SPARES Negligible

a. Volume

b. Quantity

c. Weight

6. TOOLS No special requirement

a. Volume

b. Quantity

c. Weight

d. Power

7. HEAT OUTPUT 50 watts

8. STABILITY Not available

a. Moving parts

9. VIBRATION LIMITS Not available

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ATTACHMENT A (Cont'd)

10. SHOCK LIMITS Not available

11. HAZARDS (fire, explosion, electrical, toxics, other) None

12. TEMPERATURE LIMITATIONS None

13. TYPE AND RANGE OF MEASUREMENT (definition of parameters to be measured while test is underway). Water flow rates and chemical analysis

14. SPECIAL ENVIRONMENTAL REQUIREMENTS None

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS: None

Station

Equipment

16. EQUIPMENT OPERATING CYCLE

Frequency Intermittent

Time Duration 4 to 12 hours per day

17. EQUIPMENT LOCATION REQUIREMENTS Must be accessible

18. SPECIAL MOUNTINGS REQUIREMENTS None

Apertures

Booms

Windows

Antennae

Bracketry

19. PRESSURE VESSELS - fluids, gases, etc. None

20. ELECTRO MAGNETIC INTERFERENCE (spurious generation, special shielding required, etc.) None

21 MAINTENANCE REQUIREMENTS

Ground None

Space Replace liner in evaporator every two weeks

ATTACHMENT B

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA

   a. Tape

   b. Film

   c. Other Notebook

2. HANDLING (special equipment required to handle items being tested).
   None

3. PACKAGING None

4. CALIBRATION - alignment, deployment None

5. JIGS AND FIXTURES None

6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION None

7. SENSORS (TRANSDUCER - OUTPUT SIGNALS) None

8. TRAINERS/SIMULATORS None

9. INSTRUMENTATION - cockpit and/or laboratory (note effect of time sharing instruments with other experiments). None

10. RELATED SUPPORT EQUIPMENT None

    a. Targets

    b. Ground Stations

    c. Tracking

    d. Handling Equipment

11. AGE None

12. ENVIRONMENTAL TEST EQUIPMENT None

13. FACILITIES None

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ATTACHMENT C

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS (desired) None
   a. Altitude
   b. Inclination
   c. Epoch
   d. Ellipticity
2. PLANE CHANGE None
3. ALTITUDE CHANGE None
4. TIME ON ORBIT 30 days
5. TEST DURATION 30 days
6. TOTAL NUMBER OF TESTS One continuous test, but of an intermittent nature
7. TEST FREQUENCY
8. INTERVAL BETWEEN TESTS Not applicable
9. CREW TASK LOADS - man hours 10
10. CREW TASK FREQUENCY Once per day
11. FIELD OF VIEW REQUIREMENTS None
12. GROUND CONTROL LIAISON DURATION None
13. GROUND CONTROL LIAISON FREQUENCY None
14. EXTERNAL TEST ITEMS: None
    a. Launched from Station
    b. Launched from resupply
    c. Launched from ground
15. QUALIFICATION TESTS (other than space)
    a. Ground Unit must be fully qualified on the ground
    b. Atmosphere None
16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT No special sequence required.
17. HANDLING PROCEDURES No special requirements

ATTACHMENT D

FUNDING SUMMARY

BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing		50,000	50,000				100,000
Integration & Installation							
AGE							
Simulators/Trainers							
Data Reduction							
Equipment Rework							
Other							
TOTAL		50,000	50,000				100,000

Source of Funds - Hitch Line Number

Exp No. S-13

ATTACHMENT E

MANNING DESCRIPTION

1. ASTRONAUTS

   a. Number required One

      (1) Man's function

         (a) As part of test Yes. Supplies working fluids (waste water and urine)

         (b) As technician conducting test Yes. Monitor test and make chemical analysis of purified water

   b. Crew skill requirements None

   c. Manpower Profile Once per day for 10 minutes

   d. Critical Functions None

   e. Work Positions No special requirements

   f. Time controlled Tasks None

   g. Human Performance Measures None

   h. Physiological and Psychological Measures None

   i. Selection Factors None

   j. Training Requirements Astronaut should be familiar with operation of system

2. GROUND PERSONNEL None

   a. Number required

      (1) Man's function

         (a) As part of test

         (b) As technician conducting test

   b. Crew Skill Requirements

   c. Manpower Profile

ATTACHMENT E (Cont'd)

MANNING DESCRIPTION

d. Critical Functions

e. Work Positions

f. Time Controlled Tasks

g. Human Performance Measures

h. Physiological and Psychological Measures

i. Selection Factors

j. Training Requirements

Exp No. S-13

ATTACHMENT F

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE Very slow
2. FUNCTIONS TO BE MEASURED Water flow rates, power consumption
3. TYPE OF ANALYSIS REQUIRED Chemical Analysis of purified water
4. PICTORIAL DATA REQUIRED None
5. REAL TIME MONITORING REQUIREMENT None
6. DATA EDITING OR COMPRESSION None
7. READ-OUT TIME Not known
8. REQUIREMENTS FOR PERMANENT DATA RECORDS Permanent records of system performance required
9. MANUAL AND/OR AUTOMATIC CONTROL Manual
10. SIMULTANEITY No requirement
11. GROUND COMMANDS REQUIRED None

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ATTACHMENT G

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME Two years

2. FINAL DEFINITIVE TEST DESIGN TIME One year

3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED Two

4. TYPE OF DEVELOPMENT TEST ITEMS

   a. Vacuum Chamber

   b. Shaker Yes

   c. Thermal No

   d. Acoustic No

   e. Simulators No

   f. Aircraft No

5. SUPPORT EQUIPMENT DEVELOPMENT TIME None

6. NUMBER OF TEST ARTICLES REQUIRED FOR:

   a. Ground Test Two

   b. Atmospheric Test None

   c. Space Test Two

7. DATE AVAILABLE FOR TESTS 1965

8. CURRENT DEVELOPMENT STATUS

   a. Proposed only System has been studied and proposed

   b. Project or program is approved and test item is under study, breadboard stage, etc.

   c. Funds expended to date.

Experiment No. S-14

SUMMARY

PASSIVE PROPELLANT SETTLING SYSTEM

I. Test Objective

Prove feasibility of using surface tension forces (wetted and/or non-wetted surfaces in conjunction with intermolecular fluid forces) to control location of liquids in tanks during extended periods of zero gravity. Demonstrate feasibility of expelling only liquid and/or only gas from a tank containing both, when using a fluid control device employing surface tension forces.

II. Importance of the Test

The purpose of this experiment is to demonstrate feasibility of the use of "passive" positive expulsion systems. The term "passive" is used herein with reference to a system that uses surface tension forces, wetted or non-wetted surfaces, screens, baffles, etc. to keep fluid at the tank outlet so that only one phase of fluid (liquid or gas) is expelled from the tank during zero gravity conditions.

Current operational techniques of fluid control at zero gravity employ "active" devices such as bladders or diaphragms that physically separate the liquid and gas in the tank. These techniques have been acceptable for many applications, but are not without limitations. The "passive" fluid control technique holds promise of being more universally applicable and may eventually result in lighter weight, more reliable, and less complex systems than possible through "active" fluid control techniques.

The "passive" fluid control technique will have applications in many areas, e.g., propellant systems, life support systems, and power systems. This experiment concentrates on applications to propellant systems; however, results will be applicable to other areas as well.

Application of bladder or diaphragm techniques has been limited by existing technology to relatively small tanks; positive expulsion of propellants from large tanks in main propulsion systems is typically accomplished by the use of small ullage rocket firings prior to main engine ignition. "Passive" settling techniques promise to provide both positive expulsion of propellants only (no gas), and control of propellant location in the tank so that vehicle c.g. is predictable and unchanged at main engine ignition.

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Two cryogenic propellants (LOX and LH_2) and two storable propellants (N_2O_4 and N_2H_4) are suggested for this experiment; however, a better choice might be made at the time of the test.

It is expected that tests with the cryogenic liquids will be more difficult than those with storable liquids due to the difference between liquid temperature and the temperature of the environment surrounding the tank. A potential problem is the accumulation of frost on the outside of the cryogenic propellant tanks. This frost would obstruct viewing the propellant. Frost accumulation may be prevented by either a zero humidity atmosphere or operation in a depressurized section of the station.

The cryogenic liquids, LOX and LH_2, have applications in life support and power systems, as well as propulsion, so the more difficult nature of experiments with these liquids may be justified by the usefulness of the data.

a. Configuration of Test Items

See Attachment A.

b. Test Support Equipment Required

See Attachment B.

c. Test Procedure

(1) Unstow tanks and place in observation position.
(2) Still photographs of tanks at regular intervals.
(3) At scheduled time, man applies disturbing forces to each tank by manual means or by placing each tank on acceleration table;he records the liquid behavior with the movie camera.
(4) Replace tank to observation position until next test requiring disturbing forces and continue to record still photographs.
(5) After last test using disturbing forces (and acceleration table), stow tanks and conclude experiment.
(6) Prepare camera films and recorded accelerometer data for return to earth.

See Attachment C for additional detail. Man's role is delineated in Attachment E.

Tests aboard the orbiting laboratory will serve to prove feasibility during extended zero gravity conditions and determine effects of disturbing forces created by reaction control system operation and propulsion system on-off thrust transients. These effects cannot be observed without orbital flight.

III. Description of the Experiment

The experiment will use small transparent tanks containing the test liquid and the liquid control device. The liquid position control device in each tank will represent that configuration judged best for eventual application to full-scale tanks containing that particular liquid. Cameras will be used to record the behavior of the liquid in each of the tanks.

It is desirable to test the tanked liquid behavior during stabilized flight in order to observe any upsetting effects on the liquid induced by the small correcting forces of the attitude control and translation system. The astronaut will manually supply disturbing forces to the tank to observe their effect on liquid behavior. The disturbing forces applied should range from those small enough to only cause slight motion of the liquid-gas interface to those sufficient to break that interface and cause liquid-gas mixing. The observer will note the time for the fluid disturbances to damp out and the nature of the damping action. The equilibrium configuration reached after liquid-gas mixing in the tank will be recorded and any deviations from the intended stable position of the liquid in the tank will be noted.

If weight and volume budgets permit, it is desirable to have an acceleration table on board to supply controlled disturbing forces to the tanks. The acceleration table would use an electric motor to give short term continuous acceleration at any selected level. Desirability of both linear and rotational accelerations should be considered in design of the table. Movie cameras would record the liquid behavior when it is subjected to small accelerations.

d. Category of Experiment

Omitted

e. Cost

See Attachment D.

f. Schedule

FY 65	Evaluation and determination of passive settling system design concepts and prelim hardware design.
FY 66	Development of hardware and prototype delivery. 0-g aircraft flights for checkout, simulation and training using prototype hardware.
FY 67	Procurement of test hardware. Integration of hardware with other test gear and AGE.
FY 68	Flight readiness.

IV. Participating Government Agencies

Sponsor: Research and Technology Division

V. Additional Requirements

a. Special Security

None

b. Manning Description Summary

See Attachment E.

c. Logistics

Omitted

d. Facilities

See Attachment G, Sec. 4.

e. Simulation and Training

The astronaut-test conductor will have to be trained in the test procedure and versed on the general results expected from the test. He will be trained using test hardware. The training will not be extensive and he will not have to develop unusual talents nor acquire extensive specialized knowledge.

The man assigned to ground back-up duties during the flight test should be trained similarly in test procedure with the astronaut. He should have the specialized knowledge concerning the scientific nature of the test that the astronaut will not have.

VI. General

a. Communications and Data Handling Requirement

See Attachment F.

b. Development Characteristics

See Attachment G.

Exp No. S-14

ATTACHMENT A

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. EQUIPMENT TO BE TESTED

		Number	(2) Weight lb	(3) Size ft^3
LOX tank	may not require 4 separate liquids for test	1	23	0.5
LH_2 tank		1	6	0.5
N_2O_4 tank		1	27	0.5
N_2H_4 tank		1	17	0.5
Movie camera		1	10	0.25
Still camera		1	5	0.1

Tank shapes will be spherical or cylindrical with ellipsoidal domes on each end.

2. WEIGHT - (as stated above)
3. SIZE - (as stated above)
4. POWER - no significant requirement except for optional acceleration table. A few watts will be required for accelerometer instrumentation. It is assumed cabin light will be sufficient for photography.
   a. Continuous - none
   b. Stand-by - none
   c. Average operating - 50 watts
   d. Peak - 50 watts
   e. Duty cycle - acceleration table would be used intermittently over course of several days. May be used from once to 3 or 4 times a day. Total power required is estimated to be 25 watt-hours. Duty cycle requirements are flexible and can be arranged to avoid high peak power drain on station power supply.
5. SPARES - none
6. TOOLS - none required
7. HEAT OUTPUT - essentially zero. May be slight heat absorption if cryogenic fluids are used.
8. STABILITY - very slight disturbing forces are transmitted to the space station when test tanks are moved to study effect on liquid behavior.

9. VIBRATION LIMITS - no unique requirements
10. SHOCK LIMITS - no unique requirements
11. HAZARDS - test tanks must be leakproof to prevent toxic gas from escaping to cabin atmosphere.
12. TEMPERATURE LIMITATIONS - normal cabin temperature range is sufficient.
13. TYPE AND RANGE OF MEASUREMENT

    Still and movie cameras will be used to record the behavior of the tanked liquid. Still photography will be used at regular intervals to record any changes in the position of the liquid in the tank that may occur as a result of extended time at 0-g conditions. The movie camera will be used to record liquid behavior when disturbing forces are applied to the tanks.

14. SPECIAL ENVIRONMENTAL REQUIREMENTS

    Tests involving cryogenic liquids may have to be done in an unpressurized section of the space laboratory to prevent frost accumulation from obstructing view of the liquid through transparent tank walls.

15. ORIENTATION AND POSITION ACCURACY REQUIREMENTS - no unique requirements
16. EQUIPMENT OPERATING CYCLE

    Frequency - intervals of several hours; one or more times a day
    Time Duration - several days

17. EQUIPMENT LOCATION REQUIREMENTS - locate tanks so they can be handled and manipulated by man.
18. SPECIAL MOUNTINGS REQUIREMENTS - cryogenic liquids will require insulated tank and mounts.
19. PRESSURE VESSELS - tanks will be pressurized from a few psia to 2 or 3 atmospheres.
20. ELECTRO MAGNETIC INTERFERENCE - none
21. MAINTENANCE REQUIREMENTS

    Ground - cryogenic liquids should not be loaded until shortly before launch.
    Space - occasional venting of cryogenic tanks may be required.

ATTACHMENT B

TEST SUPPORT EQUIPMENT

1. RECORDING MEDIA
   Film - still and movie. Log of times of photos.
   Accelerometer readouts of disturbing forces applied to test tanks will be recorded for later transmission to earth or recovery with the film.
2. HANDLING - no unique requirements
3. PACKAGING - stowage position for tanks will be different than test position. No unique packaging requirements are foreseen.
4. CALIBRATION - no unique requirements
5. JIGS AND FIXTURES - optional acceleration table requires firm hold down when in use.
6. NUMBER OF LEADS FROM OUTSIDE TO INSIDE STATION - none
7. SENSORS - accelerometers
8. TRAINERS/SIMULATORS - need 0-g aircraft flights to check out test articles. Astronaut will require pre-flight training (see Attachment E).
9. INSTRUMENTATION - desire direct readout pressure gage on tanks.
10. RELATED SUPPORT EQUIPMENT - none
11. AGE - propellant (liquid) loading equipment to fill test tanks.
12. ENVIRONMENTAL TEST EQUIPMENT - vapor detectors and pressure gages for checkout of no-leak tank.
13. FACILITIES - no substantial requirement.

ATTACHMENT C

TEST OPERATING CHARACTERISTICS

1. ORBITAL PARAMETERS - normal station parameters
2. PLANE CHANGE - no requirement
3. ALTITUDE CHANGE - no requirement
4. TIME ON ORBIT - 0-g is required. Minimum of several days is desired.
5. TEST DURATION - few days
6. TOTAL NUMBER OF TESTS - few per tank (4 tanks - total of 12-16 tests is typical)
7. TEST FREQUENCY - one or more per day
8. INTERVAL BETWEEN TESTS - about 1 day
9. CREW TASK LOADS - total man-hours: 10 or less
10. CREW TASK FREQUENCY

The experiment requires one man. A typical work schedule sequence is:

10 min/hr for 12 hours	(still photography)
1 hour full time	(movie photography)
10 min/4 hours for 2 days	(still photography)
1 hour full time	(movie photography)
10 min/4 hours for 2 days	(still photography)
1 hour full time	(movie photography)

Work intervals may be altered if desirable to improve man's overall work-rest schedule.

It may be possible to make still photography operations automatic, thereby reducing man-hour requirements, however this would require additional equipment not listed.

11. FIELD OF VIEW REQUIREMENTS - no requirements
12. GROUND CONTROL LIAISON DURATION - total of 5-10 hours of stand-by communications
13. GROUND CONTROL LIAISON FREQUENCY - stand-by when astronaut is handling tanks and taking data during test.
14. EXTERNAL TEST ITEMS - none
15. QUALIFICATION TESTS - passive propellant settling system in test tanks will be given functional checkout in 0-g aircraft flights prior to space test.
16. SEQUENCE OF EVENTS AS THEY OCCUR DURING FLIGHT - see No. 10 above and III-c.
17. HANDLING PROCEDURES - no dangerous procedures. Handling procedures developed in pre-flight training.

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ATTACHMENT D

* FUNDING SUMMARY (Funding shown in thousands of $)

BUDGET REQUIREMENTS BY FISCAL YEAR

	PRIOR	FY 65	FY 66	FY 67	FY 68	FY 69	TOTAL
Engineering, Developmental Environmental Testing, Procurement		25	50	25	--	--	100
Integration and Installation		--	--	25	--	--	25
AGE		--	--	10	--	--	10
Simulators/Trainers		--	25	5	--	--	30
Data Reduction		--	--	--	10	--	10
Equipment Rework		--	--	--	--	--	0
Other		--	--	--	--	--	0
TOTAL		25	75	65	10	0	175 TOTAL

* Estimates

ATTACHMENT E

MANNING DESCRIPTION

1. ASTRONAUTS

a. Number required - one

<u>Man's function</u> -

Man's primary function is as test conductor. He will unstow test articles as necessary and place them in test position. He will do all photography or a major part of it. His ability to supply the necessary disturbing forces to the liquid-containing test tanks greatly simplifies design of the test equipment. His judgement will be beneficial in applying the necessary magnitude of forces to result in the desired level of disturbance of the liquid. He will prepare data (film) for recovery and place it in the return vehicle.

It is possible that tests of passive fluid control devices could be done on unmanned orbital flights, but with greater complication. If camera films are to be the data source, provisions for recovery will have to be made. Video telemetry might be used with some sacrifice in resolution and color. It appears that a manned test would have several advantages for initial feasibility demonstration. Camera film (color) may be used as a data source; recovery is simplified. Various camera angles and lighting conditions would be possible. Man, having a basic knowledge of test objectives, could use his intelligence in selecting, obtaining, and recording data. He serves a very important role in supplying different perturbing forces to the liquid under observation to observe their effect on liquid behavior.

b. Crew skill requirements - no unique skill required. Must have pre-flight training.

c. Manpower Profile - see Attachment C, Section 10

d. Critical Functions - photography and application of proper disturbing forces to test tanks.

e. Work Positions - no unique requirements

f. Time Controlled Tasks - no unique requirements

g. Human Performance Measures - correlation of test data with previous data from pre-flight training.

h. Physiological and Psychological Measures - none

i. Selection Factors - none

j. Training Requirements - astronaut should be thoroughly briefed in expected behavior of the liquid at 0-g and the results anticipated from the test. He should be an observer on 0-g aircraft flights when test hardware is checked out. He should have ground training in the test procedure for the orbital test.

2. GROUND PERSONNEL

a. Number required - one

<u>Man's function</u> -

Ground personnel should have participating role in development of test equipment, astronaut training, and stand-by during flight operations.

b. Crew Skill Requirements - technically oriented personnel experienced in design of test hardware, test procedure, and objectives.

c. Manpower Profile - required during portions of test when upsetting forces are applied to test tanks.

d. Critical Functions - back-up knowledge

e. Work Positions - ground communications station

f. Time Controlled Tasks - none

g. Human Performance Measures - none

h. Physiological and Psychological Measures - none

i. Selection Factors - broad knowledge and experience in developing test for space flight.

j. Training Requirements - should be trained in test procedure same as astronaut conducting the test.

ATTACHMENT F

COMMUNICATIONS AND DATA HANDLING

1. DATA RATE - on-board filming as indicated in Attachment C, Sec. 10. Ground communications as necessary and determined by astronaut. May require accelerometer readout to ground of disturbing forces applied to tanks. Readout may also be recovered in return vehicle with film.
2. FUNCTIONS TO BE MEASURED - liquid behavior in tanks.
3. TYPE OF ANALYSIS REQUIRED - film will indicate liquid behavior resulting from disturbing forces as indicated by accelerometer readouts.
4. PICTORIAL DATA REQUIRED - camera film.
5. REAL TIME MONITORING REQUIREMENT - stand-by communications during test.
6. DATA EDITING OR COMPRESSION - compression of accelerometer readouts is desirable if telemetered to ground.
7. READ-OUT TIME - few minutes
8. REQUIREMENTS FOR PERMANENT DATA RECORDS - no unique requirements
9. MANUAL AND/OR AUTOMATIC CONTROL - as indicated in III and Attachment E
10. SIMULTANEITY - none
11. GROUND COMMANDS REQUIRED - as necessary for recorded data readout.

Exp No. S-14

ATTACHMENT G

DEVELOPMENT CHARACTERISTICS

1. DEVELOPMENT TIME - about one year
2. FINAL DEFINITIVE TEST DESIGN TIME -
3. NUMBER OF GROUND OR FLIGHT TESTS REQUIRED - few 0-g aircraft flights for checkout of test articles.
4. TYPE OF DEVELOPMENT TEST ITEMS
   a. Vacuum Chamber - for leak tests and checkout of no-frost design of transparent cryogenic liquid tanks.
   b. Shaker - as necessary to qualify for normal vehicle environment.
   c. Thermal - none
   d. Acoustic - none
   e. Simulators - test procedure training (little equipment required)
   f. Aircraft - 0-g flights
5. SUPPORT EQUIPMENT DEVELOPMENT TIME - about 6 months
6. NUMBER OF TEST ARTICLES REQUIRED FOR:
   a. Ground Test - a few of each type of tank used in the test are necessary for design verification and procedural training.
   b. Atmospheric Test - none
   c. Space Test - one to four test tanks are suggested
7. DATE AVAILABLE FOR TESTS - 1967
8. CURRENT DEVELOPMENT STATUS

Air Force Research and Technology Division and the NASA Lewis Research Center have funded programs for the exploration and development of surface tension techniques for passive propellant control systems. These programs have laid a foundation for the technology of liquid control by surface tension forces and have suggested prototype designs for passive control systems. These studies should be carried to culmination in an orbital test.

COHERENT E-M PROPAGATION AND ANTENNA LOADING

I. Objective: To determine phase distortion and other effects due to the ionosphere on e-m emanation from satellites. A secondary objective is to investigate the problems of antenna loading and high power r-f distribution in the high vacuum and temperature extremes encountered in space.

II. Description: The experiment will consist of a series of tests designed to measure the extent of phase distortion of the ionosphere in two way propagation of r-f energy. Calibrated ground targets will be used. Measurements will be made and recorded at both the ground targets and in the satellite. Simultaneous measurements, performed from the ground, of the existing atmospheric, tropospheric and ionospheric conditions will be made to provide correlative data.

The astronaut will adjust the various controls for optimum system performance and also vary parameters to determine loss of performance.

An antenna and T/R unit will be required in addition to such ancillary equipments as tape recorders, clocks, etc. Photographs will be taken to determine the extent of cloud layer, moisture content and to some extent other boundary conditions.

The experiment will also determine the effectiveness of various design for loading the antenna with high peak powers during the experimentation.

The astronaut will make repairs and adjustments as necessary to complete the experimentation.

III. Importance of Test: The tests are needed to provide basic data for the design and development of a high resolution radar system.

IV. Vehicle Requirements:

Power:	Never more than 1 kw for short periods
Volume:	10 ft^3
Weights:	250 lbs
Stabilization:	.05 $^{\circ}$/Sec
Aperture:	Window for viewing antenna and antenna alignment

V. Participating Agencies:

RTD

SOLAR X-RAY MONITORING

I. Test Objective

To monitor the solar X-Ray flux in certain selected bands to indicate solar activity.

II. Importance of the Test

The MOL flights will occur during a period of maximum solar activity. Studies of the soft X-Ray region of the solar spectrum currently being undertaken may identify certain spectrum lines which are precursors to lethal solar flares. Since soft solar X-Ray radiation can only be detected from above the atmosphere, it would be necessary under these circumstances to provide a monitoring device for protection of the astronauts. Also, material samples exposed to space environment will receive a substantial integrated dose of soft X-Rays. In order to understand property changes, it is important to determine the energy spectrum and time history of these X-Rays.

III. Description of the Experiment

Soft X-Rays will be detected with a gas-filled thin window proportional counter The transmission of the window and filling gas determine the wavelength region over which the detector is sensitive. This region will be subdivided into narrow wavelength groups by amplifying the signal and sending it through a five-channel pulse height analyzer.

a. Configuration of Test Items

Since X-Rays of this energy are readily absorbed by minute quantities of matter, the sensor window must be exposed to space with a clear view of the sun. To maximize monitoring time, the detector should be mounted on the solar cell panels which will be oriented toward the sun during the sunlit portion of the orbit. If this is not feasible, then four or five sensors can be dispersed along the periphery of the unpressurized module in order to provide suitable coverage. The detector box dimensions are 4" x 4" x 3" deep. The electronics box including the PHA is the same size and can be separated from the sensor box by a large distance. Weight of each box is estimated as 2# and power consumption is 2 watts continuous. A sketch of the instrument is shown in Fig. 1.

The output from the electronics box are presently planned to be analog voltages. These signals will be fed in parallel to the TM system and to a D.C. voltmeter in the MOL. The astronaut can cycle through the channels with a simple switch to read the voltages. A warning flight will flash whenever the signal exceeds a preset level.

b. Test Support Equipment Required

1) The TM outputs from the electronics box consist of eight analog voltages. It is desired that these voltages be recorded as frequently as possible (every 1 - 10 seconds) on a tape recorder which is played back at high speed when passing over tracking stations.

2) No AGE is required other than that for normal TM reception at tracking stations.

c. Test Procedure

As indicated in (a), no services are required from the astronaut other than occasionally checking output voltages. However, if the warning light threshold is exceeded, the astronaut would be expected to take whatever precautionary measures were practicable such as remaining in capsule during the solar storm, keeping shielding material around himself, etc.

d. Category of Experiment

Category C

e. Cost

Cost of furnishing units for MOL should be quite low, approximately $20K per unit for flight-qualified hardware. (See Section VI (b)).

f. Schedule

Hardware could be made available by the end of 1964.

IV. Participating Government Agencies

Sponsor: OAR

V. Additional Requirements

None

VI. General

a. Communications and Data Handling Requirement

The data consist of 8 analog voltages which includes 5 counting rates, 1 high voltage monitor, and 2 temperature sensors. It is desired that the counting rates be recorded every few seconds. The other functions would not need to be measured more than once every few minutes.

Data stored on an on-board tape recorder would be read-out once per orbit to a ground station. The information on the ground station tape would be decommutated, digitized, converted to physical quantities, and merged with satellite ephemeris. The output tape from this operation would then be sent to Aerospace for further analysis.

b. Development Characteristics

This experiment will be completely designed, fabricated, and flown on Program 162 vehicles in 1964. Improvements in design will certainly be made for those units to be flown on MOL. However, these are expected to be minor and final MOL design should be finished by the end of 1964. Due to the relatively simple nature of the experiment, any number of required items can be delivered within 90 days after design freeze.

Exp. No. S-16

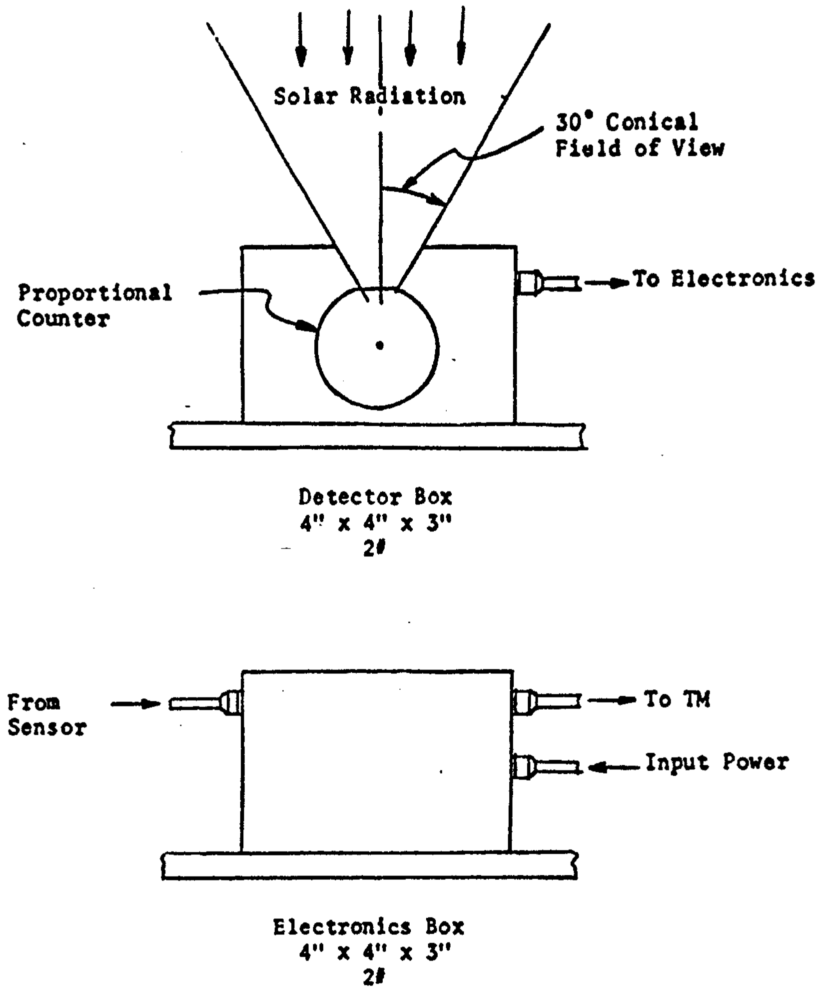

Fig. 1. Sketch of Solar X-Ray Experiment

Experiment No. S-17

MATERIALS DEGRADATION AND MALFUNCTION ANALYSIS

I. Test Objectives

The purpose of this experiment is to evaluate degradation and analyze any malfunction of MOL components and materials under actual space flight conditions. The spacecraft and its auxiliary equipment will be used as the object of the tests. The primary goal of this experiment is to determine the cause of failure or degradation, if it occurs. A secondary objective is to determine whether or not current strict specifications on materials and components can be relaxed without sacrifice in reliability. Maintenance and repair functions will be demonstrated by the astronaut.

II. Importance of Test

1) The MOL vehicle affords an opportunity to study the performance of critical materials and components under actual space mission conditions. The presence of man permits an unambiguous visual observation of any degradation or malfunction. This includes such items as seizure of bearings, cold welding of metal surfaces, discoloration of thermal control surfaces, and erosion or sputtering of optical surfaces. Knowledge of degradation and minor malfunctions would permit the optimization of equipment for following missions especially those of longer duration. A specific course of action must be set up which permits a routine check of potential trouble areas since under normal conditions such observations would be made only in the case of gross malfunction.

2) Similar investigations might also be made on selected components which might be expected to fail. This would mean, for example, the inclusion of various substandard components in the solar cell array or thermal control system. Present specifications, particularly cleanliness, for such components are extremely rigid. Some inflight experiments have suggested that these specifications might be relaxed without loss in reliability. An astronaut could evaluate selected substandard components with the view of relaxing standards. For example, a filter was inadvertently left off one solar cell in a recent test vehicle. To date this cell has shown no more degradation than the cells with the filters. This is in contradiction to laboratory experiments. Removing the filters could greatly reduce the cost of such arrays. A second example is the delay in launching of a vehicle when the solar panels and thermal control coatings were accidently flooded with condensant. An elaborate cleaning procedure was needed before launch costing many hundreds of thousands of dollars. The possibility exists that all that was needed was to clean the surfaces with distilled water.

3) The role of the man will be to determine degradation or malfunction visually and to perform the necessary operational tasks to determine the cause. Even in those cases where much of the data can be obtained remotely, the astronaut is needed to unambiguously pinpoint the exact nature of the malfunction. In some cases it might be of interest to return the defective component to the ground.

III. Description of the Experiment

A. This experiment must be coordinated closely with the MOL vehicle design group. A meaningful description of the experiment is possible only after such discussion. The experiment will consist of detailing a continuous observation of selected MOL components, and providing the necessary equipment to evaluate same. This equipment might include such items as a low power microscope with camera attachment, a portable reflectometer and a volt-ammeter. Typical of the experiments which might be performed are the following.

1) Friction. Auxiliary components such as telescopes and cameras will have exposed bearings. These bearings might fail or degrade in performance. Torque measuring devices might be simply installed which measures the extent of degradation. The astronaut would attempt by visual observation to pinpoint the source of the degradation or malfunction.

2) Solar Cell Degradation. A number of test solar cells will be placed in the array. This will include some without UV filters, and some which have had specified pre-flight preparation (i.e. a calibrated dirty fingerprint). This cell will be monitored remotely. If degradation occurs, the astronaut will attempt visually to pinpoint its exact nature.

3) Thermal Control Coating Degradation. Certain portions of the vehicle are not particularly thermally sensitive. Thermal control coatings, other than that to be used on the main vehicle, will be placed in these regions. These test coatings should be designed to test not only the material itself but also application technology.

4) Cold Welding. Exposed metal surfaces might weld. If this occurs the astronaut would attempt to break the weld. In the case of a hatch, for example, he might have to force it open. A detailed description of the position of the welded area, its magnitude and perhaps a photograph of the weld would be made. This would be of help in preventing future malfunctions of such components.

B. Cost

This experiment is relatively low cost. Simple diagnostic instruments and tools, sample components and mechanisms, and post flight analysis costs should total less than 100 K.

IV. Participating Government Agencies

Sponsor: RDT

Equipment: Supplied by MOL contractor.

V. Additional Requirements

This experiment must be coordinated closely with those agencies responsible for the design and construction of the MOL vehicle.

a. Special Security: None

b. Manning Description Summary

1) 30 minutes per day average for one astronaut.

ASTRONOMICAL PHOTOGRAPHY

I. Test Objectives

The objective of this experiment is to obtain direct photographs of various astronomical objects, including the sun, planets, and selected and extra-galactic objects, with a resolution exceeding any previously attained. Clearly, the increased detail visible on these photographs would contribute greatly to the better understanding of these objects. Experience gained through executing this program of astronomical photography would contribute greatly to the planning of future astronomical space telescope systems.

II. Importance of the Test

With the growth of Man's efforts to explore space, astronomy is rapidly gaining significance, not only in an intellectual sense, but in a practical sense, as well. A capability for contributing to astronomical knowledge, such as will be provided by MOL, should certainly be taken advantage of. Orbiting a camera capable of extremely high resolution photography is a unique, as well as an expensive accomplishment, and the opportunity to evaluate the role man can play in operating what is equivalent to an astronomical observatory in space should be exploited to the fullest.

Exp No. S-18

III. Description of the Experiment

A. Background

According to present planning, a major portion of the MOL payload is to be assigned to a optical system, capable of high resolution. The required resolution far exceeds the performance of ground-based astronomical telescopes, which are limited by the image blurring effects produced by the atmosphere. Because the primary mission of the camera does not require continuous operation, the system offers a potential for making a highly significant contribution to astronomy, if it could be used for this purpose, when not otherwise employed.

As currently envisioned, the MOL camera system would have a unique capability offered by no presently planned astronomical satellite payload; namely, the system would make it possible to utilize photography for recording astronomical data, thereby exploiting the high information storage capacity of a photographic emulsion, and its ability to record fine image detail.

It should be pointed out that this class of experiments has no counterpart in the astronomical experiments which comprise the current NASA Orbiting Solar Observatory (OSO) and Orbiting Astronomical Observatory (OAO) programs. These experiments deal exclusively with the measurement of ultraviolet and x-ray radiation from the sun and astronomical sources, which can only be recorded with telescopes operating above the earth's atmosphere.

The experiments we are proposing for MOL do have counterparts in the Stratoscope II program, which aims at securing the highest resolution photographs obtainable, and also infrared spectra of selected astronomical objects, exclusive of the sun. A 36-inch telescope is carried by a balloon to altitudes of approximately 80,000 feet, where it is expected that image degradation by the atmosphere will be reduced to the point where resolution approaching the diffraction limit of the telescope will be achieved. The balloon is unmanned, the telescope being controlled from a ground command station. The program, devoted exclusively to astronomical studies, has already made two preliminary flights.

Clearly, the importance of conducting astronomical photography with the MOL camera system will depend primarily upon whether the system is capable of producing results which are significantly better than the data existing at the time MOL is in operation. This depends to a great extent upon the results of Stratoscope II, and also upon the performance specifications finally adopted for the MOL camera. Finally, irrespective of the direct astronomical results, MOL provides a unique opportunity to experimentally evaluate whether or not the presence of man is desirable in future orbiting astronomical observatory systems.

At the time of writing, MOL camera system concepts are in a fluid state, but it appears rather well established that a prime technical objective will be to explore the practical limit of resolution which can be achieved with an orbiting camera system.

B. Stabilization Problem: "Snapshot" Photography

In examining the feasibility of conducting high resolution astronomical photography with the MOL camera, a fundamental problem immediately presents itself.

This arises from the fact that vehicle orientation stability performance is being specified to only meet the requirements imposed by ground photography, for which the exposure times are not expected to exceed 0.005 sec. With the exception of the sun, Mercury and Venus, all other astronomical objects have lower apparent surface brightness than does the sunlit earth, and therefore require longer exposure time, (assuming same emulsion, f-stop, etc.). In order to fully exploit the optics, it is essential that during the exposure time, image motion relative to the film must not exceed a small fraction of the dimensions of the diffraction disk. This is possible if:

i. Exposure times are sufficiently short.

ii. Vehicle orientation is stabilized during an extended exposure to a small fraction of the optical angular resolution.

iii. Image motion relative to the film is cancelled out to sufficient accuracy by some kind of device located near the focal plane of the system.

Clearly, the simplest condition is (i), because it permits "snapshot" photography, imposing a minimum of special requirements on the overall MOL system. An estimate of the maximum allowable exposure time can be made, assuming that the vehicle angular rates do not exceed 0.001 deg sec^{-1}, a value which we have been given to work from. For the assumed resolution of 0.1 arc seconds, the exposure time cannot exceed 0.01 sec. This value can be modified by noting that is is directly proportional to the assumed angular resolution and inversely proportional to the maximum vehicle angular rate.

The objects suitable for such "snapshot" photography, using panchromatic emulsions, are severely limited in number; namely, the Moon, Mercury, Venus and Mars. Unfortunately, the sun is so bright that special provisions are likely to be required, which remove it from this category. Even "snapshot" planetary photography is likely to involve a modification of the camera system. In order to minimize the exposure time, it appears to be advantageous to enlarge the image by means of secondary magnification, which permits emulsions of lower resolving power, but greater sensitivity to be used. The increased sensitivity then more than compensates for the decreased image brightness associated with enlargement of the image. Also, a greater selection of emulsion characteristics is available in this sensitivity range. This happens to be practical for astronomical photography, because the angular field to be photographed is generally small.

"Snapshot" photography would therefore require an auxiliary, compact camera assembly consisting of enlarging optics, filter holder, shutter, film holder and magazine, viewing eyepiece and focusing mechanism. This camera assembly would either be located so as to intercept the image ahead of the focal plane of the primary camera, or would be designed to attach to the primary camera film transport assembly.

It is important to emphasize that although important results can be obtained, restricting the system to operate in this fashion imposes a severe limitation on its usefulness for astronomical work. Note that photography of Mars, only marginally possible with the assumed value for vehicle angular rate, would not be feasible if this proved to be too optimistic an estimate.

C. Solar Heating Problem

By making it possible to point the primary camera at the sun, the usefulness of the system would be significantly extended, because the sun is an especially interesting object to observe with high resolution, and it presents many exciting problems to be studied by this means. It should also be noted that the finest photographs of the sun yet taken were made with a telescope of 12-inch aperture, so that the gains achievable with a larger aperture are evident. The principal problem is that of heating of the secondary mirror of the camera, which intercepts the highly concentrated beam from the primary mirror. The flux of radiant energy incident upon the secondary may exceed a value 50 times normal sunlight, depending upon the specific geometry adopted. Unless special provisions are made, this can detrimentally affect the optical figure of the secondary mirror, thereby impairing the resolution of the camera. There exist a number of approaches to the solution of this problem. One method would be to incorporate some form of shutter which would shield the secondary, except at the instant the photograph is taken. This is easier said than done, when the relatively large size of the secondary is taken into account. A fuzed quartz, or metal (beryllium) secondary might not require protection. Exposure times, even through a narrow bandpass birefringent filter, are sufficiently short that vehicle stability is not likely to be a problem.

D. Extended Exposure Capability

We now discuss the highly important subject of how exposure times in excess of 0.01 sec can be made, without image blurring.

(ii), requiring extremely precise vehicle stabilization, is very unlikely to be technically feasible. Aside from the extreme precision of pointing required, the problem is aggravated by the large moments of inertia of the vehicle, and the many sources of disturbing torques and vibration; e.g., moving machinery, involuntary movements of the astronauts, etc. It does, however, appear to be technically feasible to considerably tighten up the vehicle attitude stabilization, at least during the period that astronomical photography is in progress, by feeding the control system with three-axis attitude error signals derived from a pair of star trackers. These star trackers need not be boresighted with the axis of the main camera, and could be independently oriented to acquire sufficiently bright stars. It would be sufficient to maintain vehicle pointing within the dynamic range of some form of image motion compensation device (i.e., iii). This range could be typically two (conceivably, three) orders of magnitude greater than the ultimate tracking accuracy required; i.e., 0.1 to one minute of arc. Naturally, the closer the vehicle can be controlled, the less severe the problem of image motion compensation. Factors which would contribute to making this more feasible would be incorporation of cold gas jets in the vehicle control system and provision for reducing the coupling of the astronaut to the vehicle.

There is also a distinct possibility that the astronaut may be able to accomplish the same function as the star trackers; namely, it may prove to be feasible for him to manually supply the vehicle attitude corrective commands to sufficient accuracy to allow the image motion compensation device to operate. This would be directly analogous to the manner in which an astronomer "guides" his telescope on the ground by supplying corrections necessary to maintain the image of a preselected guide star fixed with respect to the reticle of a guiding eyepiece. Either the visual tracking telescope associated with the primary camera system, or a guiding eyepiece suitably located in the focal plane of the primary camera could be utilized for this purpose. It should be noted that the astronaut may have to supply corrections about a third axis, as well. However, in view of the inherent simplicity of several star trackers currently available, it is felt advisable to utilize such devices to relieve the astronaut from the task of guiding the vehicle.

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The basic principle underlying the image motion compensation devices that have been referred to is to utilize some form of low inertia device, with corresponding high frequency response and low power requirement, to sense image motion photoelectrically, and compensate for it. The simplest requirement would be to compensate only for image translation along two orthogonal axes lying in the focal plane. Depending upon the degree of vehicle control, rotation about an axis normal to the focal plane may or may not be required. Either the film can be translated (and rotated) by means of a double slide movement, or equivalent, or the film can remain stationary and image motion cancelled by translating an image transfer lens, or by tilting a mirror or plane parallel plate about two orthogonal axes, etc. The problem is somewhat simplified because the field of view requiring compensation will in most cases be relatively small; i.e., less than one minute of arc. Also, because the primary camera optics are corrected for a relatively large field, the excursion of the image off the optical axis will not be detrimental.

The problem which appears to us to be potentially the greatest source of difficulty in accomplishing successful image motion compensation is vibration, because of the high frequency components which are likely to occur, and which would be very difficult to sense and to compensate for. We can only point out that such high frequency components would create a similar problem for ground photography, and because of the importance of the latter, the problem will no doubt receive careful attention.

The above considerations suggest a feasible scheme; namely,

iv. Vehicle stabilization to approximately 0.1 minute of arc utilizing star trackers (or the astronaut) as error sensors in the control system, combined with an independent image motion compensation device to supply the ultimate correction.

It should be noted that once the features of (iv), necessary for exposures times exceeding 0.01 sec, are incorporated into the MOL system, then exposure times as long as tens of minutes are, at least in principle, equally feasible. This is of profound significance, because it would then provide MOL with an essentially universal capability for astronomical work. More specifically, it would transform MOL from a system of limited astronomical utility into a system capable of tackling some of the most significant problems in astronomy.

E. Recommended Astronomical Objectives

The following are a number of recommendations for astronomical photography, with a brief description of their significance. The recommendations fall into essentially three categories.

Category A. "Snapshot" photography; exposures less than 0.01 sec; minimum number of special requirements.

Category B. Solar photography; requires solution of the problem of secondary mirror heating.

Category C. Extended exposures exceeding 0.01 sec requiring improved vehicle stabilization, combined with image motion compensation.

No claim is made for comprehensiveness. As previously noted, only a few problems fall into Category A. In passing on to Categories B and C the number of possible problems multiplies rapidly, and it is possible to only select a number of representative problems to serve as a guide. Naturally, the final selection of experiments to be performed must be limited, and will depend upon a number of factors over which we have no control at the present.

1. Category A.

a. Planets

Direct "snapshot" photography is possible for the planets Mercury, Venus and Mars. High resolution planetary photography can contribute in many ways.

For example, we can hope to achieve considerably better definition of surface details; namely, topographic outline and relief for Mercury and Mars. The low contrast features in the cloud cover of Venus can be studied, and large scale patterns in the cloud structure can be analyzed to determine circulation patterns, polar orientation, etc. The finely resolved extended crescent of Venus near conjunction can be analyzed to determine the vertical extent and non-uniformities of the atmosphere. Improved measurements of the diameters of the planets can be made, as well as of their flattening. The diameters, combined with independent mass determinations, lead directly to improved mean densities for the planets, and the flattening measurements are essential to studies of their internal structure.

b. The Moon

The Moon is certainly an attractive subject for study, expecially because of its important role in our nation's space program. However, it must be noted that NASA plans to observe the Moon at close range with the Ranger television system, and with the Lunar Orbiter photographic system. Also, in connection with the USAF Lunar Mapping Program, the Moon is being photographed and observed visually with large telescopes, rather intensively. It is therefore not clear at the present time whether lunar photography with MOL will be able to contribute significantly to the existing body of lunar data. Increasing evidence of the occurrence of transient active lunar phenomena suggests the possibility of an experiment in which the astronaut examines a preselected region of the lunar surface visually through the primary telescope for signs of such activity, and if an event is noted to be occurring, to photograph the affected region. Another possibility is high resolution stereoscopic mapping. It is recommended that a decision as to whether or not to incorporate lunar photography in the MOL astronomical program be deferred until such time that its usefulness can be better ascertained.

2. Category B

a. The Sun

The sun exhibits a wealth of complex, time varying detail when observed both in white light, and monochromatically. Because the temporal behavior of the various solar features is one of the most important aspects of the problem, all photography should be conducted in time-lapse fashion, at intervals not exceeding five seconds, over as long a continuous span as possible. The field of view should be chosen to be as large as practical. Direct, white light photography would record solar disk features such as granulation, sunspot umbrae and penumbrae, pores, faculae, and the sharp limb of the sun. The granulation is in itself a whole subject of study. Of significance are the distribution of granule sizes, with emphasis on the smaller elements. The shapes, temporal variation (mean lifetime for an individual granule is of the order of 8 minutes) and brightness (temperature) differences are highly significant data. Temporal changes take place more slowly in the magnetically stabilized sunspots. The changes are important to observe, and the relationship of the filamentary structure of sunspot penumbrae to sunspot magnetic fields is a challenging problem. Little is known about structure within sunspot umbrae. Modification of solar granulation in the vicinity of sunspots is of significance, because of the predicted inhibition of convection by solar magnetic fields. Pores, or incipient sunspots are important features for study, because of their relationship to the formation and disappearance of sunspots. Faculae, best observed near the solar limb are of interest, because they occur where the magnetic field is locally intensified. Also, near the limb, the configuration of sunspots and the solar granulation can be analyzed to ascertain the vertical structures of these features. Finally, the sharpness of the solar limb is a subject of interest, because it represents a very high change in opacity of solar material, taking place within a very small vertical distance.

Utilization of a narrow bandpass birefringent filter tuned to trasmit only the H-alpha line of neutral hydrogen would greatly expand the program of solar photography, because of the variety of new features which are made visible by means of this device. Of primary interest is the fine structure of the "second limb" of the chromosphere, which is highly relevant to the understanding of the nature of the solar chromosphere. Other features of interest at the limb are the fine structures in prominences, active spicules, and surges. Important disk features are the projected spicule structure, filaments, bright plages, sunspot-associated fibrillar structures, microflares (and flares). Sequentially tuning the filter passband over the line profile during the series of time-lapse exposures would provide Doppler velocity information; which is highly desirable when it comes to interpreting the photographic record.

3. Category C.

a. Planets and Satellites

Direct photography is now possible for the rest of the planets; namely, Jupiter, Saturn, Uranus, Neptune and Pluto. The cloud belt system of Jupiter will reveal a wealth of detail, as should also the famous Red Spot. In the case of Saturn, there exists the possibility of discovering important new fine structure in the ring system. Both Jupiter and Saturn have satellites with resolvable disks, and diameter measurements would lead to improved density and albedo determinations for these objects.

Color discrimination could be achieved by combining filters and emulsions to isolate narrow wavelength bands in the range 0.3 to 0.7 microns. This would be especially effective in the study of Venus and Mars. In the case of Mars, blue photographs provide information on the Martian atmosphere; surface features are veiled, and bright, white patches of clouds are sometimes visible. The extensive, and rapidly changing yellowish clouds, presumably dust, which occasionally occur are most conspicuous on photographs taken in the yellow. Red and near infrared photographs provide the best views of the surface, some features of which exhibit marked seasonal variations. Martian surface markings have long been the subject of much general interest, and also controversy.

Polarization measurements, for which photography is not well suited, could still be made by differential measurement of images taken through successive orientations of a polaroid analyzer, using narrow wavelength bands throughout the spectrum. Such measurements would be extremely useful in analyzing the properties of the atmospheres of the planets, as well as their surfaces, when the latter are visible.

Ultraviolet photography of the planets below 0.3 microns has so far not been possible. The incident solar flux rapidly decreases towards shorter wavelengths, and the planet surface brightness must reflect this decrease, as well as that due to selective absorption in its atmosphere, when this occurs. MOL might very well offer the first opportunity for ultraviolet photography of the planets. In this case, resolution could be sacrificed if necessary to achieve the longer exposure times required. One particularly novel and important problem in planetary ultraviolet photography is singled out for discussion in a later section.

Measurement of the very small angular disks subtended by the satellites of planets is extremely difficult, and can probably be best done visually. The most effective instrument for this purpose is the disk micrometer, which is an instrument permitting disks of various known size, whose brightness can be adjusted to match that of the object being measured, to be placed into the field of view for direct comparison. This would require some special training for the astronaut, but the results would be of great value. Of especial interest would be a measurement of the apparent diameter of Pluto, whose currently accepted value of 0.2 arc seconds is somewhat controversial.

c. Comets

Photography of the nuclear region of a comet, especially if one should happen to approach the vicinity of the earth at a favorable time, would be of considerable interest. This is one example of many types of experiments which, even though arising unexpectedly, should be injected into the program if regarded to be of greater importance than the experiment they might have to displace.

Passing beyond the solar system, we turn to the broad field of stellar astronomy. Here the number of interesting problems is virtually unlimited. We have selected from the vast number of problems suited for investigation by means of direct photography, several which we believe to be of particular importance, and at the same time, well-suited for MOL.

d. Nearby Galaxies

The nucleus of the nearest large spiral galaxy M31, the Andromeda Nebula, is a "semi-stellar" object, sharply defined, with an elliptical structure of dimensions 2.5 x 1.5 arc seconds. Little is known regarding the nature of this object, except that observed kinematic features suggest a very large concentration of mass towards the center. Improved measurements of the light distribution in the region of the nucleus would also help to establish this concentration directly. The nucleus is sufficiently bright (equivalent to a star of magnitude 14.5) that a series of exposures varying from seconds to minutes, taken in two or three colors, would provide highly interesting data. Some other nearby spiral sytems, such as M33, M101 and M81 should be studied in a similar manner. It has been suggested that in the future, these semi-stellar nuclei may play an important role in establishing the cosmic distance scale, because they may all be intrinsically similar in size, and because it may be possible to observe them at great distances when space telescopes of high resolution can take advantage of their small angular size.

e. "Quasi-Stellar" Radio Sources

Perhaps the most remarkable of all astronomical objects are the recently discovered "quasi-stellar" radio sources, because they are the brightest known objects in the Universe. First discovered as strong radio sources, their optical spectra have recently shown them to be very distant objects of high excitation. Despite their extreme distances, they are relatively bright optically, and it has been estimated that at least two of these objects are 100 times more luminous than a typical galaxy, though at the same time, considerably smaller. Even the brightest of them, 3C 273, cannot be distinguished from a 13th magnitude star, except for an associated whisp. The determination of the angular size, and any resolvable structure, would provide fundamental information regarding their nature.

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f. "Seyfert Galaxies"

Apparently related to the "quasi-stellar" radio sources are the "Seyfert Galaxies". These rare spiral galaxies are characterized by very bright and highly condensed nuclei, whose spectra contain lines of high excitation, for example, Fe VII, I.P. = 102 volts. Analysis of high resolution photographs of the nuclei of these galaxies would be similar to that previously described for the nuclei of nearby, normal spirals, and would improve our basic understanding of the phenomenon of nuclear emission in galaxies.

g. Extremely Faint Galaxies

The following experiment is perhaps the most significant contribution which MOL could make to astronomy. Though simple in concept, the experiment would require the utmost in optical and tracking performance of the MOL system. On plates taken with the 200-inch Hale telescope, of fields situated at high galactic latitudes, the faintest recognizable images correspond to 24th magnitude, and are of galaxies situated at the limit of the observable universe. The limit in faintness is set by the combination of smearing of images due to "seeing" produced by the atmosphere, and by diffuse background radiation from the night-sky. Assuming that MOL permits a five-fold improvement in resolution, and a two-fold reduction in background radiation by elimination of the atmospheric component, the ultimate threshold of the MOL camera operating at f/30 should be 3 magnitudes fainter than the limit of the 200-inch telescope. A suitably exposed direct photograph of a preselected field near the galactic pole, even though achieving half this theoretical limiting magnitude gain, would double the distance at which faint galaxies can be observed.

The experiments we have described up to now have involved only direct photography. It would seem much more likely that this particular use of the MOL camera system would be the easiest to implement, and it has been with this in mind that we have emphasized direct photography of astronomical objects. Assuming the capability for maintaining accurate pointing of the camera over an extended period of time; i.e., Category C, there are a number of other uses to which the camera optics can be put. The most obvious are ultraviolet and infrared spectroscopy and photometry. The number of problems which these two areas of astronomical research offer are, of course, virtually unlimited. We have previously pointed out that NASA is very heavily engaged in preparation for measurements in the ultraviolet. The following are two very interesting ultraviolet experiments which do not appear to be included in NASA's plans.

h. Planetary Hydrogen Coronas

Hydrogen escaping from the earth forms an extended envelope which resonantly scatters solar Lyman-alpha (1216A). The surface brightness of the geocorona in daylight is estimated to be 2×10^{-2} erg $cm^{-2} sec^{-1} steradian^{-1}$. If hydrogen is escaping from other planets, they should also have coronas. For Venus and Mars a possible source of neutral hydrogen is the photodissociation of water vapor, which produces the terrestrial component. Since only 10^{12} hydrogen atoms cm^{-2} are required to produce an optical depth of unity, the possibility of hydrogen coronas for these planets exists, in spite of the relatively small abundance of water vapor in their atmospheres, relative to the earth. From the orbit of MOL, scattered Lyman-alpha radiation from these planets would be viewed through the diffuse Lyman-alpha radiation of the geocorona. Neglecting any variation due to abundance of neutral hydrogen, the relative surface brightness of the planetary hydrogen coronas would scale in proportion to the incident solar Lyman-alpha flux. Thus the surface brightness of hydrogen coronas enveloping Venus and Mars would be approximately twice, and one-half, that of the geocorona, respectively. These values are sufficiently high for detection against the background from the geocorona.

To isolate Lyman-alpha radiation, a slitless spectrograph camera producing a Lyman-alpha image of the planet, such as used by NRL to obtain a Lyman-alpha photograph of the sun, could be used. The efficiency of such a device is estimated to be 10 per cent. In this case, high resolution is not required, so it would be advantageous to use a LiF condensing lens to reduce the image scale and convert the optical system to, say, f/3. Note that the requirements for precise stabilization are also correspondingly relaxed. The exposure required can be estimated as follows. Eastman Kodak SWR film has a sensitivity at Lyman-alpha

$$S = 1/E = 35$$

where E is the exposure in erg cm^{-2} incident on the emulsion required to produce a density of 0.6 above gross fog. The solid angle of an f/3 system is 0.09 steradians. Assume the transmission of all the optics is 0.5. Then the time in seconds required to photograph the geocorona to this density is given by

$$0.02 \times t \times 0.5 \times 0.1 \times 0.09 = 1/35,$$

from which t = 320 sec.

Another approach would be to photoelectrically scan the planet image, suitably reduced in scale by a condensing lens, using a small Lyman-alpha monochromator and a photomultiplier with a LiF window. Although a single scan would suffice to establish the existence of a planetary hydrogen corona, the importance of determining both extent and shape would require a number of carefully spaced scans to be made, from which isophotes could be traced.

i. Lyman-Alpha from Galaxies

Because of the cosmological red-shift, the hope of increasing the limits of the observable universe depends on finding strong emission lines in the ultraviolet spectra of distant sources. The most promising line is Lyman-alpha (1216A), because it is the resonance line of neutral hydrogen, and consequently, is the strongest line produced in any galaxy. On the other hand, because neutral hydrogen resonantly scatters this wavelength, Lyman-alpha cannot escape from most galaxies. The objects most likely to emit Lyman-alpha are the "quasi-stellar" radio sources, in which hydrogen must be completely ionized. This is because the possibilit of detecting Lyman-alpha escaping a completely ionized galaxy depends upon whether or not the neutral hydrogen that may exist between the observer and the galaxy is in resonance. Cosmological red-shift and large random motion associated with the "quasi-stellar" radio sources may displace Lyman-alpha from resonance, permitting it to reach the earth.

In the spectrum of the most distant "quasi-stellar" radio source known at present, 3C 48, Lyman-alpha should be displaced to approximately 1650A, as a consequence of the cosmological red-shift. An observation of the spectrum of this source in the 1600 to 1700A region by means of a compact, very low dispersion (say, 1000A mm^{-1}) spectrograph of high optical speed (say, f/1.5) would establish whether Lyman-alpha is observable. The exposure time for this 16th magnitude object should not exceed 30 minutes, with a spectrograph of this type. It should be noted that in the case of a slit spectrograph, pointing error will not affect the definition of the spectrogram, but will only increase the time required to obtain the desired exposure by the length of time the image is off the slit.