# Space Laboratory Mission Simulation and Test in a Closed Ecological System

R. L. Batterton Ph.D.
*Chief, Man-System Integration Branch, Advance Biotechnology Department, Research and Development, Douglas Aircraft Company, Inc.*

K. H. Houghton M.D.
*Chief Engineer,Advance Biotechnology Department, Research and Development, Douglas Aircraft Company, Inc.*

T. C. Secord
*Chief, Life and Environmental Systems Branch, Advance Biotechnology Department, Research and Development, Douglas Aircraft Company, Inc.*

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R. L. Batterton, Ph.D.
Chief, Man-System Integration Branch
Advance Biotechnology Department
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K. H. Houghton, M.D.
Chief Engineer, Advance Biotechnology Department
Research and Development
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T. C. Secord
Chief, Life and Environmental Systems Branch
Advance Biotechnology Department
Research and Development
Douglas Aircraft Company, Inc.

## Summary

The design, development, and management of advance manned space systems will be facilitated through the use of mission simulation techniques. These techniques are being used in the Space Cabin Simulator program which has been initiated at the Douglas Aircraft Company. The first phase of this program has recently been completed. In this phase, a four man crew accomplished a 30 day mission while confined in a double walled space chamber which duplicates projected space cabin conditions. This mission simulation was quite successful in many respects. Some results of this phase are presented and future phases of the program are discussed.

## Introduction

The design, development, and management of advance manned space systems will be facilitated through the use of mission simulation techniques. Simulation techniques using man-hardware and man-hardware-computer elements have already made significant contributions to the success of pioneer space missions. These contributions range from the development of design criteria, through design test, to astronaut training. Both of these simulation techniques are employed in the Space Cabin Simulator program which has been initiated at the Douglas Aircraft Company.

Data gathering for the first phase of this program was completed early in 1965. During this phase, subjects were confined in a specially designed space cabin facility for periods of 12 and 30 days. Figure 1 shows the exterior of this facility during these manned tests. Within the facility, projected space cabin environments and crew tasks were simulated with a high degree of fidelity. This first phase of the program, including some preliminary results, and future program phases are discussed in this paper.

## Objectives

The long term objectives of the Space Cabin Simulator program include the following:

- The engineering design and development of completely integrated life support systems for long-duration missions
- The design and test of hardware associated with mission-, vehicle-, and personnel-oriented crew duties
- The development of habitability design criteria and features
- The development of computer programs for design, test, control, and training
- The identification and solution of problems which emerge during simulation exercises

The first phase of the program had three primary objectives:

- To fabricate a flexible space cabin simulator for use in accomplishing long term program objectives
- To install, test, and evaluate life support subsystems, with open water and oxygen cycles, within the operational and environmental context of a manned space mission
- To develop and evaluate approaches to the solution of man-system and biomedical problems associated with manned space missions.

## Mission Definition

The specification of the context for simulation in this first phase was a result of a number of conceptual and preliminary design studies. These studies include those accomplished for MORL, LORL, and Extended Apollo, as well as portions of pre-proposal studies accomplished for Air Force systems. In addition, the 12 day mission provided a preliminary confirmation of the consistency and adequacy of various design and mission-oriented simulation factors.

The mission derived from these studies and defined for the crew had the following characteristics:

- Vehicle was early laboratory in earth orbit
- Mission duration was 30 days
- Crew was composed of four members
- Crew was to accomplish such tasks as:

| | |
|---|---|
| Mission-oriented | orbital rendezvous, earth observation<br>biomedical and behavioral tests |
| Vehicle-oriented | monitor and manage subsystems<br>maintenance and repair |

Personnel-oriented physical fitness
recreation

Crew was subject to command from ground control.

## Mission Simulation

### Space Cabin Simulator

The Space Cabin Simulator was fabricated from an existing cylindrical altitude chamber. This existing chamber was modified by the addition of an inner shell, 12 feet in diameter and 40 feet in length, and by the addition of an airlock. The final configuration of the double-walled chamber, together with the external monitoring stations and control consoles, is shown schematically in Figure 2.

During simulation exercises, the volume between the inner and outer walls of the chamber was evacuated to a pressure below the pressure maintained inside. Under these conditions, leakage was outward. Control of the pressure differential permitted control over leakage and provided a realistic check on the buildup of trace contaminants within the chamber.

The interior of the chamber was configured to include a command center, sleeping quarters, a living and recreation area, an exercise, study, and test area, galley, shower, and an environmental control and life support system. Figure 3 shows the arrangement of areas within the chamber and the location of various subsystems.

Displays and controls for the Douglas Orbiting and Landing Approach Flight Simulator (OLAFS) were located at a station in the command center. This station is shown in Figure 4. The Life Support Monitor, Figure 5, was positioned adjacent to this station.

Three voice communication channels were provided. Channel 1 allowed communication between various outside and inside stations. Channel 2 allowed communications between outside stations and the airlock. Channel 3 permitted private communication between an outside monitor and a crew member inside the chamber.

A closed-circuit television system was used for outside monitoring of crew activities and onboard systems and displays. Television cameras in the command center and in the aft end of the chamber were of the pan-and-tilt type and could be positioned from a remote control panel at the TV monitoring station outside the chamber. A portable camera was also used to monitor display panels and to enable outside personnel to assist, if necessary, in repair activities. A typical TV display is shown in Figure 6.

During the mission simulation discussed in this paper, the chamber was operated with an atmosphere of 50% oxygen, diluted with nitrogen at a total pressure of 7.0 psi. Twenty-four hour medical coverage was provided. Crew members were kept under surveillance through one-way view ports and through the TV system. Voice communication channels were also available.

### Life Support Subsystems

Space-type life support system baseline modules were installed and integrated in the cabin simulator along with instrumentation, displays, emergency devices, alarms, communications and other equipment. Figure 7 presents the baseline integrated advance life support subsystems used in this initial phase. The major subsystems comprising the life support system were the following:

- Atmospheric Supply and Pressurization
- Atmospheric Control and Purification
- Thermal Conditioning
- Water and Waste Management
- Space Suit Loop

Atmospheric Supply and Pressurization. The basic cabin atmosphere used was a 50% oxygen and 50% nitrogen mixture. The nominal space cabin pressure was 7.0 psia with an oxygen partial pressure of 3.7 ± .2 psia. This atmosphere is comparable to the cabin atmosphere proposed for most space laboratories and interplanetary vehicles. The oxygen and nitrogen will be stored in the subcritical state for the finalized flight-type atmospheric supply system. However, during the early phases of testing in the simulator, the baseline supply was stored as a gas.

The oxygen partial pressure was held at a value of 3.7 psia by means of a sensor which, in turn actuated a flow control valve. The valve is of the simple "on-off" type with a capacity to meet the maximum consumption rate. The nitrogen supply used an "on-off" type valve similar to the oxygen unit and limited the flow of $N_2$ to a predetermined maximum rate based on compartment leakage.

During the 12 day mission, a total consumption of 10.1 pounds/day of oxygen and 1.8 pounds/day of nitrogen was used. The gases were delivered automatically by the designed atmospheric supply system. The data from the 30 day mission has not been evaluated.

Atmospheric Control and Purification. The atmospheric control and purification subsystem accomplished all requirements of atmospheric conditioning with the exception of atmospheric temperature control. During this phase, the primary function of this subsystem was to remove $CO_2$ and trace contaminants. Water removal is considered a part of the thermal control subsystem, although a portion of the atmospheric moisture is removed in the $CO_2$ removal subsystem by silica gel. The $CO_2$ removal subsystem was designed as a module so that it can be removed for alternate replacement modules with minimum labor and rework. This feature permits direct performance comparison of other methods of $CO_2$ removal planned for future tests. The $CO_2$ removal unit was also designed to permit optimization and upgrading of various aspects of the system; such as the adsorption/desorption cycle times, heating/cooling rates and vacuum requirements. Figure 8 presents the regenerative $CO_2$ removal unit. It was designed by Tapco, TRW, to Douglas specifications.

The installed baseline unit used for the test is of the regenerable type consisting of molecular sieves, silica gel driers, debris trap, blowers, valves, and other associated components. The unit is sized so that each of two silica gel and molecular sieve beds are capable of handling the full requirements of the system. A circulating fan or blower is used to provide flow through the $CO_2$ removal subsystem. A heat exchanger using Coolanol 25 from the thermal control system as the heat sink was installed in the circuit between the silica gel and zeolite beds to improve the $CO_2$ removal efficiency. The initial thermal desorption cycle time used for the silica gel was 45 minutes at 315° F. The unit was cooled for 15 minutes prior to placing it back on the line. The molecular sieve was desorbed for 15 minutes at 315° F temperature under vacuum. The molecular sieve is also cooled 15 minutes prior to being placed back on the line.

The $CO_2$ removal unit maintained the cabin $CO_2$ level between 0.6% and 1.2% by volume during the 12 day test. A peak of 1.65% by volume was created during several brief periods of time due to a $CO_2$ unit valve malfunction, waste management contamination leakage and during the extinguishing of a small fire with bottled $CO_2$. The unit vacuum valve during tests leaked about 1 pound/day of cabin atmosphere overboard. After the 12 and 30 day missions, several new design features were added to simplify system operation and maintenance procedures and to increase the $CO_2$ unit overall efficiency. In a later phase of the program, an oxygen regeneration system will be incorporated into the test setup in conjunction with the $CO_2$ removal subsystem. In view of this future application, a vacuum pump and $CO_2$ accumulator for $O_2$ recovery were installed in the initial $CO_2$ removal unit, as shown in Figure 8. The vacuum pump is used to evacuate the sieves of most of the entrapped atmospheric gases, but without pumping off $CO_2$ prior to vacuum desorption through the accumulator. The accumulator provides storage for the desorbed $CO_2$ for usage with an oxygen regeneration subsystem.

The MSA trace contaminant control subsystem used consists of a catalytic bed, an electric heater, a regenerative heat exchanger, a chemisorbent bed, particulate filters, a charcoal filter, and associated controls and instrumentation. The catalytic burner also has a temperature controller for manually adjusting the operating air temperature in the unit. The air flow through the catalyst bed is also manually adjustable. These controls provide the flexibility required to effectively control various contaminants. Gas monitoring equipment is provided to visually observe CO concentration, $CO_2$ concentration, total hydrocarbons, humidity, oxygen partial pressure, and total pressure. Additionally, atmosphere gases were sampled from 19 compartment locations periodically for an evaluation of trace contaminants. Gas monitoring equipment consists of a gas chromatograph, infrared analyzer, wet chemical analysis, gas analysis console shown in Figure 9 and Universal Testing kits. Figure 10 shows one of the life support monitoring stations within the cabin simulator. Levels of some of the contaminants experienced during the 12 day mission were as follows:

| Contaminant | Maximum | Minimum | Remarks |
|---|---|---|---|
| CO, ppm | 29.0 | 6.0 | Maximum occurred after a small fire. |
| $CO_2$, percent | 1.65 | 0.6 | Maximum occurred during waste management system leakage. |
| Hydrocarbons, ppm | 40.0 | 0.0 | Average level was 25 ppm |
| Isopropanol, ppm | 35.0 | 5.0 | Maximum value occurred when toxin burner was inadvertently closed. Source was traced to medical supply. |
| $NH_3$, ppm | 7.0 | 0.1 | --- |
| HCHO, ppm | 21.0 | 12.0 | --- |
| Coolanol 25 | 1.2 | 0.0 | Maximum occurred during repair of an "O" ring. |

| Contaminant | Maximum | Minimum | Remarks |
|---|---|---|---|
| $SO_2$, ppm | 0.19 | 0.15 | --- |
| $H_2S$, ppm | 0.0 | 0.0 | --- |
| $NO_2$, ppm | 0.0 | 0.0 | --- |
| $O_3$, ppm | 0.0 | 0.0 | --- |

Three or four additional small peaks appeared in the gas chromatographic and their identification is in progress.

Extensive development tests on materials to be used in the cabin were made in 72 liter flasks at 7 psia. Samples in flasks were evaluated intermittently during a 30-day period. The information derived from the contaminant program was used to screen materials used within the space cabin compartment, and to obtain general data on the spectrum of contaminants evolved from each material and relate the concentration levels in allowable contaminant concentrations. The materials were allowed to cure in the cabin at pressures of 3 psia and 7 psia respectively. Samples were taken and evaluated for toxins. During curing tests it was discovered that excessive CO outgassing was obtained from insulation of the hot Coolanol lines. The CO was allowed to bake out before starting the 12 day mission. Additionally, calibration curves of critical toxic elements were established to permit rapid identification during manned tests. The 30 day mission outgassing was much reduced over the 12 day period.

The toxin burner was considered a mandatory requirement during the 12 day check-out and 30 day test runs. The waste management disposal tanks and storage system contaminated the cabin with excess CO and $CO_2$ during the sixth day of the 12 day check-out test. The toxin burner satisfactorily converted the extra CO to $CO_2$ and the molecular sieve unit removed the $CO_2$ to an acceptable level. Corrective measures were taken by the crew to minimize this gas leakage into the cabin. Additionally, the catalytic burner helped control the combustion products from a small fire and contaminants generated from the smoke from a burned out motor as well as other contaminants generated by the crew and equipment.

The crew was required to rewire the blower on the commode for continuous operation for better odor removal. The blower was initially activated only when the unit was used. Five pounds of activated charcoal installed in the toxin removal unit was more than sufficient to control the odor for the 30 day test period.

Thermal Conditioning. The thermal control system consists of heat exchangers, water separators, heat transport fluid pump and reservoir, and associated controls shown in Figure 7. The thermal control module consists of a heating and cooling circuit. The heating circuit is used to provide hot Coolanol for the regenerative $CO_2$ removal, water and waste management subsystems. Figure 7 shows one cooling loop which consists of a blower, Tapco zero "g" porous plate condenser, and water separator. The second loop shown and designed by Tapco, TRW per Douglas specification, consists of a blower, heat exchanger, and a temperature controller. The thermal control system has a cooling capacity in excess of 25,000 BTU/hour. Of this total, the condenser-separator circuit is designed to remove the latent heat plus a small percentage of the sensible heat with an atmospheric cabin flow rate of about 100 $ft^3$/minute. The temperature control circuit removes the balance of the sensible heat using an air flow of approximately 1150 $ft^3$/minute. The subsystem is designed to maintain the temperature of the atmosphere at a nominal

$75^{o}$ and the relative humidity at less than 50 percent. In lieu of the radiator which would be used in a spacecraft, a liquid-to-liquid chiller placed external to the simulator was used for the heat sink. A vehicle-type reservoir was used for heat transport fluid storage and a 100 psi fluid pump was used for circulation of the coolant (Coolanol 25). A 50 psi pump was used for circulating the hot Coolanol. The temperature and humidity control system performed as expected during the 12 day test period. The cabin humidity varied from 18% to 33% depending upon the moisture input to the atmosphere, coolant temperature, and heat exchanger outlet temperature.

Water and Waste Management. The cabin simulator had both Coolanol heated and chilled distilled water. The water was supplied to the galley, shower and commode. All waste water including urine, except for analysis samples, was collected in a waste tank. The contents were pumped to a storage tank in the cabin at regular intervals for measurement and disposal. These initial tests provided valuable water management data to permit accurate design specifications. During the first day of the 12 day run, the crew used 95 gallons when not required to conserve and manage. The very next day, the crew resorted to a minimum water management plan and used slightly more than 1 gallon in a 24 hour period.

In the next series of tests, the water management system will be in operation as a completely closed water cycle. Various methods of water recovery and pre/post treatment are now being studied prior to the development of a system for use in the space cabin simulator. The current tests have provided realistic water usage rates for modification of water reclamation unit design. Additionally, proper pretreatment and post treatment techniques will be evaluated using a small combination electrodialysis/air evaporation unit. The principal water recovery techniques being studied for later phases are: electrodialysis, air evaporation, vapor compression, vapor pyrolysis, and vacuum distillation.

The waste management subsystem consists of a space-type commode and dehydrator, shown in Figure 11, waste storage tanks, monitoring system, sump pump and reservoir. Waste management functions included the collection, measurement and analysis, transfer, processing, and storage of wastes for disposal. The waste collection included the feces from the space-type commode dehydrator, debris from shaving, hair cutting, nail clipping, food wastes, packaging material, disposable supplies, spent filters, carbon and other residue from life support system components and from scientific experiments. Although this system is primarily for the purpose of collecting, processing, and storing urine and feces, sufficient storage capacity was available to accommodate the additional wastes that were accumulated.

Space Suit Loop. The space suit loop modules shown in Figure 7 are designed to take advantage of the operating characteristics designed into the suit. Some of these characteristics include the automatic closing of the face plate with a critical drop in atmospheric pressure, suit operation with either the back-pack portable life support system or umbilical conditioning, and pressurized or unpressurized operation. There will be three independent suit loops in the simulator. Each is sized for support of two men and will use identical components which include the following: Ventilation, air-to-liquid heat exchanger, water separator, activated charcoal filter, $CO_2$ pressure control, $O_2$ supply and pressure control, suit-to-ambient $\Delta P$ control, and associated valves and fittings. One loop will be located in the airlock for use during ingress and egress simulation. The other two loops will be located in the cabin and are primarily for emergency simulation. The suit loop designed into the life support system will be used for tests in later program phases.

## Personal Equipment

The personal equipment items of primary concern in this phase of the program were shirt-sleeve garments and bedding. State-of-the-art materials for these items were selected, pre-tested, and evaluated.

Two-piece shirt-sleeve suits were designed and fabricated from selected materials. In addition to these garments, subjects also wore cotton knit T-shirts and briefs, ban lon sox, and all leather (cowhide) moccasins. The reaction of crew members to their suits was quite favorable. All expressed a desire to wear the same suits in subsequent missions and to own them at the end of confinement.

The bedding consisted of nylon net beds, cotton and nylon sheets contoured into a type of sleeping bag, and an acrilan and cotton mattress. These accommodations appeared to be generally satisfactory.

Studies were conducted to determine outgassing properties of all clothing and bedding materials using a gas chromatograph. These tests included analysis of detergents which were used for cleaning the materials. Flame resistance was tested using FAA standards. Lint found in the chamber, accumulated on the toxin burner grid and ventilation fan, was analyzed after the runs using neutron activation analysis.

## Crew Selection and Training

Initial Selection. Twenty-five male candidates for the crew were recruited from a local college population; each of these candidates was mailed a detailed biographical questionnaire and asked to report for group orientation and individual interviews. At the orientation, the candidates were given an over-view of the Space Cabin Simulator program. Following this orientation, each candidate's questionnaire was examined and the candidate was interviewed. An interview summary form was used, the interrogation covering such topics as physical condition, psychological appraisal, education and experience, and availability. Eight candidates were ultimately chosen for training. All were given USAF Class III physical examinations and all passed. Some descriptive facts about these candidates are given in Figure 12.

Training. The training program was developed from an inventory of training requirements which were developed by engineers, psychologists, physicians, and other technical personnel associated with the project. The training methods adopted to satisfy these requirements included lectures, films, demonstrations, and on-the-job practice. A list of subject matter areas covered in the program is shown as Figure 13. In addition to the formal training program, some additional psychological and behavioral testing was conducted in order to assist in a final selection of four subjects for participation in the simulation exercise and in order to contribute to a pool of data which could be analyzed for significance later in the program, after a large number of candidates had been processed.

After eight weeks of training, testing, and evaluation, a four-man simulation crew was selected and a leader and sub-leader were designated. The selection was based primarily on the results of the psychological and performance tests, the sensitivity training, instructor evaluations, and achievement in the training programs. Some extraneous factors had a bearing on the crew selected in that two candidates became unavailable during the training program.

Crew Activities

The work-rest schedule for the mission crew had many of the characteristics to which they had become accustomed during their pre-confinement activities. These characteristics include eight hours for sleep each day, four meals each day, a period of recreation or rest, and a total schedule duration of 24 hours. This type of schedule has often been suggested for space vehicle crews. In addition, the control station was manned at all times. Earth observation tasks at this station were timed to correspond to a 90 minute orbit period. A schedule for a typical day is shown as Figure 14. Schedules varied slightly from day to day over a six-day period. The six-day schedule was repeated once for the 12-day mission and five times for the 30-day mission.

Observations of crew activities were made by outside monitors according to a planned schedule. Additional observations were made by the crew by such means as collecting samples, self and peer evaluations, and habitability assessments. Some of these observations are discussed below.

Mission-Oriented Observations

(1) Earth observation and orbital rendezvous. The Orbiting and Landing Approach Flight Simulation (OLAFS) was used to evaluate crew capabilities in earth observation and rendezvous. Each crew member spent about one-half hour a day on one of these tasks. Performance was handled automatically by a computer. The performance data are currently being evaluated. It is interesting to note that accomplishment of these tasks was considered by the crew to be one of the "biggest" events of a day.

(2) Behavioral tests. Behavioral testing was used generally to provide a basis for evaluating the adequacy of each crew member's ability to perform behavioral tasks as an index of his current fitness and performance efficiency and to obtain objective information about the performance of each crew member as an aid in detecting deterioration and in evaluating significant behavioral changes.

The Arm-Hand Manipulation Test was provided to give a standard basis for evaluating the adequacy of each crew member's ability to perform moderately complex arm and hand manipulations. In this phase of the program, the test took the form of a mechanical assembly of a standardized configuration; in later program phases, the test will be administered as an OLAFS task.

The Speech Perception Test provided a standard basis for evaluating the adequacy of each crew member's ability to perceive spoken words. Pre-recorded tapes containing degraded phonetically balanced word lists of 50 words each were fed into the private communications system shown in Figure 15. After each test word, the crew member wrote down what he had heard. When the list was completed, he passed out his responses. This test was administered every six days. After several administrations, it was discontinued because of technical difficulties. It may, however, be administered again in later program phases.

The Arithmetic Computation Exercise provided a standard evaluation of each crew member's ability to perform arithmetic computations under stress. The crewman, using a pencil and paper, worked multiplication and division problems under time constraints of 10 minutes for each. He then passed out his answers to an outside observer who recorded the responses. This test was given once every six days.

The Troubleshooting Exercise provided structured practice in performing logical troubleshooting. It measured changes in problem-solving ability during the period of confinement and required special signal flow diagrams. This exercise had been designed for computer administration and evaluation; however, during this phase of the program it was conducted manually. The crewmen obtained needed information for problem-solving from the outside monitor over the private communication system. Each crewman was tested every six days for 30 minutes per session.

The Taped Diary supplemented and corroborated other records of the activities and effectiveness of crew members, as well as constituting a daily log of events. It provided a method for recording special impressions and matters of interest to the crewman. At times, dairy recording was combined with TV interviews. The diary was recorded at daily intervals on the private communications system. Each crewman was asked to cover certain standard topics, special events, and opinions as they occurred during the mission. The crewmen were encouraged to express criticisms, problems, and grievances.

The Performance Ratings Test obtained objective and subjective information about each crew member as an aid in detecting deterioration in performance and in evaluating significant behavioral changes. These ratings were conducted every 6 days by each crew member. They were asked to appraise the performance of the other three crewmen on special rating forms. These ratings were passed out from the Space Flight Simulator at periodic intervals.

(3) Biomedical tests. Crew members cooperated as necessary in groups of two in taking biomedical measurements from each other. Each member had his blood pressure, pulse rate, temperature, and weight measured daily. Every third day, each member had an electrocardiogram and a respirogram made. Related physical fitness activities are shown in Figure 16. Every six days, each crew member had blood and urine samples taken. Figure 17 shows a blood sample taken. Record and samples from these measurements were sent out of the chamber by means of pass-through ports for analysis.

Every 6 days, each crew member also filled out a weekly evaluation of health form. A TV interview was conducted by the medical monitor in conjunction with completion of the form.

Vehicle-Oriented Observations

(1) Monitoring and managing subsystems. These tasks were used to evaluate crew proficiency, equipment design and equipment arrangement in relation to the performance of necessary station operation tasks. To achieve this, the efficiency of subjects in monitoring such subsystem parameters as oxygen partial pressure, toxic contaminant levels, power supply levels and others was made. This evaluation was made by observers outside the chamber using direct vision through the one-way view ports or by television monitoring. The monitoring of subsystems required one crewman full time for the entire mission and was distributed among individual crew members. Critical parameters were displayed externally for outside monitoring. Thus, any deviations from normal operational status that were not indicated by the crew were noted by the outside monitoring personnel.

(2) Maintenance and repair. Both scheduled and unscheduled maintenance tasks were recorded and performance on these tasks was evaluated. Two unscheduled repair events occurred in connection with the commode, in three instances an oxygen sensor required replacement. In these cases, the crew was sufficiently well trained and instructed to accomplish the repair.

Personnel-Oriented Observations

(1) Eating. A diet consisting of freeze-dried foods (Pillsbury) and supplying approximately 2,800 Kcal per day was supplied to the crew members. This diet was distributed over four meals each day. Since an accurate record of all liquid intake was made, a 30 cc graduate was used to measure water of hydration. All crew members were encouraged to completely consume all of the meals. The quantity of any meal left uneaten was estimated and entered into a nutritional record.

(2) Physical fitness. Two of the crew members exercised in a formal eight-minute program each day while the remaining two served as controls. The program consisted of flexibility, strength, and endurance exercises. One exercise is illustrated in Figure 16. Strength and flexibility measures were unchanged for crew members over the 30-day period; activities within the chamber, including informal "exercise" appeared sufficient to sustain these fitness measures. However, the crew members who exercised maintained their work capacity as measured by the Balke Treadmill Test, while the work capacity of the non-exercisers was significantly impaired.

(3) Recreation. Crew members were allowed to bring recreation materials of their choosing into the space cabin. Favored recreational activities were reading, chess, "GO", and drawing. Time allocated for these activities is indicating in Figure 14. Participation in chess recreation is shown in Figure 18; the game pieces are a standard set which might be used in a rotating vehicle.

## Conclusion

The initial phase of the mission simulation program has been quite successful in many respects. It has qualified a flexible space cabin simulation facility, incorporating on-board life support systems, for further program phases. It has also provided information on man-system and biomedical activities and provisions within the context of manned space missions. Only a small part of the quantitative data from the 12 and 30 day missions has been reduced and evaluated at this time; however, certain qualitative assessments are now available.

The manned Space Cabin Simulator permitted the life support subsystems to be tested on an integrated basis. This is the only technique available that allows an accurate evaluation of system performance in which associated interactions are present. The Simulator was designed to operate at any reasonable and habitable total pressure and gas mixture. Outboard leakage rates can be controlled to a level as low as 1 lb/day. These features permit a realistic evaluation of toxin build-up, toxin control, and equipment performance over the range of cabin pressures that have been proposed for manned space vehicles. A contaminant program is extremely valuable in the selection of materials for space cabin design. It is also necessary to obtain the proper calibration curves for identifying the trace contaminants detected during gas monitoring.

Developmental work on personal equipment was particularly rewarding. The shirt-sleeve garments designed for this program possess many of the qualities that are desirable for their intended use. However, there was some suggestion for improvement which will be considered in future program phases.

In general, the morale and motivation of the Space Cabin crew was high and there were no serious problems in interpersonal relations. This is remarkable when it is considered that the same crew made two successive confinement runs. All are willing to participate in a much longer exercise in a succeeding phase of this program. The crew members were unanimous in stating that the most important aspect of their preparation was their psychological training. They felt that learning to take physiological data was next most important.

The mission was terminated with all crew members in good health. Although the behavioral test data have not been completely reduced, there appeared to be no serious behavior degradation. At the time that these tests were planned, the intent was to present them in the context of operationally meaningful tasks. This intent was not completely realized. In view of the positive crew response to OLAFS tasks, renewed efforts will be made to cast all behavioral tasks into this context.

Future work on this program will also include such developments as closure of the water and oxygen cycles in the life support system, the achievement of greater efficiency in crew orientation and training, and the further development of operationally significant behavioral and biomedical procedures. Although a college population probably will serve as a source for future crew members, additional populations may also be sampled.

An additional contemplated development is the integration of the hard Space Cabin Simulation program with soft simulation techniques. Computer techniques have broadly applied to the design and management of a variety of contemporary systems. Studies have been initiated at Douglas to apply these techniques to manned space systems. This application is particularly important because of the requirement for maximum effectiveness in accomplishing space system objectives at minimum cost. Cost-effectiveness measures can be minimized only if all relevant data are brought to bear upon decisions at the appropriate time. Computer techniques are desirable in this data processing because of the number of relevant data sources, the contingency nature of mission events, and real time management needs.

Initial studies at Douglas have resulted in the development of an automated Test Operations Planning System (TOPSY). The TOPSY computer program has been designed to sequence a set of events with regard to their priority, interrelationships, and effect upon a space system. TOPSY has been used successfully in a number of space system study programs. Integration of TOPSY with the Space Cabin Simulator program would yield broad implications for vehicle design, software development, crew training, and space systems management.

## SPACE CABIN SIMULATOR DURING MANNED TESTS

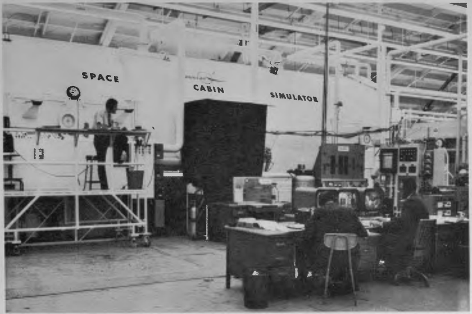


FIGURE 1

## DOUGLAS SPACE CABIN SIMULATOR

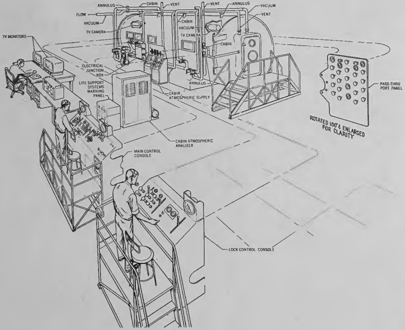


FIGURE 2

## DOUGLAS SPACE CABIN SIMULATOR

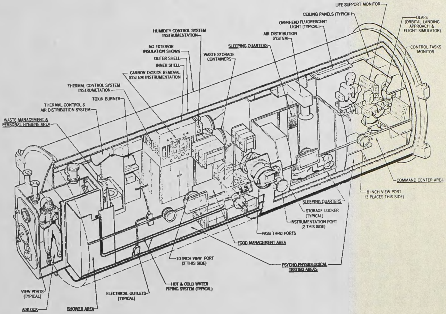


FIGURE 3

## OPERATIONS CONTROL CONSOLE

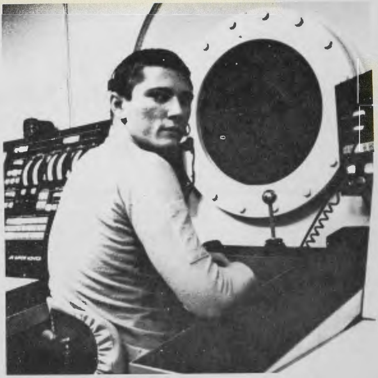

FIGURE 4

## LIFE SUPPORT CONTROL CONSOLE

FIGURE 5

## CLOSED CIRCUIT TELEVISION DISPLAYS

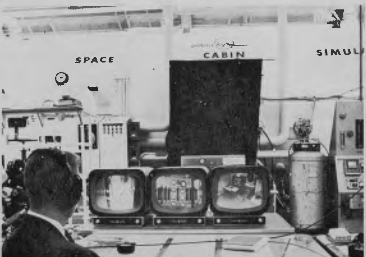


FIGURE 6

# SPACE CABIN LIFE SUPPORT SYSTEM MODULES

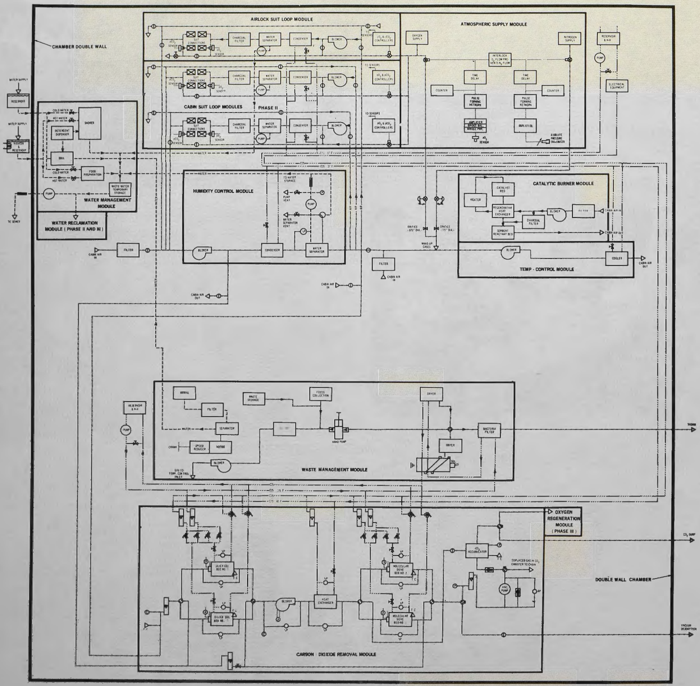


FIGURE 7

## ATMOSPHERIC CONTROL AND PURIFICATION

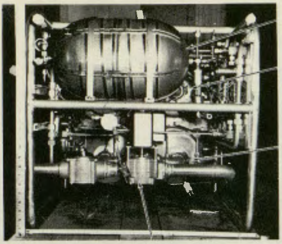


FIGURE 8

## EXTERNAL GAS MONITORING CONSOLE FOR SPACE CABIN

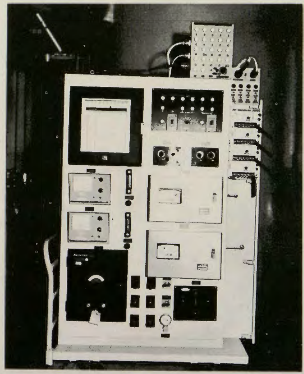

FIGURE 9

## CABIN LIFE SUPPORT MONITOR

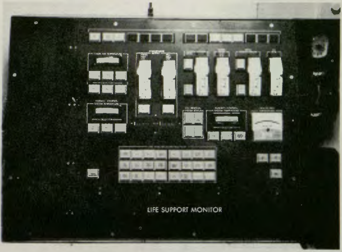


FIGURE 10

## WASTE MANAGEMENT

### COMMODE

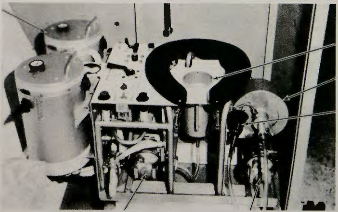


FIGURE 11

## CREW CANDIDATE DESCRIPTIONS

| SUBJECT | AGE | COLLEGE MAJOR | DEGREE | MARITAL STATUS | CLUBS & ORGANIZATIONS | MILITARY SERVICE |
|---|---|---|---|---|---|---|
| 1 | 21 | Biotech. | None | S | 3 | None |
| 2 | 21 | Philos. | None | S | 0 | None |
| 3 | 23 | Math.<br>Philos. | B. A. | S | 2 | None |
| 4 | 27 | Biology<br>Pre-Med | None | M | 2 | USMC |
| 5 | 26 | P. E.<br>Geog. | B. S.<br>M. A. | S | 3 | ROTC<br>USAFR |
| 6 | 23 | Architecture | None | S | 2 | None |
| 7 | 21 | Bus. Admin. | None | S | 2 | None |
| 8 | 23 | Life Sciences | None | M | 1 | USN |

FIGURE 12

TRAINING PROGRAM SUBJECT MATTER AREAS

Space Station Operations

Space Cabin Simulator Subsystems and Maintenance

Housekeeping

Communications

Biomedical and Behavioral Tests

Personal Hygiene

Safety and First Aid

Space Cabin Simulator Emergency Procedures

Sensitivity Training

Atmospheric Physiology

Altitude Chamber Indoctrination

Food Preparation

Physical Fitness

Group Dynamics and Leadership

Space Habitation Garments

Tilt-Table and Centrifuge Indoctrination

FIGURE 13

## TYPICAL DAY IN THE DOUGLAS SPACE FLIGHT SIMULATOR

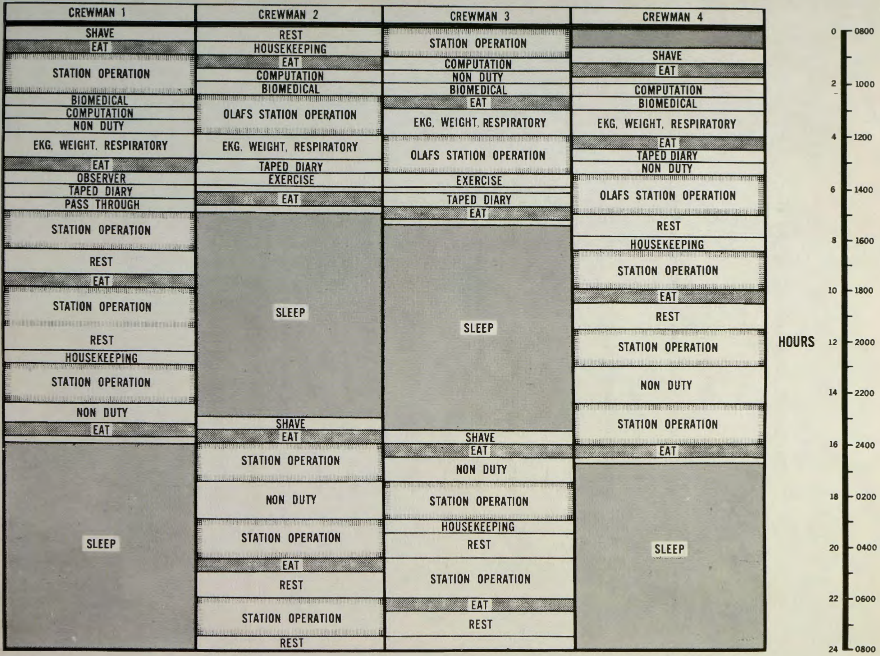


FIGURE 14

## SPEECH PERCEPTION TEST

FIGURE 15

## RESPIRATION TEST

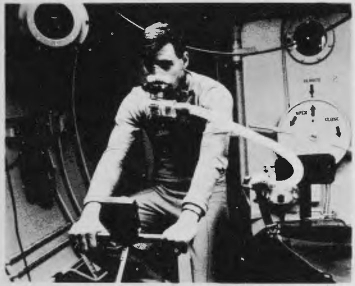

FIGURE 16



## BLOOD SAMPLING

FIGURE 17

## CREW RECREATION

FIGURE 18