Enclosure (1)

Statement of Work for Lunar Housing Simulator (Denver Operation)

dtd 27 July 1959

The work to be accomplished under the preactivation phase of the Lunar Housing Simulator project will consist of a study-research program and a component design and procurement or fabrication program. The first program will consist of research and development leading to (a) design and fabrication of a 5-man closed ecological system capable of initial short term independent operation under partially simulated lunar conditions; and (b) leading to the design of an advanced research program to be conducted in the Lunar Housing Simulator. These preliminary research projects will expose to critical examination such basic problems as the biological effects of reduced pressure per se, the feasibility of human consumption of algae, and the design and placement of critical information presentation displays and manual system controls. The data obtained from these studies and laboratory research projects will be used to design system components and to design experiments for inclusion in the operational phase in which man is the principle subject. The research to be conducted during the Lunar Housing Simulator operational phase will include a program to improve the reliability and period of independent operation of the system and to study effects of environmental variables imposed by actual lunar conditions. The goal of the operational research program will be to provide sufficient information to permit the design and fabrication of an actual lunar base.

The development program will be carried out under the general headings of (a) Mission Analysis, (b) Life Support Systems, (c) Psychology and Human Engineering, and (d) Instrumentation and Control.

Prepared by
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Mission Analysis

A mission description for the Lunar Housing Simulator stems from a mission analysis of anticipated actual lunar installations.

Lunar missions will consist of four activity phases:

A. Maintenance of living conditions in the lunar installation.

B. Research projects conducted inside the lunar installation.

C. Establishment of living and working conditions on the moon's surface outside the lunar installation.

D. Exploration, field research, and engineering studies conducted outside the lunar installation.

Phases "A" and "B" and certain aspects of Phase "C" will be carried on inside the Lunar Housing Simulator. Phase "D" is reserved for actual lunar sites.

Phase "A" includes: (1) monitoring, trouble-shooting, and conducting research upon various bio-engineering systems designs relevant to atmosphere control, food production, and waste processing; (2) investigating crew schedules and behavior patterns for work, rest, exercise and recreation; human engineering analysis of instruments, controls, personal gear, and accessory equipment.

Phase "B" includes physical, chemical, biological, and psychological research studies suggested by observations of lunar conditions. These would comprise selenological studies as well as biological and psychological investigations deemed appropriate.

Phase "C" will involve studies of space suit utilization as well as categories of tasks and types of task configurations that may be effectively employed in a low pressure environment.

Life Support Systems

The required environment will be defined in terms of functional limits and optimum conditions. Such definition will include atmospheric requirements such as total pressure, oxygen partial pressure, carbon dioxide partial pressure, humidity, inert gas, control of noxious gases and acceptable temperature. Methods for the maintenance and control of acceptable environmental conditions will be defined and will include consideration of emergency procedures, methods for identification and control of toxic gases, etc. The problems associated with temperature control will be defined in terms of a quantitative estimate of all heat sources and methods for collecting and rejecting heat. A study will be made of problems expected to be encountered in working outside the inner shell in a vacuum.

The human requirements for food and water will be specified in detail as end products of digestion, i.e., sugars, amino acids, minerals, vitamins, etc. Any special problems in feeding peculiar to lunar base operation will be considered. A plan for providing the complete nutritional requirements of the human component will be provided. The nutritional value of the algae produced by the photosynthetic gas exchanger will be determined. Supplementation and variety of diet by the inclusion of hydroponically grown higher plants and small animals will be studied. Determination of space requirements for each crop and animal will be made. Methods for recovery and reuse of water will be determined.

The design of a waste disposal system will be preceded by a study of the kind and amount of wastes produced, methods for recovering human nutritional requirements, and methods for processing human and other wastes to provide nutrient for algae and higher plants.

The subsystems required to provide the complete life support system are (a) air conditioning system and atmosphere regeneration system, (b) waste processing system, (c) food producing system and (d) water recovery system. These systems and their components considered to be essential, are shown in the attached drawing. Detailed study of each system will be made, and the final determination of the essential nature of each component will be determined. Some items of equipment will be "off the shelf", others will require design and fabrication. All components determined to be essential will be provided and installed prior to activation.

A brief description of the function of each component follows. Numbers refer to figures in the attached drawing.

(a) Air Conditioning System

1. Algal Photosynthetic Gas Exchanger

The photosynthetic gas exchanger will provide CO_2 uptake and oxygen production capability sufficient to satisfy all requirements for gas exchange for the simulator population. Gas exchange rate will be sufficient to cover requirements for respiration as well for food production and waste processing.

2. Algal Harvester (Centrifuge)

The algal harvest unit will separate algae from the liquid nutrient automatically at a rate equal to the production rate. Harvested algae willbe processed for storage as food, and the liquid nutrient returned to the photosynthetic gas exchanger.

3. Carbon Dioxide Concentrator

It is desirable to keep the carbon dioxide as low as possible in the manned compartment but furnish partial pressures perhaps of 40 mmHg. or so to the photosynthesizing organisms. We are already working on a simple diffusion process which is expected to serve as a concentrator with minimal power and material expenditure.

4. Catalytic Burner

A wide variety of potentially toxic gases can be expected to accumulate in a sealed environment. Our approach will be to determine what toxicological hazards still exist after the air has been acted on by a catalytic filter and activated charcoal system.

5. The CO_2 reserve supply will provide a source of carbon dioxide for initial activation of photosynthetic gas exchanger and hydroponicum.

During operation, it will serve as a temporary storage for temporarily excessive amounts of CO_2, so that the partial pressure of CO_2 in the cabin can be maintained at the proper level.

6. Oxygen Reserves

For establishing an initial balance between plants and animals and for possible emergencies, a reserve oxygen supply is required. Various systems will be considered such as chemical oxygen, electrolytic decomposition of water or carbonates, compressed gas, liquid oxygen, etc.

7. Inert Gas Reserves

The requirement for inert gas reserves must be established by further research and study. Possible uses are dilution of the oxygen atmosphere, fire control, and pneumatic controls or equipment.

8. Dehumidifier

Required for maintaining humidity in the human comfort range, this device will also serve as an important water recovery system.

11. Activated Charcoal System

See Catalytic Burner for comments.

12. The air heat exchanger will transfer heat produced by the catalytic burner and the photosynthetic gas exchanger to the heat rejection system.

13. Surrounded by a vacuum, the Lunar Housing Simulator living quarters will accumulate heat. Temperature regulation will be primarily a problem of transferring heat to the outside and reducing solar input. For heat transfer, a system is envisaged, consisting of liquid cooled panels or <u>heat sinks</u> located at the primary sources of heat production

and transferring heat outside the whole facility to a heat pump such as an evaporative cooler.

14. Heat sinks will serve as the main method of temperature control. Heat will be taken up at its source by means of panels and heat exchangers and transferred by a liquid system to an extaior rejection system.

(b) Waste Processing System

15, 16, 17, 18. Waste collectors will control odors and transmit wastes to the processing system.

19. A waste homogenizer will prepare raw wastes for accelerated microbiological digestion by increasing available surface area through particle size reduction.

20. An accelerated anaerobic digestion unit will control temperature, pH, recirculation, and other factors to effect maximum microbiological conversion of wastes in a minimum time span.

21. A gas storage unit will receive and store digester gas produced in the digester unit.

22. A solids separator will extract the material not liquified in the digester unit.

23. A pasteurizer unit will inactivate any living organisms surviving the accelerated digestion process.

24. An incinerator will use stored digester gas as fuel to oxidize the separated solids to ash.

25. A scrubber unit will use clear pasteurized waste solution from the separator to take up the acidic oxide gases from the incinerator.

26. A dissolver unit will use the acidic solution from the scrubber to dissolve the basic ash from the incinerator.

27. Processed waste storage will receive both pasteurized liquid from the separator and soluble minerals from the dissolver unit.

(c) Food Production System

Food will be provided from both plants and animals.

28. The plant nutrient storage system will be supplied by processed waste from storage.

29. Plants, selected for their efficiency in producing material edible to man and food animals, and compatibility with the environment, will be grown by hydroponic methods for maximum efficiency. Hydroponics tanks, plant supports, and accessory equipment will be provided as necessary. Temperature and humidity will be controlled as required.

30. Special illumination systems will provide lighting necessary for plant growth.

31. Spent hydroponic solutions will go to temporary storage prior to testing and rebalancing of nutrient composition.

32. A nutrient adjustment unit will reduce excess accumulations of salts, correcting imbalance of spent nutrient solution due to preferential absorption of elements by plants.

33. pH adjustment and control of plant nutrient solution will be provided as required by each crop requirement.

34. Growth regulating chemicals will supplement the basic nutrient solution as required by individual crops, to accelerate harvest and increase yields.

35. Certain animals, selected for their efficiency in producing edible animal protein, and for their compatibility with the system, will be grown in the animal colony.

36. A food preparation center will trim harvested plants for storage, butcher food animals for storage, and prepare crew meals from stored algal, plant, and animal material. Suitable resultant wastes will feed back directly to animals.

37. Algae harvested as a by-product of the operation of the photosynthetic gas exchange system will be a primary source of food. Storage facilities will be provided.

38. A food storage unit will accommodate harvested algal, plant, and animal materials, prior to daily usage.

39. A refrigerated storage unit will ensure viability of seeds and certain plants requiring a dormant period in their life cycle.

(d) Water Recovery System

9. The water purification system will produce potable drinking water by means of redistillation, pasteurization, freeze drying, or other methods that may be developed. All free water in the closed system will be recycled.

10. A clean water storage and distribution system will be provided.

In addition to physiological problems, human factors in the design of the Lunar Housing Simulator may be assigned to four categories: (1) task analysis, (2) human engineering, (3) crew requirements, (4) psychological effects of long term confinement.

Task analysis must be conducted in terms of mission requirements and objectives. To some extent, this will interplay with human engineering analysis of man-equipment interactions relating to instruments, controls, personal gear, and accessory equipment. Preliminary task definition must be provided to indicate the material upon which human engineering analysis must be available to assist in finalized definition of tasks. The number of tasks, their detailed requirements, and the work load they present when considered in conjunction with scheduling factors in work, rest, and recreation will be studied and will determine the size and composition of the crew.

Detailed task analysis will involve determination of specific task functions, their chronological sequence, their interactions with other task functions, precise statements of workloads related to total operator capacity, and final design of task behavior configurations to optimize total system efficiency and to minimize operator fatigue.

Human engineering analysis will provide detailed statements of information display inputs to the operator and demanded response outputs of the operator. We will seek to eliminate ambiguity or conflict in information inputs and response competition and over load in operator outputs. Emergency procedures will receive special examination.

Long-term confinement effects upon crew task efficiency and social interactions have been studied fairly extensively in recent years by a number of research and industrial groups. Their data will be utilized in crew selection.

Additional studies will be conducted if suggested by special problems arising in operation of the Lunar Housing Simulator.

Instrumentation and Control

Selection and incorporation of instruments necessary to assess the performance of the system and to provide automatic control will be accomplished during the entire course of other development work. All information and control data will be recorded.

Some of the required instrumentation can be identified and is shown in the attached.chart. Other instrumentation requirements may become evident during the course of system development.

Instrumentation

Instruments Required	Factors Sensed	Functions Controlled
Air Conditioning System		
Pressure transducer	P absolute in chamber	Inert gas reserve
O_2 analyzers	Partial PO_2 at various points	Oxygen reserve
CO_2 analyzers	Partial PCO_2 at various points	CO_2 reserve
Hygrometer	% R.H. in chamber	Dehumidifier
Photometer	Density of algal culture	Harvest rate
Conductance meter	Specific conductance of algal nutrient	Nutrient input to PSGE
Flow meters (gas)	Rate of gas flow at various points	Pumps & blowers
CO sensor	CO concentration in chamber	Regenerative catalytic burner
Thermomitors	Air temperature in chamber	Heat pump
"	Liquid T° in PSGE	" "
Light meter	Incident illumination on PSGE	Same
pH meter	pH of algal suspension	Same
Waste Processing System		
Thermomitors	Digester T°	Sewage input rate Digester heaters
	Incinerator T°	Incineration rate
	Pasteurizer T°	Same
Flow meters	Fluid and gas flow	Same
Gas pressure sensors	Gas pressure	Same
pH meter	pH of effluent	Remote control valves
Specific conductance	Plant nutrient condition	

<u>Food Processing System</u>		
Thermonitors	Animal & hydroponic air T^{o}	Heat pump
	Food & seed storage T^{o}	" "
Light meter	Incident Illumination hydroponics	
Moisture content meter	Agregate water content	
pH meter	pH of hydroponic medium	
<u>Water Supply</u>		
Conductance meter	Specific conductance	
Turbidity meter	Undissolved solids	
Thermomitor	Purification T^{o}	Same
<u>Overall</u>		
Watt meters	Power consumption by component & total	
Elapsed time meters	Time of operation of lamps and other components	