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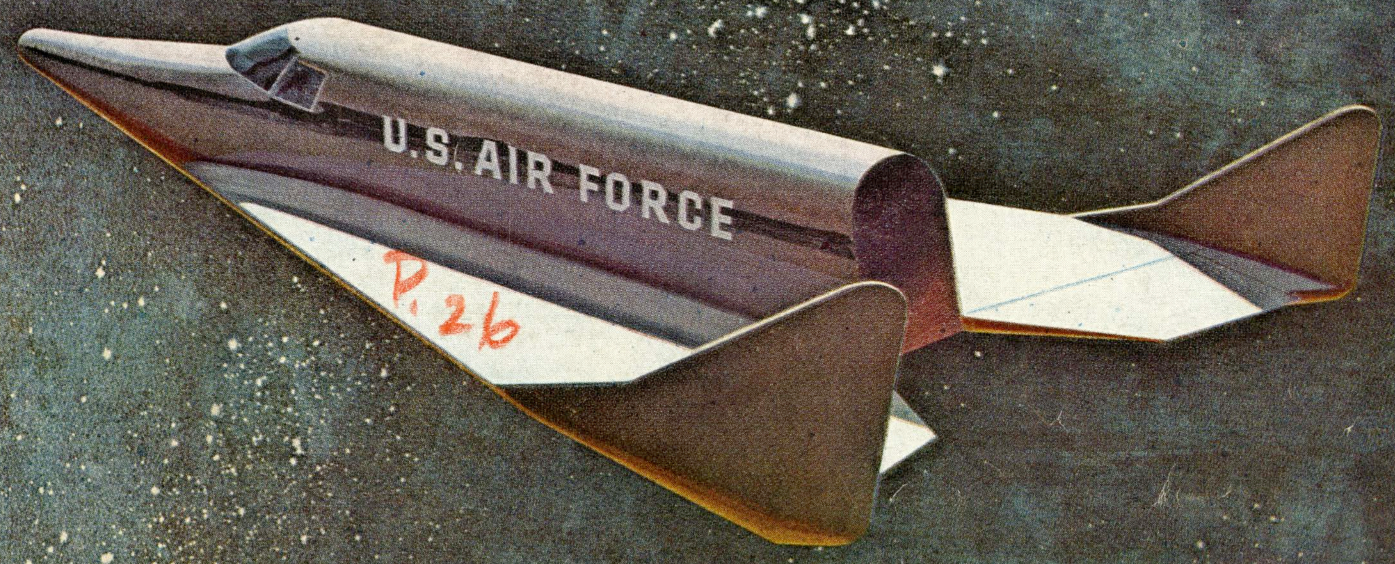

LEARNING TO LIVE ON THE MOON
Oct. 1961
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by James Gaume

40 BILLION DOLLARS – Is President Kennedy throwing it away trying to put American men into space?

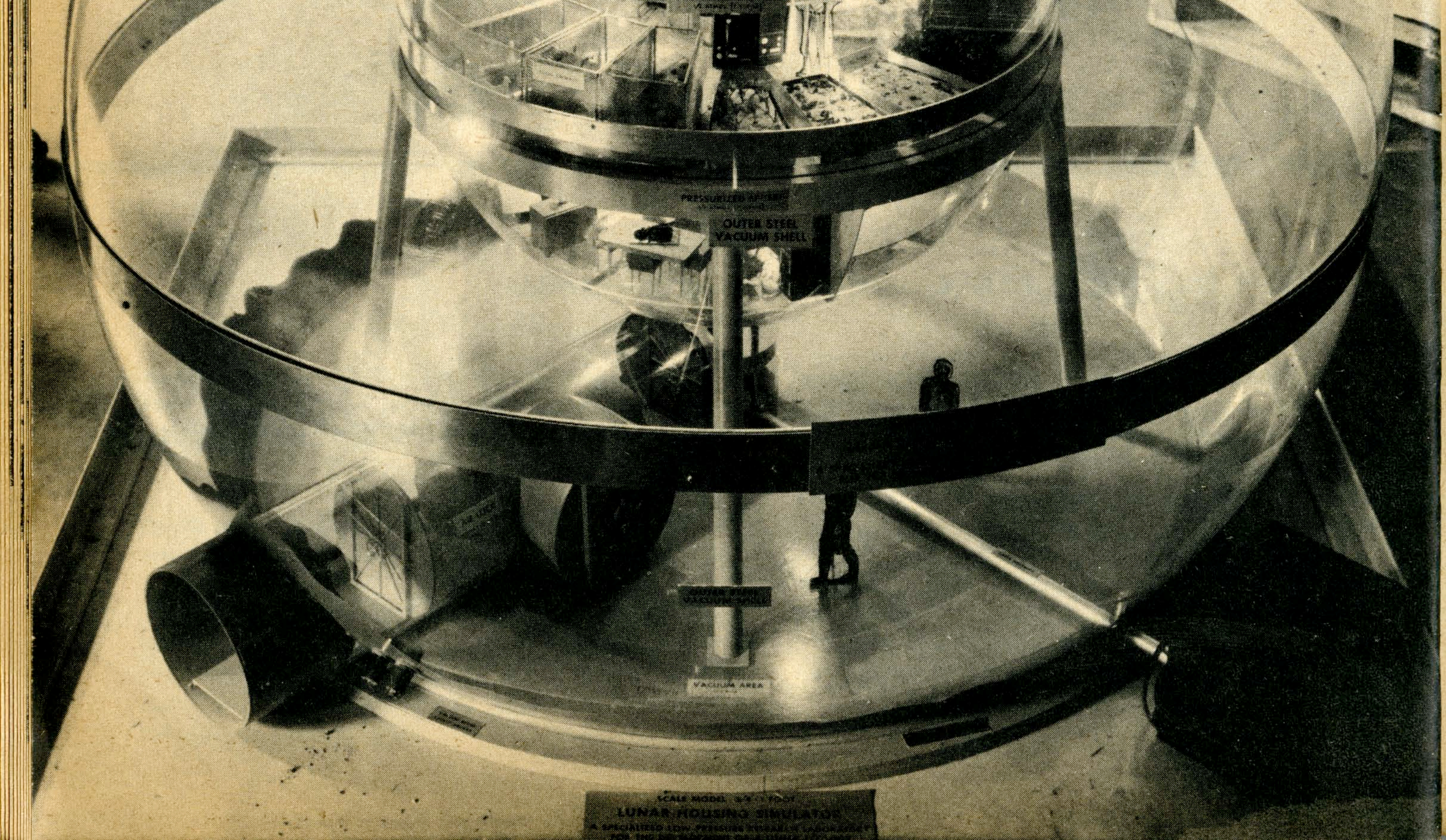
WILLY LEY REVEALS THE FULL STORY–

The Russian 'Murders' In Outer Space

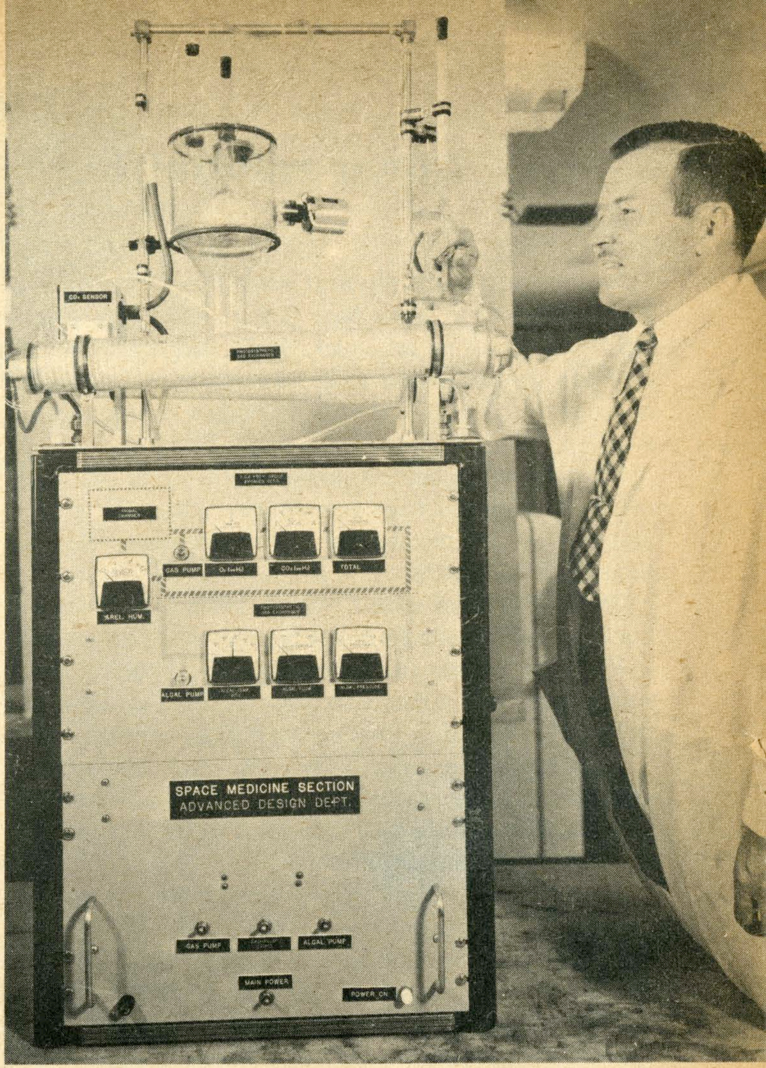
LEARNING TO LIVE ON

Techniques of lunar survival will be proved out in this environment simulator

by JAMES GAUME



THE MOON



Low Pressure Studies. Physiologist N. LeVora studies reactions of mice subjected to moon-like, low pressure conditions.

Under President Kennedy's directive of last May, an American will within 10 years set foot on the moon. Though preliminary exploration will be accomplished by instrumented vehicles, the scientist-astronaut will eventually be there to see with his *own eyes,* and not through artificial eyes, what the moon is like.

The establishment of a manned moon base will be difficult and costly, but the rewards will be spectacular. Man will find the answers to extra-terrestrial questions that have puzzled him for centuries. He may discover unexpected bonanzas to supplement dwindling earthly minerals and materials with lunar resources.

Because it lacks a distorting atmosphere, Luna offers an unparalleled opportunity for telescopic observation of the earth, the solar system, and the outer universe. The moon will also form a stable platform for the study of space conditions and radiations. Furthermore, since lunar escape velocity is only one-fifth that of earth, the moon will form an effective point of departure for further interplanetary explorations in the solar system.

In short, the moon can serve us in many useful and wondrous ways.

Certain problems must be solved before human residence on the moon becomes possible, however. Over the ages of his earth-bound residence, man's life has become so interwoven with his native habitat that extra-terrestrial existence will tax his powers of survival to the utmost.

To exist on the moon man must carry with him, or maintain locally, an environment closely resembling that of his home planet. To survive he must, as a minimum, have: a breathable atmosphere, food, drink, and shelter. He must be conditioned mentally and trained physically to meet the circumstances of an alien environment.

Regenerative Life Support

In order to prepare moon men in advance for the hazards of lunar residence, Martin-Denver proposes the construction of a Lunar Housing Simulator Laboratory (LHS) here on earth.

Built underground, this artificial "moon manor" would house five men, plus the plants and animals necessary for long-time survival without outside supplies. In this way, we will determine how a complete balance of life can be achieved on the moon, and what methods will best maintain the large-scale, self-sustaining, ecological system that is the key to successful lunar habitation.

The Martin concept of a regenerative life support system closely imitating a lunar base includes a biological atmosphere exchanger; a waste processing and food production system; crew quarters including areas for eating and sleeping; provision for recreation and sanitary facilities. Observation equipment to monitor the results from outside and control the various processes and tests are included in the complete design.

The Lunar Housing Simulator will consist of a pair of airtight, steel spheres, one within the other, with an adjacent support building. The outer sphere will be about 64 feet and the inner sphere about 32 feet in diameter. Entrance to the LHS will be through the support building by means of an air-lock chamber.

On the moon, an identical air lock would provide access to the life support enclosure or to the lunar surface. On earth, by donning a full pressure suit, a crew member could enter the vacuum area between the shells

(continued on next page)

Lunar Environment Simulator. Scale model, left, shows double-walled testing installation under construction for detailed studies of lunar survival techniques and systems.

Lunar survival will depend on what we learn on earth

and actually perform physical work like that required in constructing a lunar base. Of course, the gravity factor would not be accurately duplicated but what the man can do under one *g*, he can obviously do much easier under 1/6 *g*, so that is no barrier to the experiment.

On the moon, electrical power for the lunar base will readily be obtained from generators run by solar radiation or a nuclear reactor. On earth, commercial electric power will be substituted in the simulator.

The LHS's inner sphere will be divided internally by three decks to make four levels. Access to the various levels is by means of a vertical, central, utility core whose shaft will contain an elevator for the crew, as well as the plumbing, ducting, and wiring necessary for the simulator's operation. The core shaft will extend down through the base of the outer sphere and connect with the entrance air-lock that leads to the outside observation and control laboratory.

The uppermost level of the inner chamber will be occupied by plants that form a part of the closed, ecological system. The median deck will contain laboratory facilities as well as more animals and plants taking part in the life-support system. The lower deck (the most protected from possible meteor hits in an actual lunar structure) will be equipped as living quarters for the crew. Below the crew deck, the base of the sphere will be used for tanks, pumps and other mechanical equipment that will require infrequent access for repairs or maintenance.

The large space between the two spheres is deliberately planned as a giant vacuum chamber for a variety of space studies carried out by the "lunarites". Conventional vacuum pumps are capable of evacuating this area to a pressure that is comparable to lunar conditions —0.15 pounds per square inch—about a hundredth of normal earth pressure. Such problems as emergency survival on the moon, the detection and stoppage of air leaks, and the development of space suits plus the ability of men to live and work in them, may be investigated with greater thoroughness than by the use of ordinary, small, pressure chambers so far used in space medicine experiments.

In its essentials, this LHS will be a miniature replica of earth's natural ecology—a *terrela* or "little world".

The success of a manned base on the moon will depend upon the possibility of maintaining there the equivalent of our terrestrial environment. The enormous problems of continuous resupply from earth that would otherwise be demanded make it imperative for the lunar outpost to be self-sufficient to a maximum extent.

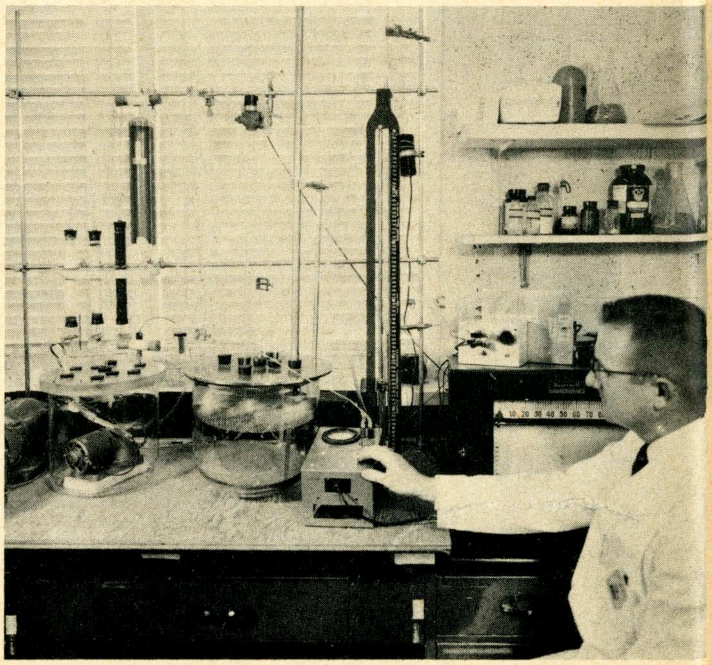
Excluding the possible but unforeseeable discovery of lunar resources such as frozen water, or minerals containing readily available oxygen, the lunar base can best achieve self-sufficiency by use of a closed ecological system similar to the age-old symbiosis between plants and animals on earth.

Atmosphere

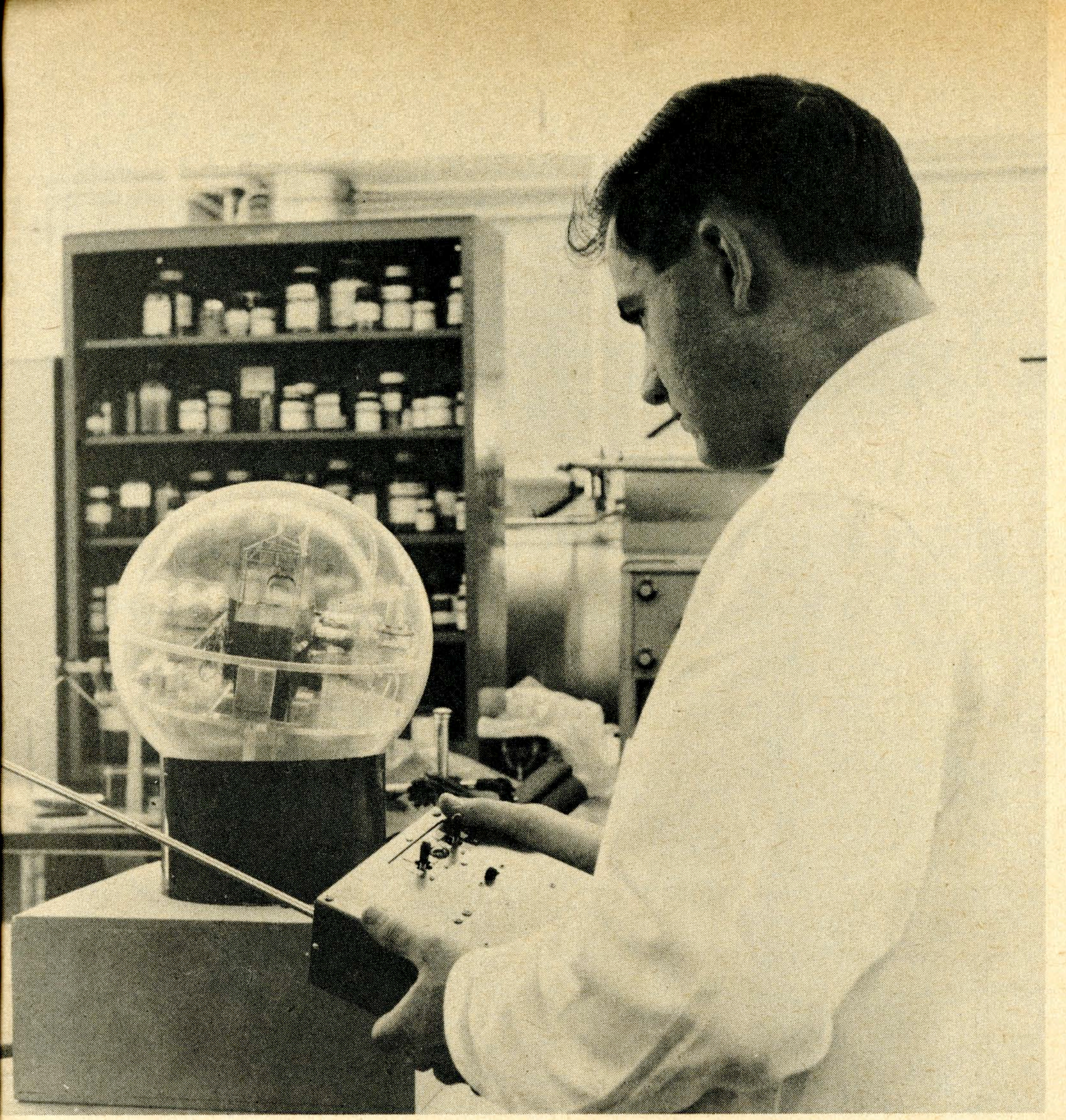
On earth, vegetation produces oxygen for men and animals who in turn exhale carbon dioxide needed for plant growth. The same would be true in the moon housing, in which the lunar colonists would maintain *algaecultures* for oxygen production. Algae are microscopic marine plants which multiply rapidly under proper conditions of light and nutrient. During this rapid growth they consume carbon dioxide and produce oxygen.

Certain strains of green and blue-green algae *(Chlorella pyrenoidosa* and *Anacystis nidulans)* have the highest known rate of photosynthesis, a characteristic that makes them the most efficient organisms for our purposes. Light to promote their growth will be provided by fluorescent bulbs or filtered sunlight.

The simple one-celled algae plants may be grown in a liquid culture occupying illuminated tanks. As the air in the LHS is pumped through these tanks, water and carbon dioxide are converted into organic compounds



Closed system. White mouse housed in container breathed oxygen supplied by algae culture growing in horizontal tubes.



Reaction Control Simulator. Designed to prepare man for extended space flight, this facility will consist of a 10 foot sphere of light material supported by a cushion of low pressure air. This will permit the simulator to assume any attitude by the thrust of reaction jets that will be under the control of the pilot trainees.

while releasing free oxygen. This system provides for a level of control that is not possible with higher forms of plant life.

Although natural growth of the algae will provide a surplus that may be harvested as food for the men, the vegetation's specific function is supplying life-giving oxygen. Accumulating odors and traces of toxic gases, such as minute amounts of carbon monoxide produced by algae during photosynthesis, can be easily removed by activated charcoal and catalytic oxidation.

The lunar dwelling's air will be continuously humidified by transpiration (water vapor release) of the plants plus the breathing of the animal occupants. Excess humidity will in time accumulate, to be removed by freezing so that the ice will constitute a source of pure water for the men.

A mouse has lived a number of days in a small pilot model of this Martin system without outside food or air, both being furnished by the algae.

The choice of the best oxygen-producing alga has yet to be made. Each alga species has a certain desirable characteristic and some algae have several favorable factors in combination. But the best "triple-threat" alga has not yet been selected. By triple-threat we mean oxygen-production, utilization of animal wastes as nutrients, and the ability to serve as a dietary supplement. Further screening of the most suitable plant organisms must be done before a single best type of alga can be named.

Food

In the long-term lunar life-support system, food must be provided in one of two ways: 1) by supply from earth; or 2) by production within the manned base.

The first method will cost exhorbitant sums of money to blast a few tons of food to the moon. The present Thor-Able booster is estimated by NASA to cost from $10 to $14 million per firing. Saturn launchings will be approximately $20 million each. With these figures facing us, it is obvious that we must attempt to develop a system of food production within the lunar closed ecology before man gets to the moon.

This is the second task of the versatile algae cultures in our experiments. In the LHS, as well as in the outside world, plants will thus supply the basic nutritional needs of the five men. There would be no room for crop fail-

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simulating the actual conditions on the moon are now being constructed.

"When we try the models here," Andy said, "we will know whether or not they can really do the job they are designed to do. We will have a fissure covered surface, one with thick dust and another with a smooth glass-like surface. We will see how they work there."

Though Andrew Anchutin can cock a wry eye at himself and his work for an easy laugh, he realizes that this work is earnest and vitally serious.

"Man is going to explore space," he says. "He will go to the moon and the planets. Our job is to design and make the equipment that will take him there and bring him back again, alive." ■ ■

Cape Carnival *continued from page 37*

record and the achievement was hailed as an example of open progress in a free society.

That is all well and good, but this was only the first step in the man-into-space effort. There will be more launchings, there will be more firsts, and there will be more brave men risking their lives for science.

We've had our publicity extravaganza. From now on, let's keep Project Mercury on a scientific level. The astronauts and the men behind them deserve nothing less than this kind of consideration.

"Science," explained one Project Mercury official, "cannot operate effectively in a glass bowl—it's the wrong environment. What we are trying to do is widen the horizons of knowledge for all mankind—not stage a publicity stunt." ■ ■

Learning to Live on the Moon *continued from page 29*

ures, but overproduction would be acceptable and in fact desirable. Sealed in gas-tight containers, surplus food crops could be stored outside in the natural deep-freeze of the moon —any shadowed or shady nook out of sunlight, which even in the lunar daytime would be far below zero.

For long-term lunar living a diet as completely normal as possible should be provided for the moon men for both nutritional and psychological reasons. An unvarying menu consisting solely of algae would be comparable to eating nothing but grass for a year or two. To keep the lunar explorer happier, a normal cuisine of meats, vegetables, grains and fruits must be supplied.

The plants besides algae to be included will be chosen on the basis of maximum food value and tastiness to men and animals. Because soil is heavy and bulky, and only a very limited part is actually useful to plants, hydroponics will be more practical for lunar plant culture. To give them support, the plants are grown in a layer of inert, fibrous material, with their roots immersed in a liquid nutrient medium. While these crops will carry on photosynthesis and also supply some oxygen like the algae, it is in this case only secondary to their food producing function.

Via hydroponics, large quantities of food can be grown in relatively small tanks during short periods of time. Soil-less tomatoes, for example, are known to ripen from seed plantings some 30 days earlier than they mature in a standard greenhouse. Other plants we have under experimentation include kale, peanuts, soybeans and rice. These would furnish a basic diet for spacemen living on the moon for long periods of time.

Such fruits as the apple, pear, peach, apricot, pineapple, cherry and plum would provide additional interest in the menu. But the design of these enclosed culture beds must allow for new factors different from open-air gardening. Pollination of flowering plants is one of these and it might require the full time of two or more men to carry out the task. Two bees, however, could do the same job in a fraction of the time. Thus, in order to assure adequate fruiting of plants, insects should be included in the simulator system.

By controlling rigidly the temperature, light, humidity and available nutrient, growth rates and plants can be increased markedly. Previous experiments show that tomatoes planted from seed can reach a height of 28-30 inches to flower in 21-24 days, while the average California tomato takes 70-75 days. Fruit can be harvested in 48-50 days after planting. Similar rapid growth rates can be obtained in other plants nourished under hydroponics techniques.

Animals, to be used as food by the crew, will be included in the lunar chamber's ecology. These animals will be selected for convenience of size, ability to live on a vegetable diet, and efficiency in converting vegetable matter into meat. No attempt will be made to establish a full-fledged farm in the Lunar Housing Simulator. In the interests of simplicity and efficiency, the varieties of plants and animals will be kept to a minimum.

Waste Processing

A necessary link in the closed ecology of a lunar house is the collection and reprocessing of all human, plant or animal wastes. This includes: 1) exhaled carbon dioxide; 2) liquid and solid animal/man excreta; 3) leftovers from animals slaughtered for meat, such as hides, bones and entrails; 4) plant leftovers including stalks, roots and leaves; 5) even the washwater, soap and detergent solutions used by the men.

By proper ecological planning certain scavenger animals or fish can probably be used to consume remnants of butchered animals. Other animals can be chosen for their ability to eat plant wastes as food, either alone or when mixed with grains and algae. Or, it might prove necessary instead to process all wastes so that the end product will be a nearly complete nutrient for food plants and algae.

In another type of experiment at The Martin Company, wastes are treated by an automatically controlled process whereby anaerobic digestion —by bacteria needing no air—breaks down the raw materials into usable form. The solid and liquid materials are then separated. The latter becomes the nutrient solution for food plants and algae. The remaining solids are burned to convert them into usable fertilizer, minerals, and carbon dioxide, to be re-cycled into the plant-growing facility.

Physiological Conditions

Space installations must be built to withstand a pronounced pressure differential between the exterior vacuum and interior aeration. No atmospheric pressure to speak of exists in space. Lower than normal (14.7 pounds per square inch) air pressure within the lunar house would produce less strain and reduce the structural strength needed, making a saving in the weight and size of the chamber. Martin scientists are experimenting to determine if such interior pressure can be reduced to 5 psi, equal to the air you would breathe on the top of Mount Everest.

For the comfort and survival of the men, this low-pressure atmosphere would be enriched with a higher level of oxygen than normal air contains. Investigation now is proceeding on the effect of long-term low atmospheric pressures on plants, animals, and humans. Our Physiology Unit of Space Medicine at Martin is working with a variable low-pressure research chamber for these tests.

The same scientific group also is studying the effect of ionized air on living things. On the moon, this ionization of the housing atmosphere will be caused by the impact of cosmic radiation upon the outer shell. A secondary radiation will originate within the inner shell, since sealed enclosures fill up with increased ion concentration caused by electronic-electrical devices. This, coupled with the exterior cosmic rays raining down from outer space, probably will result in a high ion level inside the lunar house.

Little definitive work has been done in this field, but there are indications that positively-ionized air produces dizziness, headaches and lassitude in man, while negatively charged air seems to induce a sensation of pleasant well-being. Either effect, whether adverse or euphoric to the oxygen-producing algae, food plants or animals, might be enough to upset the delicate balance of their closed ecology. Rigid standardization is needed for the smoothest long-range operations under sealed conditions.

Psychology

The psychology unit of Martin's Space Medicine Section is concerned with human mental and emotional factors in the maintenance of manned lunar camps. The moon dwellers will require a completely new standard of reactions for they will be exposed to a lunar environment in which their terrestrial upbringing will be of little use. The development of training projects and devices to prepare man for life on the moon is an important function of the human engineering program here on earth.

Studies on isolation effects, long periods of confinement, crew personality changes, and the degree of group compatibility, are important areas of this research to be conducted with our LHS.

Forearmed

The Martin-Denver Lunar Housing Simulator Laboratory will allow investigation of all phases of proxy residence under scientifically-controlled conditions that closely approach those of the moon. The studies would materially contribute to our chances of successful exploration and development of earth's satellite by American lunarnauts.

When do we need to start these lunar simulation experiments?

The answer, we at Martin believe, is as soon as possible. It is essential that the "lunar preview" system be built soon so that man will be ready, perhaps by 1967, to begin his great venture to the moon.

When the moon ships are ready for the first landing and those to follow, any problem that has been overlooked or neglected may lead to disaster. In the unfamiliar and hostile environment of cratered Luna, man should never be called upon to improvise. He must, as far as is scientifically possible, be forewarned and forearmed to cope with any contingency.

Then our lunar frontiersmen will not skirt along the thin marginal line that may mean life—or death—in establishing America's first inhabited outpost on the moon. ■■

Answers to Space Quiz on Page 49

1. B	9. A
2. B	10. B
3. C	11. A
4. None	12. C
5. C	13. C
6. A	14. C
7. A, B, C	15. A
8. B	16. B