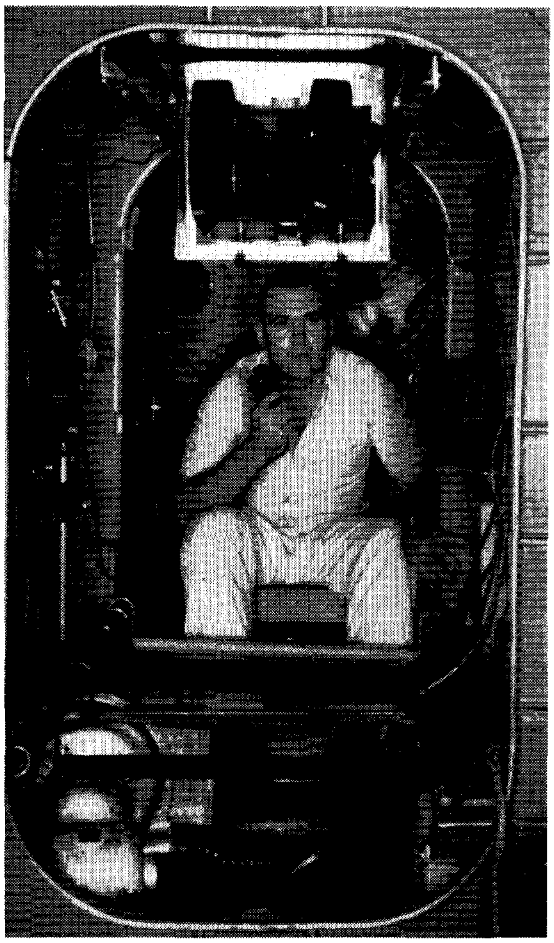


Airman Donald G. Farrell, who spent seven days in a sealed cabin simulating conditions of a space flight

Food—Space Age Problem

A STAFF REPORT

Future astronauts will not sit down to dinner as usual. It will take ingenuity to feed them. Unfortunately, astronauts' biological problems are not so close to solution as are space flight's engineering problems

A PARADE OF HEADLINES—Sputnik, Explorer, X-15—is making the public aware that we are fast approaching the era of manned space flight. But hidden behind the headlines is a problem which may determine just how far the future astronaut will venture. The question: How do you feed him?

This problem has received little publicity compared to its more glamorous sister headaches like rocketry, thrust, weightlessness, and others. It has also received relatively little attention in the research laboratory. One nutrition expert frankly admits that the engineering problems concerned with space flight are far more nearly solved than the biological problems of the astronaut.

In the simplest terms, there seem to be two possible solutions. One, the man can carry his food with him. Or, two, he can produce it along the way. Since storage space and weight will be at a premium, the first alternative requires that nutrients be highly concentrated in miniaturized or dehydrated food. Probably the only feasible way to accomplish the second alternative is with a closed ecological system—with the astronaut himself a part of it.

In the closed system, photosynthetic plants would convert the astronaut's exhaled carbon dioxide into available oxygen. Human wastes would provide nourishment for plants' growth and the plants, in turn, would provide food for the space man. Energy for the system would come, of course, from light, just as it does for nature's photosynthetic phenomenon.

Both approaches to the space feeding problem have their advantages; neither is without complications. Primarily, though, the choice between them hinges upon two vital factors—time and weight. How long will the flight last? When does stored food's weight become greater than that of the equipment needed for a closed ecological system?

The cutoff point is hard to pin down because it depends upon too many as yet unknown factors (such as available thrust, total weight of the space vehicle, number in crew). Estimates vary from a few days to about six months.

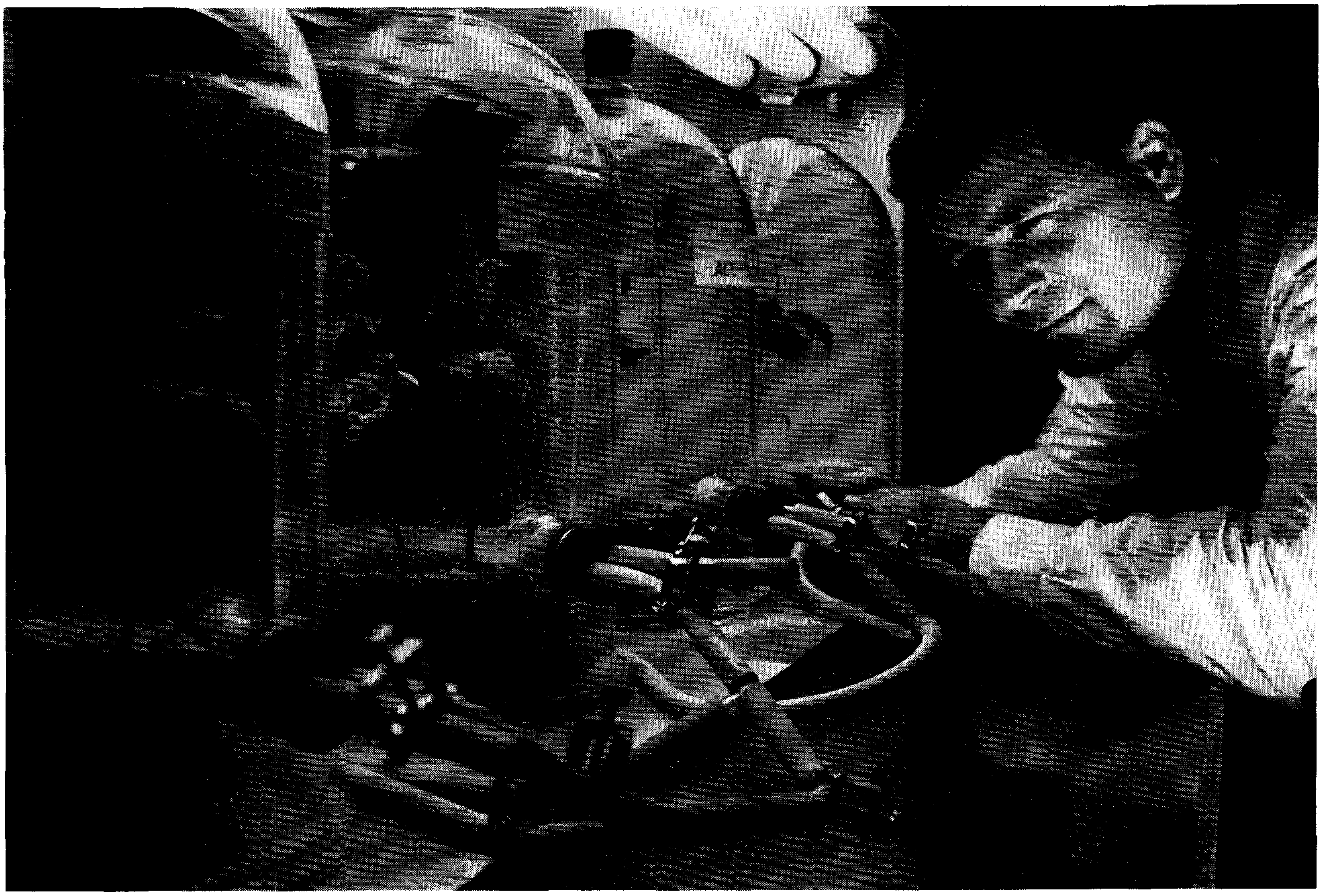
Miniaturized Food

The art (or science) of miniaturizing food is perhaps further along than any other aspect of the space feeding question. And well it should be, for the first manned space flights will be very short, orbital trips by a single person. Longer probes by crews of two or more must wait their turn.

Yet, it has only been within the past two years that major efforts have been made to perfect food for these early space flights. This effort has been concentrated on three objectives:

- Reduce the weight of packaging
- Make the food easier for the crew to eat
- Make it appealing gto the crew.

The astronaut will find it difficult to eat and drink in the zero-gravity



Vegetable cultivation may be necessary for earthmen if they hope to survive long on the Moon. At Republic Aviation scientists are nurturing carrots, beets, snap beans, and turnips at various simulated low-pressure, high-altitude conditions in a research program conducted for the Air Force on the feasibility of establishing a base on the Moon

state. During weightlessness, liquids do not pour from open containers, but break up into droplets. This makes it not only difficult, but dangerous, to drink in the conventional way, since the droplets may get into the respiratory tract. Solid foods form dusts which may also get into the lung unless they are converted to semi-liquids in the mouth. Once inside the mouth chewing and swallowing are no problems.

All of this points to special feeding techniques—using squeeze tubes or otherwise piping the food directly to the mouth. The food would have to be in liquid or semi-liquid form and under small positive pressure so that the crewman could easily control it. Last year the Air Force tested over 3000 aluminum squeeze tubes at very high altitudes. Supplied by American Can Co., the tubes were not affected by differences in pressures inside and outside the pilot's helmet. Although they were light (9 gm.), they withstood the food sterilization process. The tubes held flavored milks, fruit juices, and meats in semi-solid form.

Compared to liquids, solid foods "stay down" better under emotional stress and when there is a tendency for nausea. Thus, the big question about a liquid or semi-liquid diet is: Will it stay down?

Some nutrition experts pin their hopes on dehydrated foods. They say these are the closest thing to miniaturization so far, and the "only known form of food which shows any promise." But they also admit to difficulties.

Stability is a problem. Off-flavors often develop when dehydrated foods are stored for long periods. Some foods become tough. Potatoes in beef hash, for instance, become tough after long storage, although the meat remains stable. There are still only a limited number of dehydrated foods; and there are production problems. It is difficult to remove all the water from some foods, and with others color is a problem.

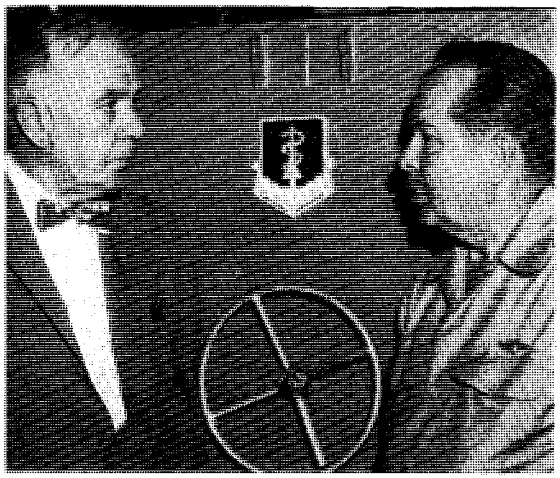
Still unsolved is the question of how to rehydrate the foods during a space journey. Foods are normally reconstituted at 212° F., but at high altitudes, water boils as low as 160° F.

Another observer warns against thinking that foods can be miniaturized like transistors. The best that can be done, he says, is to remove the water and compress the food. Then, unless water can be recycled (by recovering urinary wastes, for instance), there is little advantage to dehydration. Reason: water must be supplied in equal amounts whether it is carried in the food or stored separately.

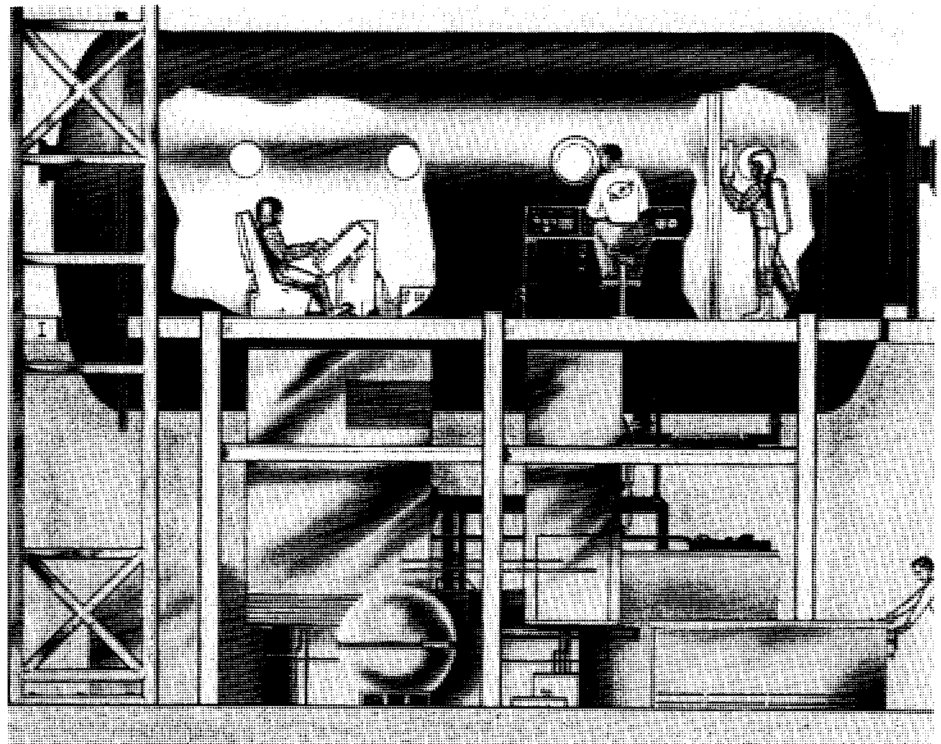
Algae on the Menu

In space flight, there is one outstanding critical factor—permissible payload. It determines the thrust of the engine required to accomplish a given task. As a rule of thumb, one pound of freight requires 1000 lb. of thrust.

Man's minimum water requirements run about five pounds per day; his oxygen needs are about two



Among top space scientists are Hubertus Strughold (left), professor of space medicine and advisor for research at the School of Aviation Medicine, and Col. Paul A. Campbell, chief of the school's division of space medicine. Behind them is the school's space cabin simulator



First space chamber capable of taking a human 150 miles up into simulated ionospheric conditions will look like this sketch. The $500,000 chamber will be built into Republic Aviation's astronautics research center at Farmingdale, N. Y. Men and material will be tested under space flight conditions

One way to provide the astronaut with food and oxygen is with a closed ecological system using algae. But how near reality is it and what is needed to complete the work? Here's what the experts tell AG AND FOOD:

". . . research . . . should be on a practical basis . . . here on earth with closed systems including man . . . This is not being done."

"We are a long way off. I would guess that it would take more than $100,000 and more than a year's time to build one right now without space and weight restrictions."

"We can only guess, but we feel a closed ecological system will not be developed for 10 years."

"At the current rate of research, there will never be a practical closed system for space travel . . . These are problems which cannot be solved on a part time basis by one or two men."

"The amount of money available for research in this area is pitifully low."

"Many more scientists need to become interested and a large amount of financial support must be made available."

"If all-out effort were made, I should be optimistic enough to say substantial progress would be evident in five years."

"The problem will be licked as soon as any agency, government or otherwise, spends $5 to $10 million a year on it for at least three to five years, probably ten."

"At the rate of research progress now in evidence, I should guess that ten years may be required to produce a workable system. If more brains and talent are engaged soon, perhaps in five."

"From an examination of the literature and from personal observation of the extent of work being done in this field (we conclude that) the research should be multiplied by a factor of 10 to 100, if a closed-cycle system is to be produced in five to 10 years."

"If 20 or 30 . . . independent groups could work on . . . the problem unhampered for a couple of years, after which integration of results might be attempted, at least one workable system would result."

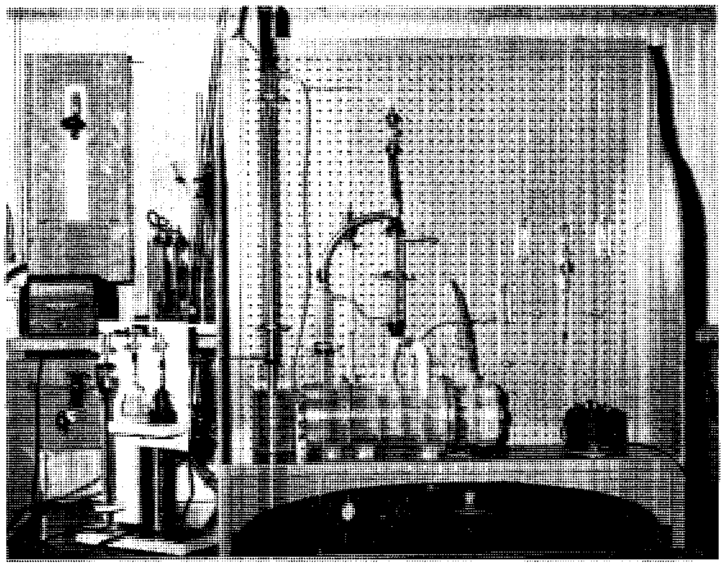
pounds more. He also eats anywhere from 0.8 to about 1.7 pounds of food solids per day. At this rate, a space ship with a three-man crew on a one-year trip would have to carry over four tons of cargo for food, water, and oxygen alone! And this does not include packaging. Since a round trip to Mars would last two, three, or more years (depending upon which space expert you ask), it is easy to see why all the food can't be packed.

For the extra-long hauls, nearly everyone agrees that the answer lies in a closed ecological system . . . a balance between man and a photosynthetic plant. To be successful, the plant should provide:

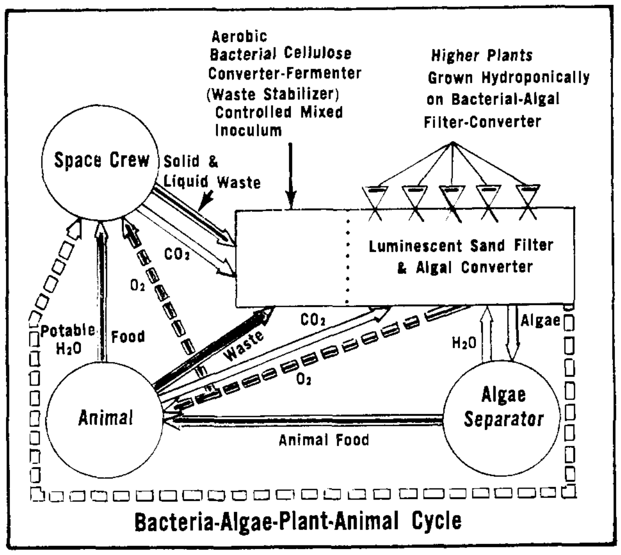
- Gas exchange between itself and the space man
- Means of consuming human waste
- Food.

Right now the leading contenders for the job are algae.

Jack Myers, University of Texas botanist and zoologist, has found that from 5 lb. to as low as 2.5 lb. (fresh weight) of the common alga, *Chlorella pyrenoidosa,* can absorb the carbon dioxide exhaled by one person and, in turn, produce enough oxygen to sustain one person. It can also supply his food needs, with some supplemental help. What's more, it can



Lab set-up for closed cycle air purification with algae. It is theoretically capable of caring for the gas exchange requirements of one to two men. It was designed by scientists of the Electric Boat Division of General Dynamics



One scheme for avoiding the monotony of an all-algae diet is the inclusion of an animal in the closed ecological system. This added step could raise the cost by a factor of five, because production of a pound of animal requires five to 10 pounds of food

do this indefinitely if it has light and nutrients. It must be remembered, however, that the algae must be kept in water to function properly, so that the weight of the whole system is 10, 20, or perhaps 50 to 100 times the weight of the algae alone.

One drawback to *pyrenoidosa* is the fact that its optimum light intensity, in the range of 500 to 1000 foot candles, is low. By comparison, incident sunlight at the earth's surface is more than 10,000 foot candles. To be practical, plants would probably have to be capable of withstanding 10,000 foot candles of light and have an operating generation time of not more than three hours. There are other known algae which, compared to *pyrenoidosa,* produce oxygen three times as fast and which need from three to 10 times as much light. Surprisingly, the need for more light will generally decrease, rather than increase, the engineering problems.

Although several types of plants could be used in such a system, they are eliminated for many practical reasons. Higher plants, for instance, are generally considered unsuitable except as minor supplements, because they are not "fast" enough. Even so, higher plants are not being entirely neglected. Republic Aviation, for instance, is working with a variety of higher plants; it is looking particularly for plants which have low seed weight, which can be eaten entirely, including roots and tops, and which contain a relatively low percentage of waste material. Republic scientists have tentatively established that some higher plants can be grown at the reduced pressures that would be required, and that growth rates can be speeded up at least part of the time at low pressures.

Algae multiply faster than higher plants, but even most known algae are not fast enough. Hopes are to find new strains of algae which will fill all requirements. Possibly, new strains can be developed. One optimistic prediction calls for photosynthesis which can use infrared.

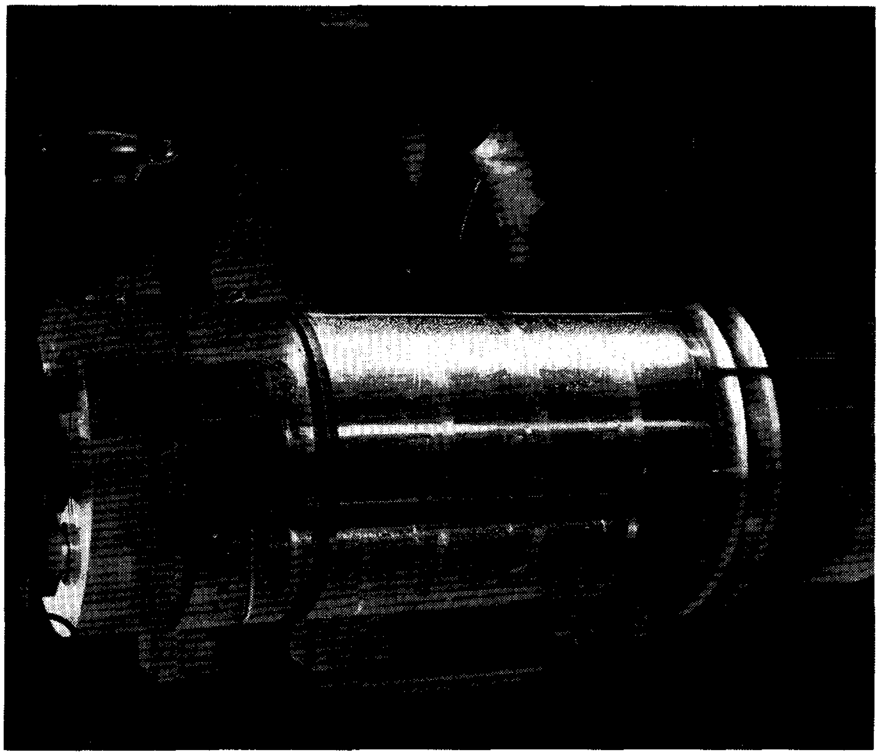
Algae are potentially a nourishing food. They contain roughly 50% protein, 15% carbohydrate, 25% fat, and 10% ash. These percentages vary, of course. Some B vitamins, carotene, and ascorbic acid also are present. True, some essential nutrients are lacking, but since such a high percentage of algae is digestible and since some species can double their weight 12 times in a day, they are almost certain to be on the menu for long space trips.

What nutrients do algae need to flourish? Mostly they are the same ones required by higher plants—nitrogen, phosphorus, potassium, and carbon, plus some trace elements. Fortunately, human wastes contain most of the needed elements. Nitrogen as urea, for instance, makes up about 50% of urinary solids. Thus, a useful as well as a practical means of disposing of wastes is available.

Although using algae in a closed ecological system is theoretically possible, there are many difficult engineering problems which must be solved before it becomes a reality. Algae will need illumination, using solar or artificial light. They must be aerated and their population density must be controlled. Scientists must find a way to harvest them and transmute them into a form acceptable as food. They must also design a miniature processing plant to handle human wastes. Another problem: controlling the cellulose build-up which is certain to occur. To further complicate all these requirements, there is the all-important weight limitation, plus the fact that the system must operate in the zero-gravity state.

There are two very strong objections to the use of algae as food for the spaceman. The first concerns the one-food diet aspect; the other concerns algae's aesthetic values—flavor, odor, textural quality—or lack of them.

No one food is perfect. Even milk, which comes as close to the ideal as any food, is deficient in a number of minerals and vitamins. Edible plants,



Close-up of the algae chamber in the laboratory unit designed by General Dynamics' scientists for air purification. It has algal suspension capacity of about 1.5 liters. Entire unit occupies much less than 1 cubic foot. Algae used are the thermophilic Chlorella strain discovered by Myers and Sorokin

including algae, are likely to be lacking in even more nutrients.

Lack of variety is a big drawback. How long a man can stand an unvaried diet is the subject of much debate, but it has been hinted that even the best steak becomes tiresome after three days if that's all there is to eat. And who dares classify algaeburgers with steak?

This factor becomes very important in long space flights because food will be man's chief link to the world as he knows it. He will be subject to many physical and physiological stresses. If his food is not what he is used to, it becomes an additional stress. Added to his other problems, his antipathy toward a monotonous diet may be the straw that breaks the astronaut's back.

Algaeburgers, algae stew, algae soup. Can the future space man take this monotonous diet if it comes down to it? Here are some opinions:

"I doubt that enough variety can be obtained . . . to make it attractive . . ."

"Man has considerable capacity to adapt himself to a diet. If it is nutritionally adequate, I should expect him to develop a taste for it."

". . . This is a challenge to food technology."

"It is doubtful that man can adapt himself to a nonvaried diet . . . Food should be as close to what he is accustomed to as possible . . ."

"I do not envision difficulty in making the taste of algae acceptable and varied . . . Recall the constituents of margarine to realize what can be done with food processing."

"I think it . . . possible to make (algae) . . . acceptable. I doubt . . . (that) it is necessary to make it attractive."

"There is a good possibility that many individuals will rebel after eating a few meals that are exactly the same."

"(Making) . . . a closed cycle system which will provide well known, palatable, motivating foods is indeed difficult."

Psychological Factors

On top of all this is the knowledge that he is eating his own wastes, with but a few steps in between. This psychological factor may be enough to discourage even the most dedicated space traveler. Scientists at the USAF School of Aviation Medicine, Randolph Field, have recently suggested a way to circumvent this. They advocate putting some kind of animal into the closed ecological system. The animal could eat the algae and the man could eat the animal—in a form more agreeable to him. But another expert points out that this added step could raise the over-all cost of the system by a factor of at least 5, since production of a pound of animal requires 5 to 10 lb. of food.

Most estimates have it that a closed ecological system will not become practical for at least 10 years, although some are willing to gamble on five years. Most agree, however, that it won't be needed for 10 years because other food forms will satisfy the needs of short space flights.

When it does come, the closed ecological system probably will not be the astronaut's sole source of food. Rather, it will provide a supplement to his diet. A partial balance has been suggested. Water and oxygen could be recovered from wastes and recycled. Food could be transported. Solid wastes would be stored in the space vacated by the food as it is used. Still another possibility is chemical synthesis of at least part of the food, and chemical reduction of the carbon dioxide waste to carbon and oxygen.

Money for Research

The variety of opinions on almost every aspect of space feeding suggests one conclusion: a practical solution to the problem is still a long way off. Research must be increased significantly if a feasible closed system is to be developed, even in 10 years. According to Robert G. Tischer of Mississippi State University, there are only about a dozen laboratories in the U. S. actively working on the problem. Another observer puts it this way: "The problem will be licked as soon as any agency, government or otherwise, spends $5 to $10 million a year on it for at least three to five years, probably ten."