The March Into Inner and Outer Space

by Fritz Zwicky

Both scientists and laymen frequently inquire why we should want to journey into space. Also, in connection with rocketry, the question is constantly being asked why we let the Russians get ahead of us. Dr. Edward Teller, of H-bomb fame, recently remarked that unimaginative and materialistic thinking in missiles planning led to the loss of the race into space to the Russians.

If many things in the past have gone wrong in the lives of men and in the lives of their communities it is because both small and large scale activities were blundered into without any thought or vision of universal planning.

In our time we have marched into the air age without the benefit of any realistic vision of what was to come. Likewise, radio and radio communication were developed without any planning as to their basic technical and sociological aspects. On the technical side the failure to plan the use of modulation of amplitude, of frequency, of phase, of polarization, and of other parameters of radio waves resulted in a nasty and interminable confusion of channel allocations and led to very costly legal controversies.

The atomic or nuclear age was blundered into with the pitiful result that supposedly enlightened scientists coaxed President Harry S. Truman into using the atomic bomb to wipe out the civilian populations of Hiroshima and Nagasaki. This regrettable action has had the most disastrous influence on the efforts of all men of good will toward the establishment of constructive relations among all races and nations.

We are now at the beginning of the space age. Activities so far hardly indicate that the development of rockets, of propulsive power plants in general, and of the future march into space have been materially directed or even greatly influenced by great men of mature outlook and technical knowledge. In addition we suffer heavily from the blunders of the past. Indeed, the work on rockets started in earnest with World War II, mostly under conditions of military secrecy which carry over to the present day. As a consequence, even the cooperation among free men and free nations has been poisoned. Under the circumstances, major actions by courageous and wise men will be necessary to avoid our continuing to blunder into the space age like unenlightened and selfish idiots.

To achieve cooperation, both a holding action as well as a more effective approach toward large scale planning, education, invention, and construction will be necessary. We are not concerned here with the holding action. Suffice it to say that this action involves a defense against destructive forces and agents of all kinds which threaten our march toward the realization of the freedom and genius of man. We shall here be rather concerned with the more restricted problem of the technical planning for the exploration, ultimate utilization, and colonization of space and the bodies within the solar system.

In this planning we shall include both *inner* and *outer space*. By *outer space* we mean extraterrestrial—interplanetary, interstellar and intergalactic — space. *Inner space* includes both the interior of the earth and the depths of the oceans.

A successful march into the spaces above and below the surface of the earth requires that:

A. The characteristics, material, and phenomenological content of inner and outer space must be clearly visualized and explored.

B. The goals to be reached must be clearly formulated.

C. Practical means must be conceived and constructed which make the journeys into inner space and outer space possible.

D. Finally, the journeys themselves must be undertaken and the spaces penetrated, explored, exploited, or colonized, as the case may be.

The exploration of outer space has been for thousands of years the prerogative of the astronomers. Three great names come to mind in this connection. Aristarchus of Samos (320-250 B.C.) clearly conceived of the sun and of the planets as bodies in space, and he and Hipparchus, around 160-125 B.C. showed the way to survey this space. Giordano Bruno (1548-1600 A.D.) was the first to "break through" the immutable celestial sphere which for the ancients bounded the solar system. Bruno correctly thought of the stars as real bodies in an essentially unlimited space. Finally Knut Lundmark (1889-1958) in 1918 opened up for us the immense spaces beyond the confines of our own Milky Way and first determined the distances to the nearest galaxies, such as the great spiral nebula (Messier 31) in the constellation of Andromeda.

Our knowledge of the true characteristics of inner space — both of the depths of the oceans and the interior of the earth—as yet is meager. Depths of the oceans and profiles of the ocean bottoms are of course well known by now, but much remains to be learned about the various conditions in all depth strata and about all the various occupants in these strata. Still less is known of the interior of the earth, because most of our information has been derived from indirect manifestations originating in the gravitational, magnetic, and electric fields, as well as from analysis of such events as earthquakes and the eruption of volcanoes.

Outer space

The march into outer space started with the climbing of high mountains and with modest ascents in kite balloons and in free balloons. Dirigibles came next, followed by propeller-driven planes and ultimately by jet planes. The record for altitude, curiously enough, was held for more than three decades by the free stratosphere balloons, first used in 1925 by the Swiss professor of physics, Auguste Piccard. The rocket plane (X-15) and the unmanned and manned rocket have only recently topped the altitude records of the stratosphere balloons. These rockets have been successively put in orbits around the earth — and the unmanned rocket into orbits around the sun. (The first predecessor of these space travellers actually was a tiny slug of aluminum oxide and titanium oxide which Mr. J. Cuneo and I propelled into interplanetary space by means of a shaped charge with a coruscative insert, exploded from the nose cone of an Aerobee rocket at Holloman Air Force Base on October 16, 1957, just 12 days after the launching of Sputnik I. This little slug, about one centimeter in diameter, was thus the first manmade object to be propelled permanently away from the earth.)

Our march into inner space, curiously enough, is in a more rudimentary stage than our progress in outer space. Indeed, our diving devices, except for submarines (which do not descend to any considerable depth) are comparable to the stages of the kite balloon and the free balloon in the exploration of the atmosphere. This does not mean, of course, that the accomplishments of Auguste Piccard in the Atlantic and the Mediterranean, and the record dive by his son Jacques to a seven-mile depth to the Challenger Bottom near Guam in the Pacific, do not rate among the most magnificent exploits of all times.

Piccard's achievements are the more amazing since he pioneered both into the stratosphere and into the greatest depths of the ocean. He achieved this as a lone wolf, struggling for over 30 years to find sponsors and to develop the technical means for his bold plans.

Inner space

The penetration of man into the major part of inner space—the interior of the earth—has been slower yet, and has not gone far when we think in terms of the radius of the earth. No vehicles have been developed to propel man through the solid earth. What is more, no one seems to have seriously considered the possibility of such vehicles, except for the terrajet engines I first proposed in 1943.

After what has already been achieved with rockets, the three obvious future tasks are:

1. The construction and operation of more efficient propulsive power plants and of space vehicles.

2. Actual journeys of man to the moon and to the planets.

3. The colonization of the moon and the planets. This may ultimately involve the reconstruction of the whole planetary system—that is, the relocation and modification of the various members of the solar system.

Beyond the propellants and the propulsive power plants of today there lie a number of possibilities. In extrapolation of the conventional chemical propellants, condensed radicals and other fragments of molecules are being worked upon. These "frozen-in" metastable states, such as pseudostable helium hydride propellants, promise to be efficient enough to make single-stage rockets into interplanetary space a distinct possibility. The mastery of nuclear fusion reactions lets us visualize propulsive power plants of even greater efficiency.

Beyond the construction materials available today, work is now in progress to achieve solids of such light weight and superior strength that entirely new vistas open for the construction of space vehicles in the future. For example, "whiskers" and lamellae of microscopic thickness have been grown of many crystals, including iron. These whiskers and lamellae have a strength which is often orders of magnitude greater than that of conventional construction materials.

Actually, as I pointed out many years ago, nothing seems to stand in the way of producing bubbly solids—the bubbles to contain high vacuum or light gases like helium, such that the whole solid is lighter than air and exceedingly strong. Not only can the proverbial magic carpet be made of such spongy materials, but rocket chambers, solid propellant sticks, and vehicles of all kinds can be visualized which are very light—possibly lighter than air.

Engineering aspects

Once these lamellated or bubbly solids become practically available, the engineering of airplanes, rockets, and space ships will take on quite unexpected aspects. For instance, rockets will not have to be lifted away from the earth by conventional propellants, which carry both the fuel and the oxidizers. Indeed, the oxygen of the atmosphere will become available for use in air-breathing engines, which will accelerate space ships, which are floatable in air, around the earth within the atmosphere and bring them to the terminal escape velocity of 11.2 km/sec or more. Air-breathing engines, such as the aeroduct (ramjet) and the rocket pulse, will be particularly useful in this operation. The new materials will make it possible to drive space ships of any dimension off the earth with relatively equal ease. Likewise, soft landings on Mars and Venus or any planet with an atmosphere can be more easily accomplished than with the now conventional rockets.

In this connection it should be mentioned that it is a misnomer to talk about journeys within the solar system as belonging to the realm of astronautics. We should rather place them in the field of helionautics. Astronautics, strictly speaking, will be concerned with voyages to other stars. Remarkably enough, to achieve such feats, we might not even have to leave the earth. It would suffice to accelerate the sun itself to a very high speed and let it drag all its planets with it.

In order to exert the necessary thrust on the sun, nuclear fusion reactions could be ignited locally in the sun's material, causing the ejection of enormously high-speed jets. The necessary nuclear fusion can probably best be ignited through the use of ultrafast particles being shot at the sun. To date there are at least two promising prospects for producing particles of colloidal size with velocities of a thousand kilometers per second or more. Such particles, when impinging on solids, liquids, or dense gases, will generate temperatures of one hundred million degrees Kelvin or higher—quite sufficient to ignite nuclear fusion. The two possibilities for nuclear fusion ignition which I have in mind do not make use of any ideas related to plasmas, and to their constriction and acceleration in electric and magnetic fields.

Needless to say, the achievement of simple methods of nuclear ignition will be of great value in many other fields – power generation in general, efficient and sustained rocket propulsion, submarine and subterranean propulsion, reconstruction of the whole planetary system for the purpose of making thousands of times more living space available than we have now, and innumerable other applications.

Since the moon, however, may be our goal before propellants of the free radical type or the nuclear fusion types become available – and also before we can reasonably hope to achieve the ultra-lightweight-construction materials to which I have alluded – it may be well to direct our attention to some possible operations on this, our nearest conspicuous neighbor in space.

Much work is now being done to prospect the various physico-chemical characteristics of the moon by sending probes and instrumentation to its surface ("The National Program for Lunar and Planetary Exploration," by Albert R. Hibbs—*E&S, May 1961*). I only hope that these projects will succeed before astronauts actually land on the moon, so that the projects do not become antiquated even before they have been completed. In any event, it seems to me that our main concern should be to study and to make ready the means and devices which will allow men to land on the moon, to install themselves rapidly and "live off the land" as soon as possible after their arrival.

The necessary means for sustaining the lives and operations of the astronauts from resources available on the moon are:

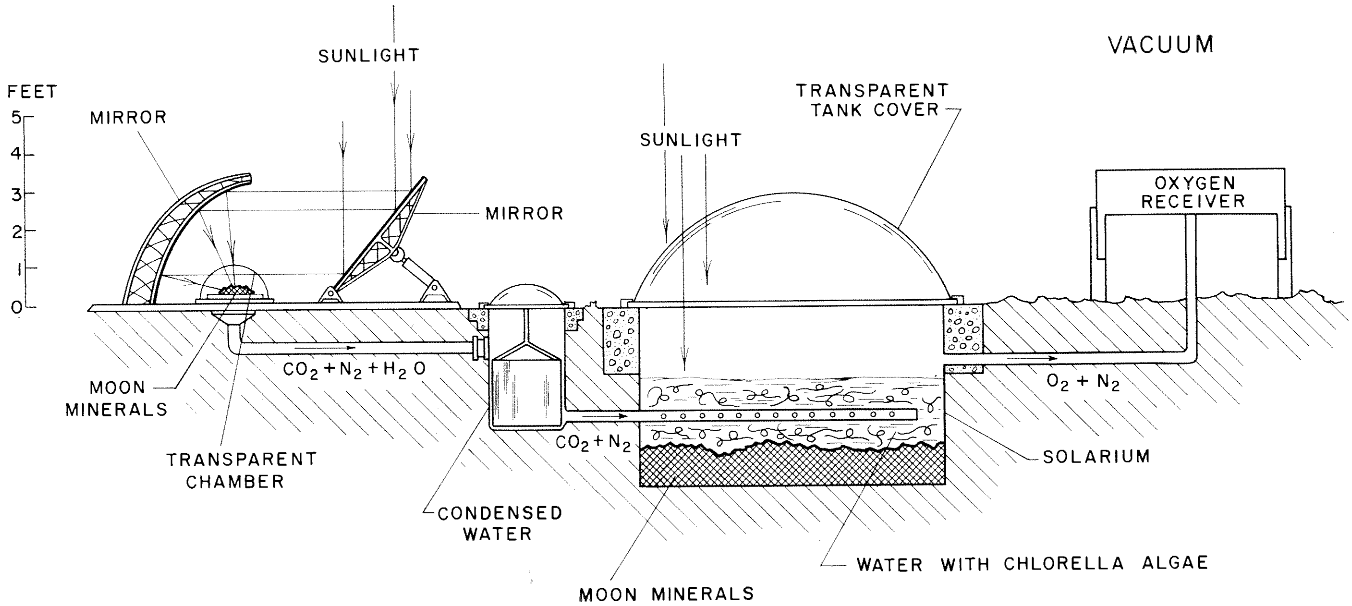
1. Protection against deadly radiations, especially the bursts of high energy particles emitted from solar flares.
2. Oxygen and water.
3. Food.
4. Mechanical and electrical power for operations on the moon.
5. Production of suitable propellants for local rocket hops on the moon and for return trips to the earth.

Solar furnaces

All of these requirements can be satisfied through the use of solar furnaces. The resources with which we propose to work are thus the rocks on the moon and solar power. From astronomical evidence, the rocks on the moon (at least at some moderate depth below the surface) may safely be supposed to contain all of the elements which we know on the earth. "Cooking" of the moon's rocks in the focal spot of a solar furnace will successively produce water vapor, carbon dioxide, and dissociation products of these gases – carbon monoxide, hydrogen, oxygen, and carbon itself.

In a very efficient solar furnace, with temperatures above 4000 degrees Kelvin in the focal spot, almost all chemical compounds will be reduced into the elements, so that elementary magnesium, aluminum, silicon, lithium, beryllium, boron, and others will become available. Furthermore, some of the resulting

An Installation for the Sustenance of Life on the Moon



Sunlight is focused on moon minerals in a vacuum-tight, transparent bell jar by a mirror combination. Water of crystallization (H_20), carbon dioxide ($C0_2$), and nitrogen (N_2) are liberated from the minerals through the intense heating and conducted into a watery suspension of chlorella algae in a "lunar garden." Drinking water is also condensed in this container. The algae, with the aid of sunlight, "digest" the carbon dioxide and exude oxygen which—together with nitrogen and some remaining carbon dioxide—is collected in the tank at the right for breathing and other purposes.

products will be ionized and partly-charged particle streams will be ejected, which, in an ion jet generator or magnetohydrodynamic generator, will generate electric currents. Electric current can be conveniently used to decompose the molten rocks of the moon in the focal area electrolytically, and to produce the elementary metals mentioned above, as well as gaseous oxygen, in this indirect way. Gaseous oxygen and food can also be readily obtained through the photodissociation of carbon dioxide in the chlorella "garden" as it is built into the installation shown above.

The qualitative and quantitative aspects of these operations have been discussed in another article, ("Some Possible Operations on the Moon" by Fritz Zwicky—*Journal of the American Rocket Society, December 1960*). Suffice it to say here that the requirements for oxygen, nitrogen, water, auxiliary mechanical and electrical power, and eventually for food, can be met with installations of moderate size, using the rocks on the moon as raw materials and the radiation from the sun as the power source.

Another operation involves the production of rocket propellants which are both suitable for powering return vehicles to the earth, and vehicles to be used for hops around the moon itself. Since it will be easy to produce both water and elementary metals such as Li, Na, K, Mg, and Al, in solar furnaces, the natural rocket motors which we should visualize as most natural with these propellants are those of the hybrid type which use a solid fuel and a liquid oxidizer. In fact, in 1944, when I was director of research of the Aerojet Engineering Corporation, I experimented successfully with a hybrid motor which contained a cylinder of aluminum metal, threaded lengthwise, with lithium inserts and water as the oxidizing agents. The water instantaneously reacts with the lithium and generates Li_20 and hydrogen at high pressure and temperature. The aluminum consequently melts and reacts with the water to form Al_20_3 plus hydrogen gas, which, as a consequence of the high heat of reaction liberated, is expelled as a jet with 2200 meters per second exhaust velocity. This is thus a rocket propulsion system which can be easily produced from the resources available on the moon.

Many scientists have claimed that not too much of scientific value can be gained in the march into space, but I maintain that scores of the most important scientific investigations can only be carried out once we establish ourselves on the moon and other bodies of the solar system.

In the first place, it may prove of vital importance for our views on the evolution of matter in the universe to explore the moon itself for all material constituents, and its magnetic, electric, and gravitational fields.

The features which make the moon an apparently inhospitable place to live — its lack of an atmosphere, its extreme differences in temperature, the absence of bodies of water — are precisely those which the scientist must have to achieve the solution of some rather burning problems which he cannot yet solve on the earth.

The astronomer and the radio astronomer will be immeasurably aided because of the absence of an atmosphere. In the first place, he need never be bothered by bad weather or, for that matter, care whether it is day or night; he will be able to observe at any and at all times. In the second place, all of the wave length regions of the electromagnetic spectrum, from the shortest gamma rays to the longest radio waves, will arrive from all cosmic sources unimpeded, on the surface of the moon—multiplying the potentiality of the analysis of cosmic bodies and phenomena a hundredfold.

Of the innumerable problems which are much easier of solution on the moon, or which can only be solved there, let us mention two. The first refers to the observation of the Lyman alpha emission line of hydrogen in the spectra of ever more distant galaxies. This type of observation, which is not possible from the earth, and which is exceedingly difficult and expensive from rockets, will give us decisive data on the nature of the universal red shift and no doubt settle once and for all the question of the evolution of our universe, and give us some understanding of its large-scale structure.

The second kind of observation which is not possible from the earth refers to the far infrared range of wave lengths from 1 micron to 1000 microns. Within this range we shall not only be able to see right down to the central nucleus of the Milky Way system; we may expect to see right through the Milky Way in all directions and observe galaxies of whose existence we have no knowledge today. Furthermore, the scanning of the skies in the ultrafar infrared will catch significant and telltale parts of the emission and absorption spectra of all molecules and radicals on planets, the sun, and the stars, as well as in interstellar and in intergalactic space.

Physicists and chemists on the moon

The absence of an atmosphere will allow physicists and chemists to carry out experiments in any desired degree of a vacuum and to produce compounds and materials, which, because of the presence of the gases remaining even in the highest artifically produced vacuum, are not possible on the earth. For instance, the highly controversial problem of what the properties of very pure crystals are can only be solved in a laboratory on the moon.

Most exciting vistas open themselves for biologists, physicians, psychologists, and psychiatrists. To be both serious and humorous—they will want to find out how humans and organisms in general fare in the new surroundings and, particularly, how much of a chance physically and mentally small people have to grow taller and wiser when having to support only one sixth of their weight – and when having the spiritual impetus of pioneering, while their tall and heavyweight comrades back on earth are being cut down to size by the high gravity on the one hand, and the desperately-growing complexities of life on earth on the other hand.

But, joking aside, the chance of exploring entirely new worlds, pioneering in making them habitable, and creating new forms of society, will be the greatest challenge for all great minds. Also, as we have observed during the past two decades, space research is not only important in itself. Our concern with this research has led to the formulation of problems and to results of scientific, technological, and human value which we should not have otherwise achieved. And much more may be expected in the future.

Submarine activity

In submarine activity the big task before us is to build craft which can navigate at will through all parts of the ocean and which will allow us to "reside" in all parts of the ocean, "see" through it, and carry out operations of all sorts, such as mining at the bottom of the sea.

For this we need powered vehicles driven either by wheels and propellers, or better yet by hydrojet engines. Also, for lift we will not only rely on buoyancy but on moving "waterfoils." As a result of my morphological analysis of the totality of jet engines which are activated by chemical propellants I conceived of a number of hydrojet engines in 1943.

The hydrojet engines, which are powered by hydrofuels – chemicals which hydrolyze water – generate hydrogen gas at tremendous pressure and release great heat of reaction, allowing us to build submarine craft which in their way are even more versatile than any type of aircraft or rocket. Indeed, vehicles driven by hydrojet engines can move through the water in all directions, including straight up and down and attain speeds far in excess of one hundred knots. At the same time these vehicles can be made to stagnate at any desired depth, a feat which for analogous heights in the atmosphere is not possible for aerial vehicles, except for helicopters under very restricted circumstances.

The problem of seeing through the ocean and communicating with one another within it is one of the most difficult tasks yet tackled, as all of those scientists know who have grappled with the problem of detecting submarines at great ranges. This task, however, is a great challenge to imaginative investigators and will no doubt be solved in the near future.

With respect to the interior of the earth our outlook and our ultimate goals must be analogous to those formulated for the march into outer space and into the ocean depths. Indeed we shall strive to navigate through the earth, to reside in it wherever we please or find it expedient, and we want to have means of communication from any point of the interior of the earth to all other points. Our first interests obviously carry over from those of the past, inasmuch as we will want to expand all mining operations and the exploitation of oil as well as deep-lying water resources, including the liberation of water of crystallization in the rocks. Beyond these, many new scientifically, technologically, and militarily important goals beckon. Whether we reach these goals depends largely on our ability to construct vehicles driven by propulsive power plants which can make their way fast through the various parts of the interior of the earth.

In 1943 I conceived of jet engines capable of boring and propelling themselves through the solid earth, and called them terrajet engines. These devices may be powered by chemicals – known as terrafuels – which react with the rocks (or possibly with some water or oil contained between the rocks). At a later stage, when nuclear fusion ignition has been mastered in a general way, terrafuels will provide the ideal driving power for terrajet engines.

Terrafuels are actually more versatile than either ordinary fuels (aerofuels) or hydrofuels. Both of the latter take oxygen from the surrounding medium and bind it chemically more strongly than before by getting oxidized. Terrafuels, however, can do both – reduce the compounds in the surrounding medium or oxidize them further. Indeed, molten lithium will reduce almost any of the minerals of the earth's crust, while liquid fluorine will liberate oxygen from them and fluorinate them instead. Without going into any details of how terrajet engines are actually constructed and operated, I can mention that a pulsating type of terrajet engine (terrapulse) looks the most attractive as a start and that it may be built initially for the purpose of loosening clogged-up oil-bearing strata, for mining in general, and for large-scale underground installations for civilian defense and military offense. (Unfortunately, while we inventors here have talked to deaf ears, the Russians again seem to have taken over our ideas and have already built terrajet engines for military purposes.)

All of the projects which I have described will be eventually realized, I am sure, and much will be gained scientifically, technically, and humanly through our occupation with the problems of the space age. As to who is going to do them first, Khrushchev has squarely challenged us and predicted that he will bury us. So let our veterans who are not yet senile and all of our virile youth take up Khrushchev's challenge and show what free men can accomplish without sacrificing the prerogatives of the human soul.