FUSION

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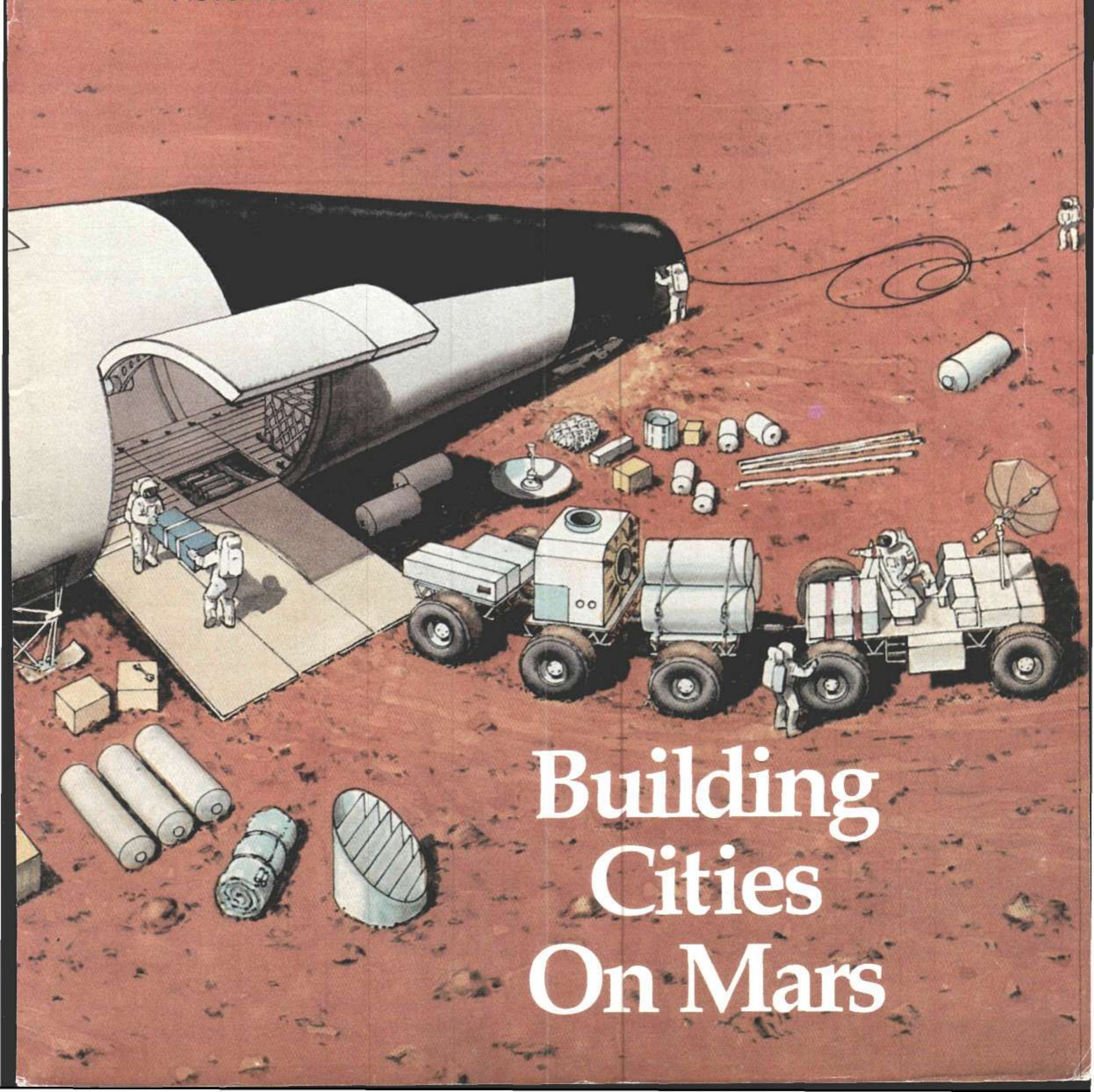

Building Cities On Mars

FUSION

SCIENCE • TECHNOLOGY • ECONOMICS • POLITICS

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Features

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On the cover: Illustration by Carter B. Emmart of six Mars landers unloading equipment for the first Mars base.

Editorial

The U.S. Should Implement Its 1980 Fusion Law!

The Magnetic Fusion Energy Engineering Act of 1980, introduced by then-congressman Mike McCormack, a Washington Democrat, was voted up by an overwhelming majority in both the House and Senate and was signed into law on Oct. 7, 1980 by President Carter. It specified that the United States would build an engineering test reactor by the year 1990 and a commercial prototype fusion reactor by the year 2000. It is a sad irony that this became the law of the land under the antinuclear Carter administration only to be consigned to oblivion—along with the fusion budget itself—by the pronuclear Reagan administration. Now, six years later, that law has died by default, while the fusion budget has been slashed by one third, in real dollars.

Even with only minimal support, this technology has demonstrated its promise to provide virtually unlimited energy for the future. And only as we have fusion energy, will we be able to achieve the goal of colonizing space. If we are to establish a base upon Mars within 40 years, we will need to deploy energy at flux densities at least one order of magnitude greater than those now available. Fusion power is the only path to such an upscaling.

This issue reports on recent results with Princeton Plasma Physics Laboratory's TFTR, which show that we can have fusion power available as an energy source on the timescale necessary. The TFTR tokamak has achieved temperatures of 200,000 degrees Celsius, 10 times hotter than the temperature of the Sun at its core.

In this issue, we are also pleased to publish Lyndon H. LaRouche's proposal for the colonization of Mars. LaRouche emphasizes that we must break sharply from the mentality which would approach the industrialization of the Moon and the colonization of Mars with existing, off-the-shelf technology, because it is thought that only such an approach will sell in a Washington dominated by the budget-cutters. We need 40 years before we can begin permanent colonization of Mars, he says, simply to give us time to develop the new technologies we will need to rely on while we are so far away "from the nearest repair shop on Earth."

The Fusion Constituency

The 1980 Magnetic Fusion Energy Engineering Act became law as the result of a mobilization, in which the Fusion Energy Foundation played a major role in organizing a national constituency for the rapid development of fusion power. We are committed to leading such a national effort again today.

The purpose of the law in 1980 was to establish a national goal of demonstrating the feasibility of fusion as a commercial energy source by the year 2000. We have lost ground since the law was passed and we are approximately 10 years behind schedule. Minimally, therefore, we can now set our sights on achieving demonstration of a commercially operating fusion plant by the turn of the century.

One proposal now being mooted is to leave the development of such a plant to private industry. This is to court the dismal fate of the breeder as well as the isotope separation program—and is directly counter to the intention of the McCormack Act, which mandated vigorous government support.

The present approach of the Department of Energy is to postpone even the development of a fusion engineering test device until such development can be pursued with international cooperation. Yet such a disingenuous bid for other countries to pick up the bill—even if it is ultimately successful, which seems doubtful—not only will paralyze scientific development in this country but also will lead to unnecessary delay.

At best, even if the Europeans and Japanese agree to such a cooperative effort, their approach is different from that typically practiced in the United States. Here, we leapfrog, planning two generations ahead, so that as a new device comes on line, the next is already in the planning phase. Such an approach implies a flexibility of design that allows for unanticipated advances. The Europeans and Japanese have traditionally taken a more cautious approach. Results from the European JET tokamak and the Japanese JT-60 are not expected before the mid-1990s, so there is little likelihood that they will move ahead with a next-generation reactor until 1992. Are we to sit idle and wait until they catch up to us?

The Soviets have also offered cooperation; however, the device they support, the INTOR (International Tokamak Reactor), would cost $5 billion—about five times as expensive as the one being considered in the United States. There is talk now of joint development of such a large-scale program as a follow-through to the Reagan-Gorbachov summit meeting, possibly involving as many as 15,000 skilled scientists, engineers, and technical workers, and their families.

There is another alternative besides the despair of budget cuts and the dream of international collaboration: The kind of increases in productivity that are already being realized by the development of the Strategic Defense Initiative will rise in a nonlinear fashion if we develop the technologies needed to successfully realize the Moon-Mars program. This will provide more than adequate funds to pursue vigorous national programs in all of these areas, and allow international cooperation to proceed as it becomes appropriate.

Letters

Golden Numerology?

To the Editor:

The May-June issue of *Fusion* contained a fascinating article on the recent challenges to the long-held assumption in physics that inertial and gravitational mass are equivalent ["Galileo Proven Wrong!" by Dr. Robert Moon and Carol White, p. 22]. There was also a brief overview of the nonequivalence theory of Dr. Benny Soldano. The article raised a number of interesting questions, and the reasoning employed was generally clean and easy to follow.

But a subdivision of that article, "Is Time Absolute? A Look at the Fine Structure Constant," threw me for a loop. I thought I smelled numerology!

The notion that there may be some meaningful relationship between the fine structure constant of quantum theory and the "golden mean" geometry of living form is certainly an interesting one. After all, one of the more profound things we can do in mathematical physics is examine the physical-geometry *bases* from which the plethora of empirical constants that we use in our studies of nature are derived. But what is the real evidence for a "relationship" between the fine structure constant and the golden mean?

The "golden mean angle" is that unique angular measure, the projection of which divides the circumference of the circle such that the minor arc produced is to the major arc as the major arc is to the whole. The "golden number" can also be seen from the point of view of the "nodal distribution" of a continuous least-action function's projection from the surface of a cone. It is a numerical representation of an important geometrical identity seen in nature.

The division of the circle into 360 equal "degrees," on the other hand, is but one way of breaking up the circumference. As pointed out in your article, we use this particular division because it approximates the relationship between the diurnal spin of the Earth and its yearly orbit about the Sun. It is presumably a convention passed down to us from the ancient astronomer-geometers and it is also arithmetically convenient.

Dividing the square of the golden number, ~ 2.618, into the number of times that the Earth revolves about its axis in a sidereal year, in order to obtain an approximation of the inverse of the fine structure constant seems an entirely arbitrary endeavor. Have we really uncovered a "relationship" between circular action, the golden mean, and the fine structure constant by this means?

Imagine an astronomically inclined civilization living beneath the dust clouds of Jupiter, where nearly 10,390 "daily" rotations occur for every trip around the Sun, who have set up a calendar and a system of geometrical conventions which reflect this fact. Should they attempt to employ the same method described in your article, they would find no relationship of interest between the fine structure constant and the golden mean. (I am assuming, of course, that the empirically determined fine structure constant and the golden mean are the same on Jupiter as on Earth!)

Galileo now proven wrong, it would seem a step in the wrong direction to return to the Earth-centered logic of the pre-Copernican era.

Please point out any misunderstandings that I may have had.

D. Thomas
Newark, N.J.

The Editor Replies

The question you have failed to address is: What is the fine structure constant? Indeed, how is it possible that any numerical constant can be of significance in quantum physics?

Clearly, the fine structure constant must reflect the actual geometry of physical space-time. You assume that the fine structure constant—or for that matter Planck's constant of action—will prove the same on Jupiter as on Earth; I do not at all accept that as a foregone conclusion.

Life exists on Earth, not on Jupiter. Indeed it is highly likely that we are the most advanced life form (if any other

Continued on page 71

News Briefs

Stuart K. Lewis

The locust plague is reversible—if the U.S. acts now, Fusion *editors White (left) and Hecht told a Washington press conference.*

AFRICA NEEDS LARGE-PLANE SPRAYING TO COMBAT LOCUST PLAGUE

"In Senegal the locust threat is under control, thanks to the spraying done by the United States," a representative from the embassy of Senegal said at a Washington, D.C. press conference Sept. 24, sponsored by the Schiller Institute. Senegal is the only country to date where large-scale spraying has taken place. Four commercial DC-7s, paid for by the U.S. Office of Foreign Disaster Assistance, sprayed 900,000 acres infested with grasshoppers in early September. At the press conference, *Fusion* editors Carol White and Marjorie Mazel Hecht reported on the large-scale effort that would be needed to stop a disaster worse than the drought-induced famine of the last two years: "In the United States we routinely spray about 13 million acres a year to control the grasshopper infestation in the grasslands. This could be done in Africa—if the international agencies including the Food and Agriculture Organization, the International Monetary Fund, and the World Bank had not already determined that Africa was 'overpopulated,' that the so-called carrying capacity of Africa had reached its limit."

PRODUCTION OF NUCLEAR POWER WORLDWIDE INCREASES 14 PERCENT

Nuclear power production worldwide increased by 14 percent from 1984 to 1985, the head of the International Atomic Energy Agency said at the 30th general conference of the group Sept. 29 in Vienna. The increase follows a 19 percent jump from 1983 to 1984 and is equivalent to the entire annual coal production of the United States or the Soviet Union, IAEA director general Hans Blix said.

CZECH NUCLEAR PLANT COULD NOT BE LICENSED HERE

The Soviet-designed pressurized water reactor in Czechoslovakia could not be licensed in the United States because it has only a modified containment of its primary elements instead of a Western-type full containment, the chairman of the U.S. Nuclear Regulatory Commission told a news conference in Vienna Sept. 29. Lando Zech, who recently visited the Czech plant, said that "to license it in the U.S. we would want that it be completely contained."

NEW YORK TIMES WRONG AGAIN ON CHERNOBYL

Stuart Diamond, the antinuclear activist who is a reporter for the *New York Times*, announced in a page-one article Sept. 23 that the "nuclear disaster at Chernobyl emitted as much long-term radiation into the world's air, topsoil and water as all the nuclear tests and bombs ever exploded." Diamond cited as his source a study by Dr. Lynn R. Anspaugh, a biophysicist at Lawrence Livermore National Laboratory, and the *Times* story was picked up internationally. Anspaugh held a news conference at the laboratory the same day to say that the *Times* report—and a similar *Washington Post* report—was untrue. The total amount of cesium, the primary long-term radioactive component released, is about one-tenth that released by all atmospheric tests, he said.

FUSION ENERGY FOUNDATION

Special Report

The Strategic Defense Initiative: Its scientific, economic, and strategic dimensions

Proceedings of the conference sponsored by the Fusion Energy Foundation and the Schiller Institute

April 22–23, 1986, Tokyo, Japan

Full transcripts (including maps and graphics) of the Tokyo conference on the SDI are available from the FEF at $100 each.

JAPAN ANNOUNCES DECISION TO PARTICIPATE IN THE U.S. SDI

The cabinet of Japanese Prime Minister Yasuhiro Nakasone announced Sept. 9 its long-awaited decision for Japan's strategic agreement for government-to-government participation in the SDI. A key point of the agreement is the continued offer from the Reagan administration to the Soviets for joint and parallel development of beam weapons systems. The FEF made a crucial intervention into the debate, holding an April 22-23 conference in Tokyo on the strategic, economic, and scientific dimensions of the SDI. Cosponsored by the Schiller Institute, the conference was attended by 180 members of Japan's government and industrial elite. Transcripts are available from the FEF at $100.

NUCLEAR POWER INDUSTRY IN INDIA UNDER PRESSURE TO PERFORM

"Nuclear power is the only source of power available in the future, and we in India must not miss this new industrial revolution; for if we do, we are bound to lead ourselves to total economic disaster." With these words, Dr. Raja Ramanna, chairman of India's Atomic Energy Commission and secretary of the Department of Atomic Energy inaugurated the department's new regional center in Bangalore Sept. 10. India's plan is to generate 10 gigawatts, or 10 percent of total power, with nuclear energy by the year 2000, a goal that is "still too low," as Prime Minister Gandhi noted. Yet even this conservative program is under pressure, reports *Fusion Asia*'s Susan Maitra in New Delhi. The political fallout from Chernobyl has helped boost the antinuclear lobby, at the same time that there is growing impatience with the Department of Energy's inability to deliver results. Reaching the 10 percent goal depends on being able to design and commission the first two of a series of 500-megawatt reactors by 1995—and another two each year thereafter, in addition to installing one 235-megawatt reactor per year starting next year.

Atomic Energy Commission

The percentage of total power produced by nuclear energy has dropped from 3 percent to 2 percent in the past few years. Here, the switchyard for the Narora Atomic Power Station under construction in Uttar Pradesh.

SUPERCONDUCTING COILS SUCCESSFULLY TESTED AT OAK RIDGE

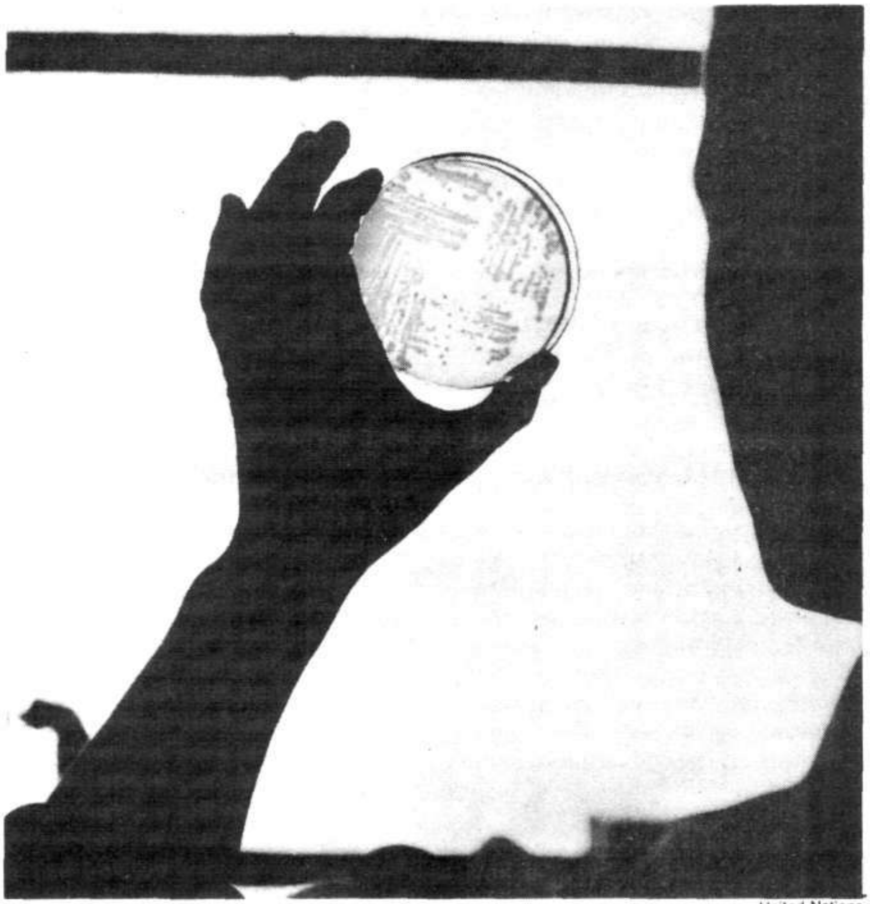
Full-scale testing of six 45-ton superconducting magnets is under way at the Oak Ridge National Laboratory, the Lab announced Aug. 18. Superconducting magnets permit production of the powerful magnetic fields necessary for tokamaks without consuming much energy. Dr. Lee Berry, associate director of the Oak Ridge Fusion Energy Division, told *Fusion* that each of the six coils was operated to full current and three-quarters of full field over the past several months. (Full field is nominally 8 tesla.) In August the six coils were operated together in a test mode, where five coils are used to provide a background field to the one tested. Three of the coils are U.S.-built and the other three were built in Japan, West Germany (for Euratom), and Switzerland. The coils are about one third to one half the size required for a working reactor.

DR. EUGEN WIERBICKI, FOOD IRRADIATION PIONEER, DIES

Dr. Eugen Wierbicki, a pioneer in food irradiation science, died June 29 of a heart attack at the age of 64 at his home in Pennlyn, Penna. Wierbicki devoted most of his life to the scientific research that would prove food irradiation a safe process for increasing the world food supply and making food more wholesome. A meat scientist with a good background in chemistry, Wierbicki came into the food irradiation program at the U.S. Army Natick Research and Development Command in Natick, Mass., in 1962. He took on the task—and succeeded—in figuring out how to produce a tasty, high-quality, radiation-sterilized meat of the sort that the NASA astronauts took with them during space missions.

LOUSEWORT LAURELS TO U.S. ENVIRONMENTAL PROTECTION AGENCY

This month's Lousewort Laurels award goes to the U.S. Environmental Protection Agency for its Sept. 25 action banning pesticide products that contain difocol in order to protect "the endangered peregrine falcon" from "DDT contamination." DDT is present in minute quantities in difocol products. Apparently, the EPA never read the extensive scientific testimony documenting that DDT never harmed the peregrine falcon or thinned its eggshells; the falcon was "endangered" long before the use of DDT by shooting, egg-collecting, and falconry. As *Fusion* readers know, DDT was banned by the EPA in 1972 for political reasons only, after seven months of hearings had established that there was no scientific reason to ban the effective, life-saving pesticide. The 1972 ban imposed by EPA director William Ruckelshaus, overrode the ruling of the EPA officer who had presided over the hearings. The ruling fattened the bankrolls of the antipesticide lobby by popularizing the environmentalist fairy-tales of thin shells and disappearing birds. In fact, according to the Audubon Society's own testimony, the bird population flourished during the 40 years that DDT was used to save human lives.


United Nations

New Animal Viruses Could Spread Diseases As Deadly As AIDS

by Dr. Hervé Fleury

Dr. Hervé Fleury, Professor of Virology at the University of Bordeaux in France, presented this assessment of new viruses that have animal reservoirs at a June 6-7 conference, "The Importance of the Method of Louis Pasteur for Fighting AIDS and Other Epidemics Today." The Paris conference was sponsored by the Fusion Energy Foundation of France. On the panel with Fleury was Dr. Mark Whiteside, co-director of the Institute for Tropical Medicine in Miami, Fla. Whiteside's speech, to which Fleury refers, pinpointed the collapse of living standards in tropical "insect belts" as a leading cofactor in the transmission of AIDS—far beyond the so-called high risk groups of homosexuals, hemophiliacs, and intravenous drug abusers.

On Aug. 23, at a meeting in Budapest of the 14th International Congress on Cancer, Prof. Jean-Claude Chermann of the Pasteur Institute announced that Institute researchers had isolated the AIDS virus from four different types of African insects—mosquitoes, cockroaches, tse-tse flies, and lion ants. Chermann told the press, "The fact that only the insects living in endemic areas are infected fits well with the epidemiology of AIDs which is different in the West than Africa. It could be possible, therefore, that insects are, in Africa, natural reservoirs of AIDs virus and they could be a possible means of contamination of the disease. . . ."

Marburg virus, Ebola virus, Lassa fever, and the Hantaan virus: Will these new viruses, with their animal reservoirs, be the next killers? Here a researcher at the National Institute for Medical Research in London examines a bacteria culture.

I would like to give you a presentation, on the one hand, on certain aspects of the LAV/HTLV-III virus [the AIDs virus] and, on the other, on certain viruses to whose existence I am going to alert you, without, I hope, alarming you.

I would like to make some comments on the importance of ecological research in virology. It is extremely important to develop ecological research, notably in the tropical zones. Ecology in the broad sense, because in fact we see that many human diseases have animal reservoirs, and these animal reservoirs are very poorly understood for many viruses. It is also necessary to demolish certain barriers, especially in our country, barriers which exist between microbiological research in medicine and veterinary microbiological research.

In effect, we see that some people work on animals and some work on people, and that there is ultimately no link between the two. I think that it is time to level these barriers, and create multidiscipline teams working along common lines.

The Issue of Viral Ecology

Viral ecology is extremely important for knowing the reservoirs of virus, and especially that of LAV/HTLV-III, because we do not always know its reservoir.

I want to give a short history of this virus. You know that LAV/HTLV-III was isolated both by a French team working under Professor Luc Montagnier, and by a team working with Professor Robert Gallo in the United States, among subjects infected with AIDS, after which they followed the thread of that virus and they realized that its cradle was indeed Central Africa. A very recent publication by a team directed by Dr. Namias, reported a seropositive result in a Zairean subject in 1959. Thus, this is perhaps a new idea, that LAV/HTLV-III had already made its appearance in the 1950s. But all the same, in terms of human evolution, this is not very old; rather, this is very recent!

LAV/HTLV-III is indeed the agent of AIDS, or in any case is associated with AIDS, if it must be completed by concurrent viral infections in order to develop into the disease, as we have just said [in an earlier panel], but we do see that there exist other viruses that are present. It is necessary therefore to speak of the isolation of LAV-II, by Montagnier, among hospitalized patients in Lisbon. This LAV-II is indeed very close to LAV, which would now be called LAV-I, in short LAV/HTLV-III.

It is necessary also to report the very recent isolation, by an American team directed by [Dr. Myron] Essex, in Boston, of HLTV-IV (this is a team which had worked in Senegal). Among patients who were not presenting AIDS, this team isolated a retrovirus, which is called HTLV-IV; this new virus is different from LAV/HTLV-III, and would be closer to a virus which we know among monkeys, called STLV-III. All the importance of ecological research, is to find out what the original reservoir of the virus is, which is probably an animal reservoir. It is perhaps the monkey, but in any case, nothing is proven at the moment.

What we can say, is that if we compare the genomes of these viruses, which have been identified by numerous teams, both American and French, we see that LAV/HTLV-III and related viruses, like LAV-II, HTLV-IV, and so forth, are closer to animal viruses—for example, STLV-III among monkeys, but these viruses are equally well known among sheep, for example, the Visna sheep virus, and the infectious anemia of horses. Thus it is probable that we will show, in years to come, that the virus, at a certain moment in its evolution, left the animal reservoir for the human, and then it evolved to become this LAV/HTLV-III which we know in the United States and Europe, and which is, if you like, the end of the thread, and evidently the end that is the most dangerous and most pathogenic.

Treating AIDS

We spoke just now of treatments linked to socioeconomic conditions. In fact, at the moment, the treatment of AIDS is not even tied to socioeconomic conditions, it is simply tied to a scientific problem: The treatments envisioned and used are, at this point, relatively ineffective. It is certain that people infected with AIDS, in a clinical phase, and who have undergone various chemotherapies that are available in this world, up to now have a percentage of mortality at three or four years, which is extremely important.

With LAV/HTLV-III, the virus is going to be able to integrate its genome into the cellular genome, and you cannot get rid of it.

Before passing quickly to a short list of viruses other than AIDS that we might encounter in tropical zones and which are of interest to us in temperate zones, I want to remind you what the present therapeutic approaches to AIDS are.

First, it is necessary to point out that LAV/HTLV-III is a virus with an extremely "twisted" molecular plan; that is to say, it is capable of integrating its genome into the genomes of the lymphocytes. That is something terrible, because normally, when dealing with an acute viral infection, you have a multiplication of the virus which destroys the cells, and after that, you rid yourself of it, and you die or you live, but the virus is gone. But with LAV/HTLV-III, thanks to an enzyme we call reverse transcriptase, the virus is going to be able to integrate its genome into the cellular genome, and you cannot get rid of it. This is one of the greatest problems.

What, then, are the therapeutic approaches? In fact, there are two.

The first consists of blocking the multiplication of the virus in the lymphocytes. We know very well that we will not be able to get rid of the virus. We block its multiplication, but the patient remains a carrier of the virus, and if you stop treating the patient with antiviral substances, the virus begins to multiply again, and you have a relapse.

The second approach consists in boosting the immune defenses. One of these, which has been developed in certain hospitals in France, notably in Paris, is to block the multiplication of the virus with a substance you have all heard of, HPR23, and then grafting the lymphocytes of subjects from a related histocompatible donor with the patient's tissue.

These are methods which are very cumbersome, very expensive of course, but which until now have not achieved considerable success, and I think that, if tomorrow morning we found ourselves confronted by a very important AIDS epidemic, we would be disarmed regardless of our socioeconomic conditions.

As for the vaccination approach, what research has been undertaken? The approaches are on several levels. In particular, we are trying to discover the protein in LAV/HTLV-III which, when injected into patients, will be able to bring on the existence of neutralizing antibodies, antibodies which will impede the presence of the virus, which will neutralize it before it has infected the lymphocyte cells.

It seems that one of the proteins, which we call in biological jargon GP110, may perhaps be suitable for the fabrication of neutralizing antibodies. The American team under Gallo has recently cloned this protein—that is, it has purified the gene of this protein, integrated in a virus of the vaccine, and they thus have a vaccine virus capable, when it multiplies inside the cells, of causing the protein GP110 to be expressed, and thereby creating an immune response, an anti-GP110 antibody.

This is a preventive approach which could be extremely interesting, but which could also be limited, because when you work with the protein GP110 of LAV/HTLV-III, you have to be very sure that the protein is common to all the branches now in circulation that are related, like LAV-II, HTLV-IV, and so forth.

Others teams envision the preparation of polyvalent vaccines and to vaccinate with surface proteins from all these branches to be able to be sure of inducing a polyvalent immune response. At the moment, we are still far—probably by several more years—from using a preventive vaccine for AIDS.

To finish this brief presentation, I want to speak to you of four viruses which are present in the tropical zones, which could—certainly for some of them—have a worldwide distribution far from their place of origin.

We are still far—probably by several more years—from using a preventive vaccine for AIDS.

Linda Ray

Animals provide a reservoir of deadly viruses that can, over time, jump to a human host. AIDS-related viruses are close to the STLV-III virus in monkeys and the Visna sheep virus.

The Marburg Virus

I want to relate to you the famous incident in Marburg in 1968: In a very well-known biological institute in West Germany, the Behring Institute, some virologists had suddenly come down with a new pathology, a hemorrhagic fever. Some died, and at exactly the same time, in Zagreb, Yugoslavia, also in a virology lab, people came down with a pathology equally hemorrhagic and febrile, with deaths. They isolated a virus no one knew about, and it was called the Marburg virus. This virus, for another reason, was not very appreciated at the Behring Institute in Marburg: They thought it had created very unfavorable publicity.

In the two cases, it was seen that the virologists had been contaminated at the time they were working with monkeys coming from Uganda. When you work in virology, you make many cell cultures, and in that period people were using many cell cultures coming from monkeys; we were especially using the kidneys of the monkeys, and it was when the virologists cultured the monkey kidneys that they were contaminated by the virus carried by these monkeys.

So here is a disease which appeared in Europe, but which we quickly realized was present in Africa and whose origin was African. Between 1975 and 1980, cases of the Marburg disease were found in Africa.

The Ebola Virus

In 1976, another disease appeared simultaneously in Zaire and Sudan, a disease linked to the Ebola virus, very close to the Marburg virus in its morphology, but completely different in its antigenic action. This disease was dramatic, because, in the cases counted in hospitals, in both Sudan and Zaire, the mortality rate was on the order of 96 percent. Thus, these diseases were irreversible as far as mortality goes.

Now we know that these viruses, and especially the Ebola virus, are present in Africa, that they circulate, they affect man, without creating the brutal epidemics that were noted in 1976.

These epidemics were due to errors in the hospitals. It was a disease which no one knew, but the patients were hospitalized in the worst hospital conditions and transmission from man to man occurred very rapidly, especially by the intermediary of unsterilized dirty needles. This is how these major infections occurred in hospitals, with such high mortality rates.

When serological studies were done, it was discovered that these viruses circulate very widely in Africa, and the World Health Organization was extremely uneasy, because it was not to be excluded that brutal epidemics, linked to the famous Ebola virus, would one day appear in the tropical zones.

This Ebola virus interested many people at the Centers for Disease Control in Atlanta, who are specialists, particularly in the laboratory of the Special Pathogens Branch, because at the time, the reservoir for the virus had not been identified. Research was done. It was thought that the reservoir was monkeys, as for the Marburg virus. I say Marburg virus, because it was concluded that in Europe it had infected people by spreading from the green monkey, but after this original contamination, we have not shown that the monkeys are carriers of the Marburg virus or the Ebola virus. We have researched rodents, but never found the reservoir of these viruses.

And, when we do not know a reservoir for a virus, obviously, we cannot take measures to prevent it.

Lassa Fever

I shall speak next about Lassa fever. In 1969, three American nuns who worked in Nigeria, presented a pathology that was both hemorrhagic and febrile; two died very rapidly, and the third was evacuated to the United States—and there, a new virus was isolated, which was called the Lassa fever virus. This virus is endemic in Nigeria, Sierra Leone, and Liberia, and it was shown through serological studies that the virus was to be found in a large number of countries in Central and West Africa.

The rate of mortality which has been described in the epidemics of Lassa fever in Nigeria was on the order of 70 percent in hospital wards.

In this case, the reservoir is very well known: It is a rat, which is the chronic carrier of the virus—in other words, the rat lives with the virus and passes it in its urine. Subjects who live under bad conditions in contact with the rodents, close to the soil, become infected by the virus by way of the respiratory system, through aerosols.

The Hantaan Virus

We mention finally the last virus, the virus named for Hantaan, which is a river in South Korea. It is very interesting, because it has a truly global distribution, probably proceeding from a tropical country. It appeared in the years 1950-1953, and struck American soldiers who were engaged in military operations in Korea. Twenty-five hundred cases were diagnosed, which were called Korean hemorrhagic fever; it was characterized by a hemorrhagic fever and a brutal renal insufficiency. The American scientists, in looking at hospital records from Vladivostok, noticed that this disease had already been described as early as 1916 in Russia. It was not a new disease. In fact, it was described several hundred years ago in China.

Then, in 1978, a South Korean researcher identified a virus responsible for this disease. What was very interesting, was that it had been noticed that in clinical cases of the same epidemic infection, it was characterized by a brutal, acute renal insufficiency, manifesting itself also in Scandinavia, Eastern Europe, and even in France where we uncovered some cases two or three years ago. It was noticed in studying the antibodies against the virus, that they were found all over the world, in Southeast Asia as well as Africa, North America, and Europe—all over the world. We have recently had the opportunity to demonstrate that antibodies against the virus of the Hantaan fever exist in the Caribbean.

In the case of this disease, the animal reservoir is known. It is the field mouse, and an American team from New Orleans has shown that rats carry the antibodies. We can very well imagine that, starting from a burrow in Asia, the disease spread by the intermediary of shipboard rats, which then infected their same species in ports. You have then a disease that was probably tropical at the outset, which has generalized itself throughout the world.

That is what I wanted to tell you, to make you aware of the problems of viral diseases, the viral ecology, and the problem of virus reservoirs, in finding out that many human diseases, in fact, find their solutions in the discovery of their animal reservoirs.

China's Move to Food Irradiation

by Lothar H. Wedekind

The author is editor of the International Atomic Energy Agency (IAEA) Bulletin, *and served as press officer at a Shanghai seminar on food irradiation sponsored by the IAEA and Food and Agriculture Organization in April 1986.*

More than a thousand years ago, during the Tang Dynasty, the beautiful Queen Yang may have set the tone for Chinese determination to overcome problems of food supply. History teaches that she ordered teams of riders on horseback to deliver fresh lychee from southern Fujian where the fruit was grown to northern Xian where it was in high demand, a distance of about 2,000 kilometers. With a racehorse distribution chain of riders galloping day and night, the goods reportedly were delivered in just about three days.

China has historically fought to balance food supplies and demands, and regional shortages resulting from natural and other causes remain a serious concern. Though the world's most populous country, China only has about one-fifteenth of the Earth's arable land. The nation can ill afford food waste, or to ignore potential weapons against it.

Increasing food production alone may not be the answer for China, or for other developing states. Pressures on food supplies will heighten in developing nations as the overall population is expected to grow by 45 percent over the next 15 years, notes the Food and Agriculture Organization (FAO); yet already nearly three of every four people in the Third World live in countries short of productive land.

Not surprisingly, given the needs and outlook, many developing countries are taking the lead in moving to promote commercialization of food irradiation. Although the preservation process, like others, is not practical or effective for all goods, irradiation has proved it can safely and effectively help extend supplies by prolonging storage times and reducing losses to spoilage and waste of specific food items.

In the bustling port of Shanghai, home of 12 million people and long the heart of China's industrial and commercial progress, the table is being set.

In January 1986, the first of five regional irradiation facilities planned in the country mainly for food processing officially opened in Shanghai. Irradiated potatoes, mushrooms, rice, onions, garlic, peanuts, pork sausage and, soon, apples will be introduced in mass marketing trials as part of economic feasibility tests.

One trial run in late 1985 of 25 tons of labeled irradiated apples sold out in less than two days, even though they were treated to hold for months in storage, reports Cao Xue Xin, an engineer at Shanghai's Science and Technology Commission who is involved in the project. Marketing research has become integral to steps being taken in China to help determine commercial viability and consumer acceptance of irradiated foods.

"It is very important to develop food irradiation . . . and, in a word, we are actively and carefully heading toward commercialization," says Zhou Ping, vice chairman of the Chinese State Council's Leading Group on Nuclear Power, a body of senior policymakers who set the country's priorities in nuclear and related fields.

Although no one is reported to be going hungry in China, food security, seasonal shortages, and the nutritional quality of the Chinese diet are topics drawing acute attention, according to Lu Liangshu, director of the Chinese Academy of Agricultural Science. Under the country's modernization drive, food irradiation is being promoted as a tool that fits.

Rapid Development Planned

Zhou and other Chinese officials outlined China's past and future directions at an April 1986 international food irradiation seminar in Shanghai, sponsored by the FAO and IAEA. The meeting was attended by about 170 participants from China and 22 other countries, primarily from the Asian and Pacific region where activities are accelerating to promote technology-transfer, governmental and consumer acceptance, and regulatory harmony in the field. Three food irradiation plants currently are operating in the region and 14 more are planned over the next five years.

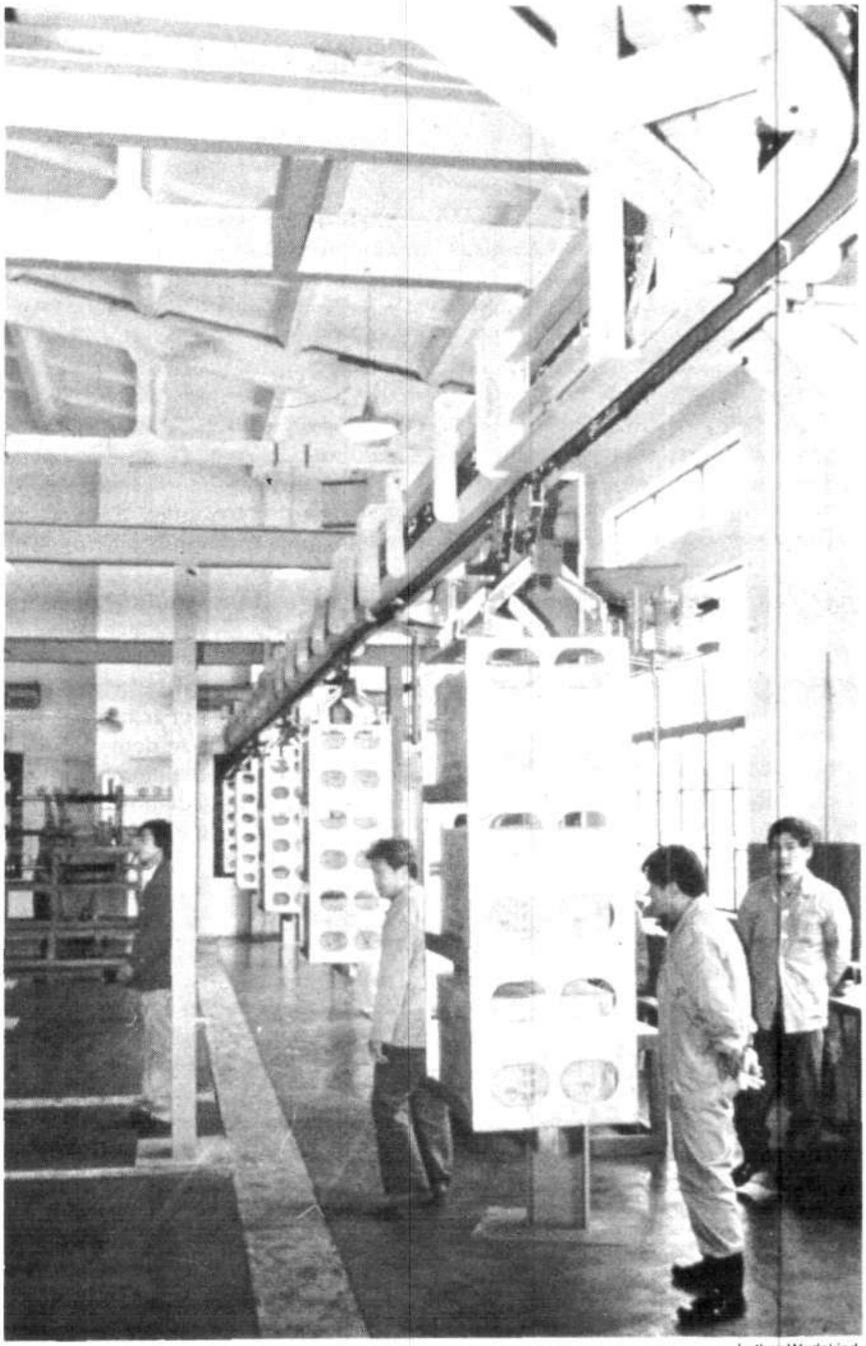
If current plans hold in China, the nation will emerge as far more than the regional leader in demonstrating food irradiation's potential.

Besides the Shanghai facility, four other commercial-size demonstration plants are reported being built, primarily for food irradiation near provincial capitals: Chengdu in the southwest, Zhengzhou in the north, Nanjing near the eastern coast, and Lanzhou in the Chinese interior. Operations are expected to start at all four within the year.

Additionally, other irradiation facilities—near Beijing, Jinan, Tianjin, and the Shanzhen Economic Zone near Hong Kong—are reported under construction as "multipurpose" plants that will mainly sterilize medical supplies but process some foods and other products as well.

Major objectives at facilities over the next four years will be to "smooth the path" toward commercial applications of specific foods by testing irradiation's economic competitiveness under local market conditions, Wu Jiaxiang of the State Science and Technology Commission's department of High Technology reported at the seminar.

How fast food irradiation develops commercially in China, as elsewhere, is largely a question of economics. One analysis done at the university of Beijing found that it is not yet economically competitive nationwide, primarily because of "considerable" transportation costs stemming from a lagging distribution system. At the local



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Racks of boxed apples move automatically to the irradiation chamber at Shanghai's food irradiation plant.

level, the picture is otherwise: In Shanghai, for instance, the trial marketing run of irradiated apples showed that "significant economic gains" can be expected, Cao reported.

To compensate for infrastructural shortcomings, China is following a pragmatic approach to commercialization. As reported at the seminar, the strategy is to design and build irradiation plants flexible enough to adapt to local market conditions and located near good transportation links. Most cities planning food irradiation plants are either major transportation centers or situated near important Chinese agricultural areas.

Local Realities: Specific Needs

At the FAO/IAEA seminar, Zhou Ping of the State Council reported that the country continues to suffer high food losses, up to 30 percent for some commodities, primarily because of preservation and storage problems.

Other food preservation methods are practiced, but not all are well advanced. Refrigeration clearly remains too expensive for China, as for most developing nations, to institute on a wide scale. Chemical fumigation, which right now is reported as less expensive to use in the country than food irradiation, is applied on rice, grains, and other foods. But there is growing concern over pollution and potential health effects, as well as over barriers that chemically treated products for export increasingly must overcome in international food trade, says Prof. Wu Jilan of the University of Beijing. Food exports are potential candidates for food irradiation, and research has been done on vegetables, seafood, and spices, such as red peppers popularly used in Szechuan cooking.

At the local and regional level, food supply problems crystallize: Serious regional shortages hurt local economies and keep many fruits and vegetables out of Chinese homes much of the year, restricting consumer diets, seminar participants reported. Cao, of the Shanghai Science and Technology Commission, offered a proverbial description of his city's vegetable market, both from the standpoint of suppliers and consumers: "Spoil in the harvest seasons, short in the off seasons. Worry when piling up, hasty when running short."

A recent market survey found that 10 to 20 percent of vegetables spoil every year at an estimated cost of "tens of millions of yuan," or upwards of U.S. $3 million. Fruits fare as badly, with those lost in transport and storage annually amounting to more than 28,000 tons valued at 12 million yuan, or roughly U.S. $4 million.

Interest in food irradiation's benefits primarily is tied to such conditions. By using gamma waves to reduce or eliminate pathogens and food-spoiling microorganisms, the country aims to prolong storage times so that localities can better control distribution to help them override seasonal shortages and stabilize food supplies.

High Technological Investment

The Shanghai irradiation center,

which opened in January 1986 and is run by the Shanghai Nuclear Research Institute, plans to process up to 35,000 tons of vegetables a year, or about 45 percent of the city's annual supply, as well as some spices, fruits, and nonfood products. Working with the Shanghai Vegetable Company, a primary role will be to "stimulate commercialization" in the area, reported Cao Xue Xin of the city's Science and Technology Commission.

Built in 18 months, the facility is a Chinese design stocked with domestically produced cobalt-60 rods; source capacity is 500,000 curies. With the exception of Canadian and Swiss participation in two of the country's facilities, other irradiators also will bear the "Made in China" label in both design and major components. The chief designer is the Institute of Nuclear Engineering in Beijing.

Chinese scientists and engineers have been studying food irradiation at small irradiators built throughout the country since 1958, but it was not until the end of the Cultural Revolution in 1976 that activity intensified. Today about 100 small research irradiators are reported to be operating to support research in various fields, and more than U.S. $10 million has been invested in food irradiation's development over the past 10 years, estimates Wu of the University of Beijing.

Today, no less than six national bodies are directly involved in various facets of food irradiation's development: the State Science and Technology Commission (policy, regulation), the State Economic Commission (marketing, licensing), the Chinese Academy of Sciences (research), the Ministry of Agriculture, Husbandry, and Fishery (research support), the Ministry of Public Health (food safety, clearances), and the Ministry of Nuclear Industry (operations).

So far, the Ministry of Public Health has approved seven irradiated foods as safe for human diets: rice, potatoes, onions, garlic, peanuts, mushrooms, and pork sausage; approval number eight, for apples, is expected shortly. Persuasive in the actions were assurances of safety from international food and health authorities, namely the Codex Alimentarius Commission of the FAO and World Health Organization (WHO), and the country's own nutritional and safety studies. China's studies included eight tests of volunteer medical students and citizens who ate irradiated potatoes, rice, pork sausages, mushrooms, and other vegetables over periods of two to four months. The tests concluded "there were no harmful effects at all after consumption of irradiated foods," Dai Yin of China's Institute of Food Safety, Control, and Inspection reported at the FAO/IAEA seminar.

All told, more than 25 separate foods now are seen as potential candidates for food irradiation processing, including fish, bamboo shoots, cauliflower, carrots, dried dates, strawberries, and oranges.

Growth Paths and Prospects

Despite their country's own long experience, Chinese officials at the Shanghai meeting stressed their openness to foreign participation and cooperation in food irradiation's development. "China has a good will to cooperate with other Third World countries and developed countries in the design and construction of irradiation facilities, communication of science and technology, training, and technical service," Gu Junren of Beijing's Institute of Nuclear Engineering reported at the FAO/IAEA seminar.

On hand to hear the message were representatives from American, Canadian, Dutch, French, and German irradiation firms who are interested in the Chinese market.

Just how far China's plans are carried in years ahead will be important to food irradiation's commercial future. If the fast-growing national economy can sustain the current and projected pace for irradiation's local and regional commercialization, China clearly will be leading the way in using gamma waves to preserve food. In the process, obstacles still hampering the technology's worldwide development may be easier for other countries to overcome.

At the Shanghai seminar, a panel of experts from Australia, New Zealand, Japan, Bangladesh, India, Thailand, and China summarized five major barriers to progress: a lack of commitment and investment from the food industry; absence of approval for the use of ionizing energy as a food process by most governments; uncertainty about consumer reaction; limited information on the economic feasibility of the process on a commercial scale; and insufficient experience on how the process may be controlled and regulated commercially, particularly for purposes of trade.

Countries were urged to take steps to implement legislative recommendations of the international Codex Alimentarius Commission as part of steps to harmonize regulations, to conduct market and economic studies to stimulate wider interest in food industries, and to establish and document good manufacturing practices, strict hygienic standards, and satisfactory processing controls. The Codex Commission has established a recommended General Standard for Irradiated Foods and an associated Code of Practice for facility operations.

To address and help solve problems more specifically related to trade, the FAO, WHO, and IAEA have formed an International Consultative Group on Food Irradiation composed of experts nominated by 23 governments. The group's major work is directed at trade promotion, training, economic feasibility studies, and public and consumer information.

In the future, national and international organizations, food industries, trade associations, and consumer organizations all will have an important role to play in introducing this new technology on a commercial scale in many countries. In particular, actions in Canada, France, Italy, Netherlands, the United Kingdom, the United States, and other industrialized countries in which food irradiation is drawing more notice are important to progress, especially concerning legislative acceptance and industrial interest. Recent positive signs for the technology's wider acceptance and commercialization will be instrumental to technology-transfer activities in the developing world directed at alleviating food losses and extending supplies to combat hunger and stimulate economic development.

Worldwide, as of 1985, there were 24 commercial irradiation facilities in 11 countries that treat food as at least part of their throughput, according to the IAEA. By 1990, the number of irradiation facilities for foodstuffs is expected to surpass 50, with operations spread among 17 countries.

Research and demonstration over the past three decades have long established the merits and safety of food irradiation as a technology holding important benefits for food producers and consumers alike. With an increasing number of commercial and demonstration irradiators becoming available to process a variety of foods, even more evidence is in the making.

International Cooperation

China is poised to become a more active participant in international efforts for food irradiation's develop-

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A Shanghai display promoting food irradiation.

ment. At the Shanghai seminar, Zhou Ping, vice chairman of the Chinese State Council's Leading Group on Nuclear Power, announced that the country has decided to join the joint FAO/IAEA Asian Regional Cooperative Project on Food Irradiation (RPFI).

Under the project, countries in Asia and Pacific have banded together to address issues related to marketing and trade of irradiated foods. They have agreed to assist and evaluate shipping trials of irradiated foods and to actively promote adoption of regulations that would provide legislative harmony. RPFI member countries are Australia, Bangladesh, India, Indonesia, the Republic of Korea, Malaysia, Pakistan, the Philippines, Thailand, and Vietnam, all of which sent experts to the Shanghai seminar. The project's overall objectives emphasize the transfer of technology to local industries and the coordination of research and pilot-scale studies on selected products of particular interest to the region.

Based on these developments and others, it is reasonable to expect that more countries in the Asia and Pacific region will be using food irradiation in years ahead to combat high rates of food losses and improve the quality of certain foods. Postharvest food losses in the region remain high—estimated at 30 percent for grains, between 20 and 40 percent for fruits and vegetables, and up to 50 percent for fish—and there is growing recognition of potential health and economic benefits arising from their reduction.

Most countries in tropical regions are major producers of fruits and vegetables, yet face serious problems of insect infestation. Treatment with ionizing energy is seen as a way of meeting quarantine requirements of international trade so that export markets can be expanded, especially in view of increasing limitations associated with the use of chemical fumigants.

Currently, Japan is the only country in the region with a commercial-scale food irradiator and it has been successfully marketing irradiated potatoes since 1974. In addition to China, other countries moving to construct irradiators in the region are Australia, Bangladesh, the Republic of Korea, Malaysia, Pakistan, the Philippines, and Thailand.

An Interview with Dr. Martin Welt

Exporting Food Irradiation Plants

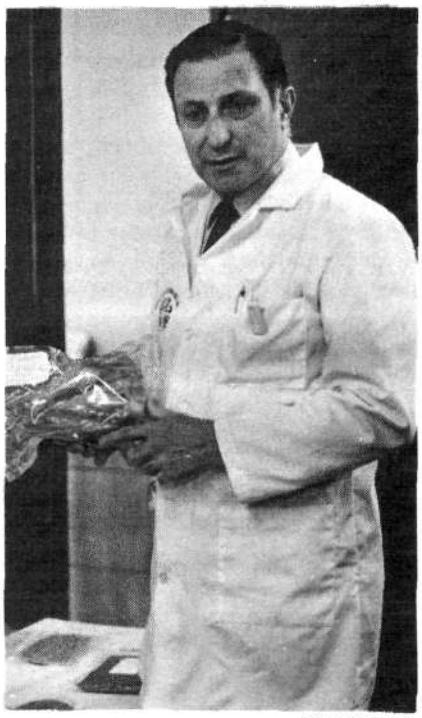
Dr. Martin Welt, founder of Radiation Technology, Inc. in New Jersey, has led the fight for U.S. commercialization of food irradiation for more than 20 years. Welt is now affiliated with Alpha Omega Technology, Inc. in Morris Plains, N.J.

Under his leadership, Radiation Technology successfully petitioned the Food and Drug Administration to permit up to 1 megarad of irradiation processing for spices, enzymes and herbs and 100 kilorads for fresh pork (for trichina control).

A new FDA regulation is expected soon, in response to a Radiation Technology petition, to permit high-dose radiation to sterilize foods. Radiation sterilization, the same process that is used to prepare the food the astronauts eat in space, allows food to be kept indefinitely without freezing or refrigeration. Welt sees this as a real boon not only to U.S. farmers, but to the developing sector, which could process available crops and meats and store them at less than one-fourth the cost of canning.

Radiation Technology's Salem, N.J., plant is the most modern food irradiation facility in the world. Another plant is being built in Elizabeth, N.J., where a federal judge ruled Aug. 12 on behalf of Radiation Technology that a local ordinance declaring the area a "nuclear free zone" was unconstitutional.

Here are excerpts from an interview with Welt Aug. 2 by managing editor Marjorie Mazel Hecht.



Stuart K. Lewis

Dr. Martin Welt holds an irradiation-sterilized chicken in a sealed pouch. The chicken will stay fresh and tasty indefinitely without refrigeration.

Question: Your company is one of the few in the world that is exporting food irradiation plants. What is the total investment cost for building a large-scale plant in West Africa, for example?

To build a very versatile pallet irradiator, like Radiation Technology's Model RT 4101, would take an investment of probably about \$4.5 million, depending on the amount of cobalt put into the facility. Most of the initial work in a plant in West Africa, for example, would be for relatively low-dose application, requiring a relatively low amount of cobalt; you could probably have the entire turnkey operation, including money set aside for a warehouse, land acquisition, and site preparation, for approximately \$4.5 million. If the same site were built in the United States, it might be less, but shipping costs and other contingencies might move the cost up to \$5 million.

Question: How long would it take to build the plant?

Once a site has been chosen and all the permits are obtained, you could figure approximately 12 to 14 months

Radiation Technology's Model 4101 can irradiate up to 2,500 pounds of food per minute. Here, a pallet load of spices moves automatically on a conveyor belt to the irradiation source at the Salem, N.J., plant. Inset is the computer used to control the positioning of the pallet from the radiation source.

Tony VanZwaren

to get it into operation. That is a little bit longer than in the United States.

Hopefully, we would be dealing with a nation that had a vested interest in getting the permits and everything else done. In some countries, we have to get special permits for bringing in even steel, since they want as much as they can to be indigenous. If the government gets behind the project, then they will give you exemptions, so you can bring in whatever is needed to get the project done.

We have done several firm proposals for West Africa, but building the first plant will tell a lot. One of the advantages is that during the last four or five months of construction we would bring over four or five people who would be trained to supervise the operations and we would train them in our plant in Salem, N.J., so that by the time the plant was built in West Africa, they would be able to go back and operate it.

Their plant would be a mirror image of what we have in Salem, the computer, the entire system. This is a big advantage, because very often when you build a plant, it is basically doing nothing for four or five months while you are training your staff. This way they can get into operation immediately.

Question: What will the West African countries be processing?

We are doing a lot of exploratory work now on some of their indigenous crops, and we had excellent results. For example, on the yams, you could see how the tubers were able to be maintained in very good condition with good starch to sugar ratio. The unirradiated yams started sprouting like the potato food crops do, and the product deteriorates as the starches are converted to sugar and the value of the product is lost. . . .

The facility I designed and which Radiation Technology now operates is the only irradiation facility in the world capable of irradiating pallet loads of food at the rate of up to 2,500 pounds per minute. Yet, it will permit the country, or user, to do any type of irradiation—sterilize food at very high doses or irradiate yams at very, very low levels—because the computer-controlled system allows the pallet to be positioned at some distance from the source so that you can develop either low dose rate or high dose rate processing and be able to get through the irradiation chamber with the required dose rate. . . .

This is a big advantage, because the other systems in the world today, by and large, only allow the product to go in one path by the source, at one distance, which means that the only way you can control the dose to the product is by adding or removing cobalt to the source. . . .

Question: Could the irradiation plant also be used to provide fresh water?

Basically, if you are going to provide people with food, you also have to contemplate maintaining their health. And one of their biggest problems is dysentery—these countries have sewage all over the place, human as well as animal. It is one of the things in my view that could be solved without a huge expenditure of money—just education and rather simple devices.

Irradiation facilities can also serve to purify water by irradiating it while the plant is doing something else, because so much radiation simply bypasses the target. You can intercept the leakage radiation with a pipe with water flowing at the proper rates, and you can purify the water supply without using chlorination. . . .

We have taken the 4101 design and modified it for this purpose. You can simply put helical pipes, carrying water at a relatively low flow rate, going either above or below the conveyors that carry the pallets of food being processed. The water has to circulate until any unit volume of water gets a sufficient dose to give reasonable assurance that the water is going to be free of contamination.

Most of the contamination is due to coliform bacteria, and fortunately these organisms are extremely sensitive to radiation. . . . With just one-tenth of a megarad of radiation, you can reduce the original bacteria population by a factor of 10^{-10}. So it doesn't take very much radiation to knock out the coliform. . . .

Question: Has there been any consideration of irradiating fish in Africa? The coastal countries certainly have an enormous source of protein in fish.

We have talked to them about fish and of course they are interested. We try to encourage them to locate the plants in coastal ports so that not only would they develop the fish for their own use, but also for export. However, the food-producing areas tend to be in the central parts of these West African nations, away from the coast.

Their thinking now is to take care of the grain-producing areas or the root crops. If that is successful, then they would build a second plant on the coast. We are trying to encourage them to confederate somewhat, so that several smaller nations could make use of this. We've proposed to use the first plant we build as a training station for other African nations and are hoping to have that funded.

Question: What about the idea of a floating nuclear irradiator that could be moved around the coast from country to country?

Of course. The Russians supposedly have a fisheries irradiator at sea on some sort of a mother-ship-type of thing. The United States had one years ago, a barge-mounted type of affair, actually used by the Icelanders under some contract with the U.S. Atomic Energy Commission back in the 1960s. (That mobile irradiator, by the way, ended up lost somewhere out in California and the Israelis found it and purchased it and shipped it off to Israel. . . .)

Question: Could your plant design fit on a big barge?

Sure. The best results with shelf-life extension of fresh seafood occur if you can irradiate the seafood very soon after you catch it, and the way to do that is to do it at sea.

These are all feasible things and I believe in the future, if these countries take their resources and put them in the right place, the machines will basically be available to do that. In harvesting fresh fish, you gut it, ice it, and it goes down a conveyor line. You can design a materials handling system which would lend itself very nicely to running under either a bremsstrahlung X-ray type beam or an electron beam. . . .

The designs for ship-mounted irradiators exist; a lot of the design work goes back to the 1960s. In the Atoms for Peace days, we were thinking bigger than today, and perhaps rightfully so. What's happening now in the United States, unfortunately, is that, with our bent on overregulation we've basically destroyed the nuclear industry. . . . I can't believe that the nation that was so instrumental in getting nuclear power going and licensing our technology overseas, is now seeing foreign governments become so smart that they can do things much better than we! You know we haven't had any new reactor sales since 1978.

The food irradiation program has made some progress, but we haven't really gotten into the market place.

Ion Exchange Gives Glass Laser Big Power Boost

by David Cherry

An ion exchange process developed at the University of Rochester so toughens the glass for glass lasers that the power may now be increased 600 percent without cracking it.

Rochester scientists say this is "the most significant development in glass laser technology in years," and makes the glass laser suitable for "high average power" applications.

Immediate performance improvements in lasers used in industrial machining, surgery, and other fields are expected. In the fusion field, the tougher glass will improve performance once laser fusion is commercialized.

The ion exchange technique for improving glass as a lasing medium may also be applicable to the toughening of laser optics made of glass, a problem faced by designers of the Strategic Defense Initiative (SDI).

Dr. Kathleen A. Cerqua of the university's Laboratory for Laser Energetics directed the work, with the collaboration of Dr. Stephen D. Jacobs. Cerqua and Dr. Ansgar Schmid, another of the scientists involved, told *Fusion* that the strengthened, neodymium-doped phosphate laser glass could tolerate thermal shocks five times greater than the same glass without the strengthening process.

Glass samples heated to about 320°C were plunged into ice water of 5-7°C, without fracturing. Untreated samples would fracture if heated to only 58°C before plunging into ice water.

The stronger glass permits higher laser power, more frequent pulses, or some of both.

How It Works

Phosphate laser glass is composed mainly of PO_4 (phosphorous oxide) tetrahedra. Unlike common silicate glass, in which SiO_4 (silicon oxide) tetrahedra bond exclusively to each other to form the molecular network of the glass, PO_4 tetrahedra can bond only to three—instead of four—like structures. So compounds such as Al_2O_3, BaO, and Li_2O (aluminum, barium, and lithium oxides) are added to the recipe to achieve better closure of the network.

Polishing produces micron-sized cracks in the surface of the glass. When used for lasing, heat stresses the glass and causes the surface cracks to propagate. The ion exchange process anticipates the problem and produces a countervailing compressive stress in the surface of the glass to a depth of 60 microns—the thickness of a sheet of paper—more than the depth of the surface cracks. The lithium ions included in the molecular network to achieve closure are the key to the ion exchange.

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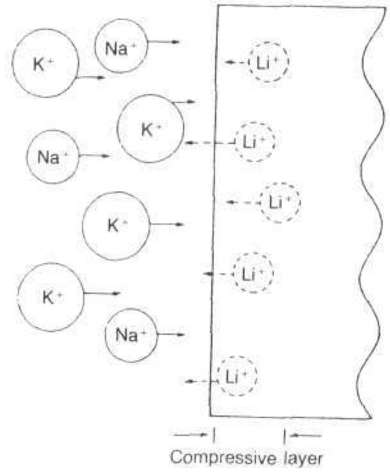
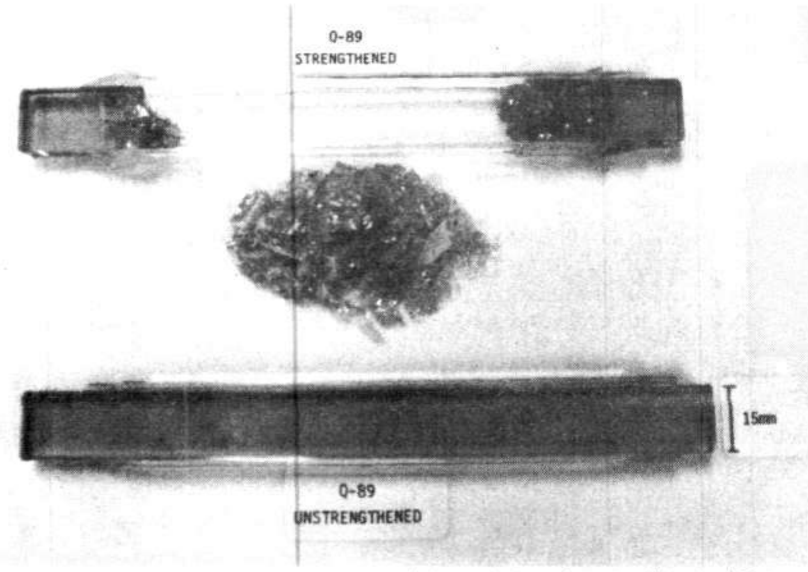


ION EXCHANGE IN PHOSPHATE LASER GLASS

Mobile lithium ions (Li^+) diffuse out of the glass, leaving vacancies behind. Large sodium and potassium ions (Na^+, K^+) preferentially diffuse from the bath into the small Li^+ vacancies, creating a compressive layer on the glass surface.



Laboratory for Laser Energetics, University of Rochester

Phosphate laser glass after testing in the laser. Below: the unstrengthened glass suffered a single crack running the length of the slab. Above: The total disintegration of the strengthened glass into many small particles indicates the extreme level of energy the sample absorbed prior to fracture. Fracture did not occur until the flashlamp stimulating laser emission in the glass was increased to six times the power that cracked the unstrengthened glass.

THE PRINCETON BREAKTHROUGH

Will We Have Fusion Power

Princeton's TFTR tokamak will reach scientific breakeven next year—but without breaking through the budgetary constraints to implement the 1980 fusion legislation, the U.S. fusion program still won't reach commercialization in our lifetime.

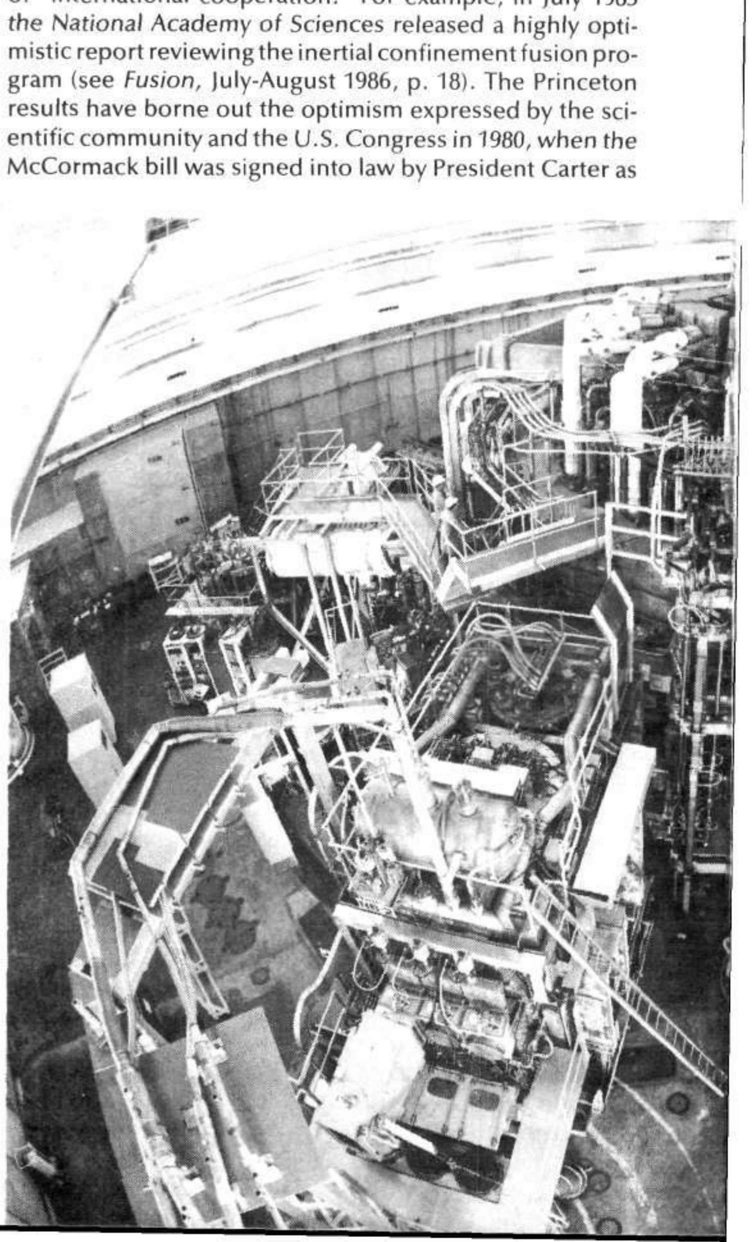
by Carol White

The Princeton Plasma Physics Laboratory announced results in August that have jolted the physics community: The Tokamak Fusion Test Reactor (TFTR) has exceeded all expectations in its performance, to achieve a plasma temperature of 200 million degrees Celsius. This is 10 times hotter than the temperature at the center of the Sun, and the highest temperature ever recorded in a laboratory.

In the first wave of enthusiasm following the announcement of the Princeton results, Department of Energy spokesmen appeared so carried away that they temporarily forgot the restraints of the Gramm-Rudman amendment. Thus, Energy Secretary John S. Herrington remarked: "The temperature achieved is in the range required for a fusion reactor. These promising results bring us closer to the goal of fusion energy." Dr. John Clarke, director of the Department of Energy's Office of Fusion Energy went even further, telling the press that we can have a practical fusion power reactor within 15 years. Since then, however, Clarke has scaled down his optimism to the size of his budget.

Scientists have known of the possibilities of fusion power even before they determined those of the fission process. Since the beginning of the atomic age they have been captivated by the notion of creating a star within a laboratory by replicating the process by which the Sun produces energy. While fusion energy, with its fuel "mined" from seawater, will greatly cheapen the cost of energy, it is not as a source of cheap and efficient power that we will come to value it, but as the harbinger of a new age. With fusion power the alchemists' dream will come true; not only will we be able to transmute lead into gold—but we will be able to create new materials at will. At the same time, the process of production will be so transformed as to be unrecognizable.

This TFTR result, along with others of similar quality—if less dramatic—reported on in this issue, merely corroborate our assertion that the only hindrances to deploying fusion energy as a power source by the turn of the century are those imposed by budgetary constraints (see Figure 1) and a policy of holding back the U.S. program in the name of "international cooperation." For example, in July 1985 the National Academy of Sciences released a highly optimistic report reviewing the inertial confinement fusion program (see *Fusion*, July-August 1986, p. 18). The Princeton results have borne out the optimism expressed by the scientific community and the U.S. Congress in 1980, when the McCormack bill was signed into law by President Carter as



A view from the top of Princeton's TFTR.

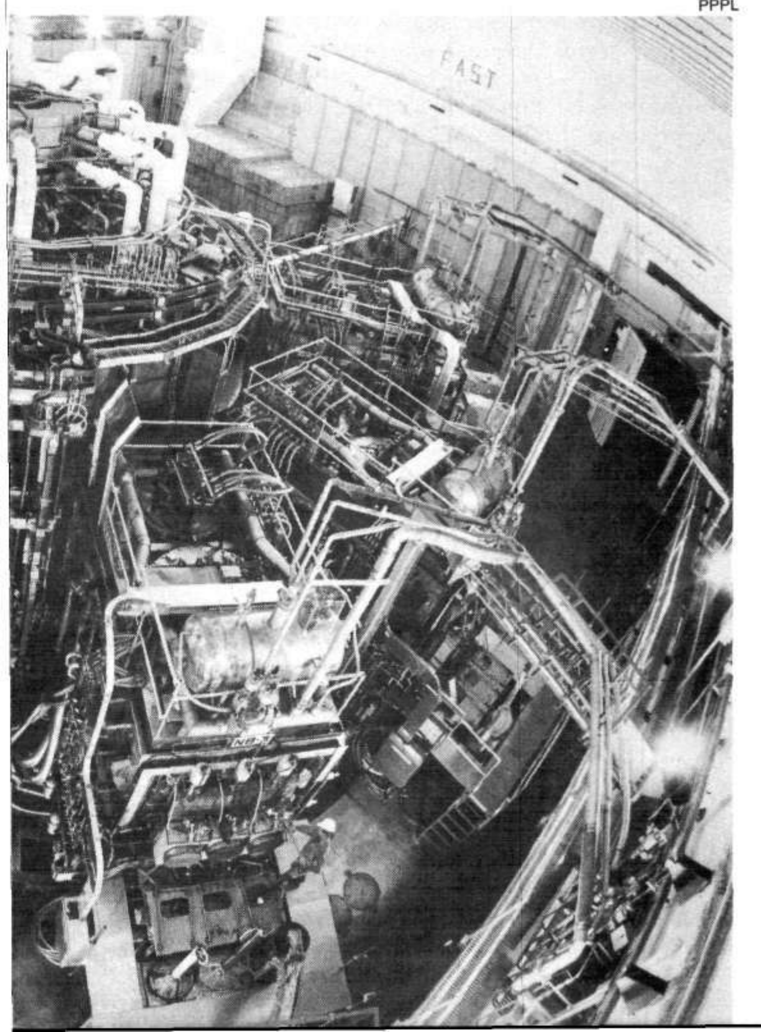
Reactors by the Year 2000?

the Magnetic Fusion Energy Engineering Act of 1980. Essentially, that law mandated that a commercial demonstration fusion plant be built by the year 2000.

Indeed, the latest results are better than those predicted by the Princeton group even as late as six months ago. They are especially important not only because of the record temperatures, but also because in a parallel experiment there were significant improvements in the density and duration of plasma confinement. The fact that all of these developments are occurring simultaneously means that we are now on the verge of a new industrial age—the plasma age, where the average production worker will have an order of magnitude higher energy density at his disposal, and our civilization as a whole will benefit accordingly.

The immediate Princeton goal, predicted for next year, is energy breakeven in principle. That is, results with deuterium-deuterium reaction rates will be achieved equivalent

PPPL



to breakeven once highly reactive tritium fuel is introduced. Such an upscaling will in practice undervalue the parameters that would actually be achieved with tritium. Tritium will be introduced in 1989. The constraint on using it before then is simply that it produces a small amount of radioactivity, requiring special handling procedures.

In order to reach breakeven in a fusion reaction, two separate conditions must be met: Both the plasma temperature and the quality of magnetic heat insulation must exceed threshold values. Achieving nuclear fusion is not just a question of simply heating the fusion fuel to some required temperature. At the same time that it is being heated, the fuel must be kept concentrated and insulated against heat loss. Magnetic confinement is the general approach to this that Princeton is pursuing.

What Is Fusion?

There are two major fusion approaches—magnetic confinement and inertial confinement. The inertial fusion program aims to make fusion occur inside target fuel pellets by imploding them with laser or particle beam irradiation in brief pulses. It produces extremely high densities in the target—the laser pulse creates a shock wave in the pellet that is intensified by its internal geometry. In contrast, magnetic fusion devices, like the tokamak, operate at lower densities, but use magnetic fields to confine the plasma for longer times. Fusion energy is released as the nuclei of the isotopes of hydrogen—in this case deuterium—fuse to form a helium atom, releasing energy in the process.

The TFTR consists of a donut-shaped magnetic "bottle," which is used to trap and insulate hydrogen fusion fuel. At the high temperature—44 million degrees Celsius—required for fusion of the heavy isotopes of hydrogen to occur, the hydrogen gas is ionized or electrically charged. That is, the gas becomes a plasma, like that in a neon light. Because plasma is electrically highly conductive, it can be confined by the properly configured magnetic fields.

The first generation of commercial fusion reactors, such as the tokamak, will likely use for fuel a combination of two isotopes of hydrogen, deuterium and tritium (D-T). In the long run, this is not the most desirable fuel because it releases a flux of neutrons that must be contained. Later generators will undoubtedly use deuterium-deuterium (D-D) reactions, or other more sophisticated fuels, and create electricity directly, rather than having to use steam turbines. Although deuterium fuel, not tritium, is now being used in the Princeton experiment, the machine is equipped to handle the radiation from tritium. When tritium is introduced it will require increased shielding of the experimental device and remote handling.

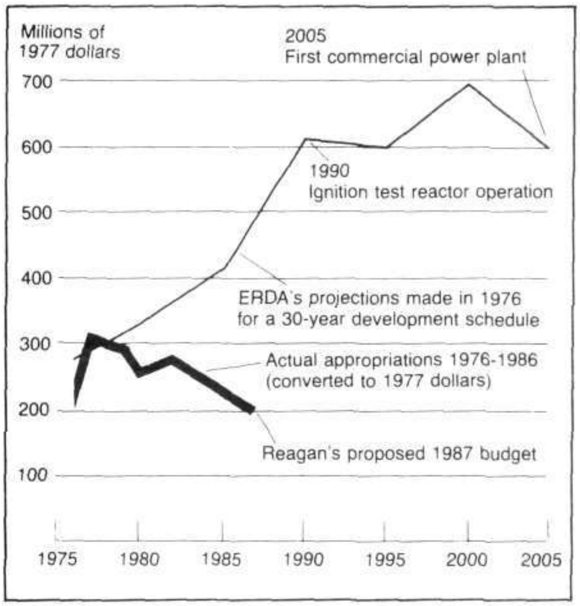


Figure 1
FUNDING FOR FUSION VEERS AWAY FROM PATH TO SUCCESS

Ten years of actual fusion appropriations 1976 to 1986, and President Reagan's proposed budget for fiscal year 1987, are shown by the heavy line. The Reagan budget sinks lower than Carter's. More startling is the comparison of actual funding to the 1976 funding projections for the achievement of commercial fusion by the year 2005 (thin line) done by the U.S. Energy Research and Development Agency, the predecessor to the Department of Energy.

The Tokamak

When it began operating, Dec. 24, 1982, the TFTR was the largest tokamak in the world, with a volume of 35 cubic meters. Now, the Joint European Torus (JET) in Culham, England, has overtaken it, with a plasma volume of 170 cubic meters, and next in line is the Japanese JT-60 with 54 cubic meters. The TFTR cost $314 million to build, and to run it requires the power supply for a large city. Since the energy is required in short pulses over seconds only, it is collected and stored in huge 400-ton flywheels. The TFTR construction was a challenge to the machining industry; the reactor platform had to be machined to tolerances of 1/30,000 of an inch—hundreds of times greater than the precision required in nuclear power plant projects.

Like all tokamaks, the TFTR is a torus in which the plasma is confined by two magnetic fields, one running the long way around the donut (toroidal), the other running the short way (poloidal). (See Figure 2.) The toroidal field is produced by electric coils running poloidally, while the poloidal field is produced by the induced electric current running toroidally through the plasma itself. The combination of the two fields creates stability in the hot plasma. Since plasma particles (ions and electrons) are electrically charged, they do not move readily across magnetic field lines.

The flow of current in the plasma column is induced: The tokamak is a single-turn transformer, in which the plasma is the single turn. The plasma has a very high but finite conductivity. The resistance within the plasma produces heat in the range of 10 to 50 million degrees Celsius. To reach temperatures in the range of 100 million degrees Celsius, where a reacting plasma can become self-heating, auxiliary heating is needed. One such method is the injection of beams of energetic neutral deuterium fuel atoms. Another heating method is the application of electromagnetic waves tuned to the gyration frequency of the ions or the electrons in the plasma.

The tokamak configuration was first proposed by Soviet scientists A. Sakharov and I. Tamm in 1950, and was developed experimentally at the I.V. Kurchatov Institute in Moscow. The success of their T-3 tokamak experiment in 1969 constituted a major step forward in both plasma temperature and energy confinement criteria relative to previous fusion experiments. In August 1978, the Princeton Large Torus (PLT) made headlines worldwide by reaching a then-record temperature of upwards of 60 million degrees Celsius. At the time, the director of the U.S. Department of Energy's Division of Magnetic Confinement said: "The question of whether fusion is feasible from a scientific point of view has now been answered. It's the first time we've produced the actual condition of a fusion reactor in a scale-model device." The TFTR is twice the size of the PLT.

The idea of building the TFTR took shape in 1973, long before the PLT had broken any records. The initial fusion advances by the Soviets in the late 1960s had been confirmed on several U.S. fusion experimental devices and there were significant advances in heating and controlling fusion plasmas. Dr. Robert Hirsch, then director of the U.S. fusion program, proposed building the TFTR as the obvious next step. It was to be the first tokamak capable of using tritium as a fuel.

It is this kind of philosophy—the conviction that the technology was possible and necessary and therefore that the next stages had to be started even before the current stage had proved successful—that has made possible the March-July 1986 achievements on the TFTR. It also meant that the TFTR, from the beginning, was designed to be modified to take advantage of new discoveries as they were developed on other working tokamaks.

The 1986 TFTR Results

Two experiments were conducted on the TFTR. In the first, the 200-million-degree temperature was reached with a Lawson confinement parameter, $n\tau$, of 10^{13} cm^{-3} sec—this is more than 10 times the $n\tau$ value associated with the previous high-temperature record set by the PLT (see Figure 3). As a standard of comparison, in 1969, the Soviet T-3 device produced a central ion temperature of 6 million degrees by ohmic (that is, resistive) heating, at a Lawson parameter $n\tau$ of about 5×10^{11} cm^{-3} sec. In 1978, the PLT used neutral-beam heating to reach a temperature of 60 million degrees Celsius, later increased to 80 million degrees, at an $n\tau$ of 10^{11} cm^{-3} sec.

Even without tritium, the TFTR high temperature experiment produced a fusion reaction rate of 2×10^{16} per second in the deuterium plasma, releasing a peak of 10 kilowatts of fusion power and a total fusion energy yield of 3 kilojoules per pulse. Thus, for the first time, there was a macroscopic power release. This was sufficient to make the tokamak components slightly radioactive.

Had tritium fuel been used, this power release would have scaled up to at least 4 megawatts. The total fusion energy yield per pulse in the equivalent D-T plasma regime would exceed 1 megajoule, going beyond one of the original objectives specified for the machine in 1976 (see Table 1). The expectation is that in 1989, when D-T experiments are actually conducted, reaction rates in excess of 10^{19} per second will be achieved, corresponding to approximately 30 megawatts, with a total fusion energy release of 40 to 50 megajoules per pulse.

One of the plans for enhancing the performance of the experiment in 1987, is to increase the time of the neutral beam pulses from ½ second to 2 seconds. In the actual D-T phase, scheduled for 1989, the TFTR beam-injection energy will also be raised from 90-95 kiloelectron volts (keV) to 120. The ideal injection energy is considered to be about 200 keV. With the temperatures already achieved, this would give fusion breakeven. Even under the conditions of the present experiment, the ratio of yield to input power—the *Q* value—increased over three orders of magnitude, to a value equivalent to .25 were D-T fuel to be used.

Another extremely important result was the apparent development of a "bootstrap" current. In 1971, Soviet and British scientists calculated that a reactor-level tokamak plasma should generate a spontaneous electric current, the "bootstrap current," strong enough to maintain the tokamak magnetic-field configuration in a steady state. The ability to operate in a steady state is extremely advantageous to the functioning of a power reactor. The Princeton scientists observed an electric current double that of the input current. The inferred value for the bootstrap current agrees with that theoretically predicted.

An equally exciting result was the refutation of what is known as Kaye-Goldston scaling. This was a hypothesis derived from observation of the results after neutral beam heating was used on the PLT. The hypothesis holds that confinement time could increase only as the square root of the power of the injected neutral beams. This pessimistic prediction suggested a saturation curve nullifying the advantages gained by the higher temperatures resulting from introducing the beams. According to Kaye-Goldston, the same negative effect might also result from internally generated ion heating. By reducing the introduction of net angular momentum into the plasma, by not injecting all of the beam energy in only one direction along the seam of the tokamak—as was done in the PLT—no such scaling occurred. This suggests that the empirically observed reduction in confinement time was actually connected not to the increase in temperature, but to the addition of angular momentum.

Table 1
FUSION REACTIONS IN THE HIGH-TEMPERATURE TFTR PLASMA REGIME

Experimentally measured deuterium-deuterium reactions	Calculated reactions under equivalent conditions with deuterium-tritium fuel
$2 \cdot 10^{16}$ reactions/sec	$>10^{18}$ reactions/sec
(10^{16} neutrons/sec)	
10 kW fusion power	~4 mW fusion power
3 kJ fusion energy yield per pulse	>1 mJ fusion energy yield per pulse
	$Q \geqslant 0.25$ ratio of fusion power to heating power

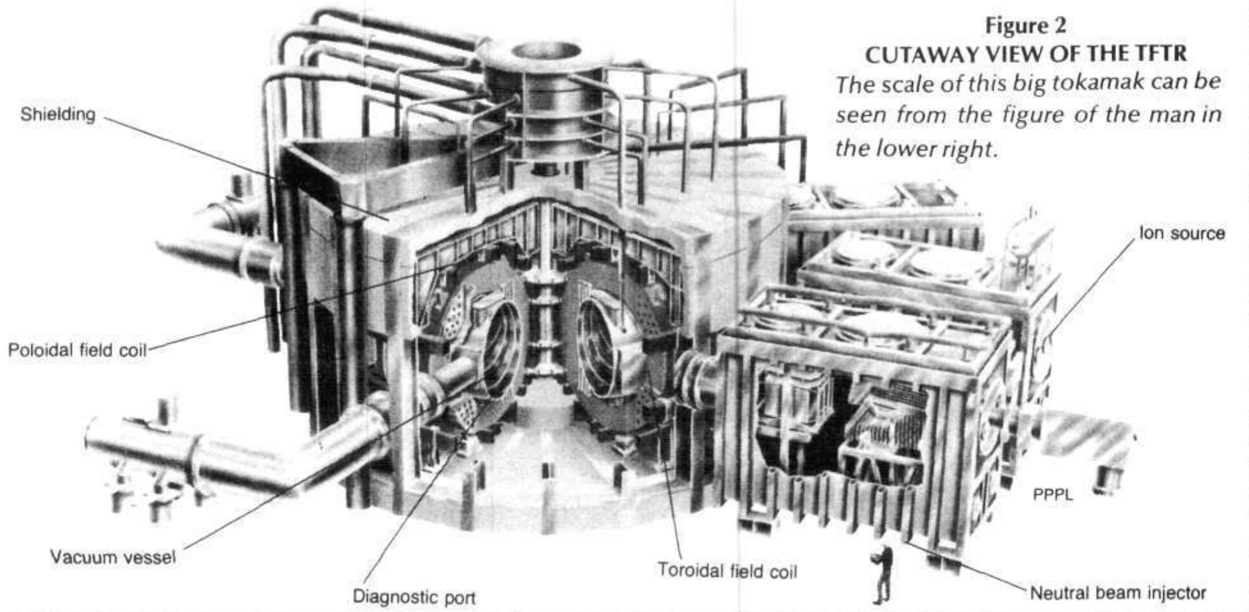


Figure 2
CUTAWAY VIEW OF THE TFTR
The scale of this big tokamak can be seen from the figure of the man in the lower right.

Suzanne Klebe

Former Congressman Mike McCormack (D-Wash.), chairman of the Subcommittee on Energy Use and Production, and Fusion *magazine's Marsha Freeman at 1980 congressional hearings on the Magnetic Fusion Energy Engineering Act. This 1980 legislation still applies today: We need a crash program to build an engineering reactor in the 1990s and a commercial prototype by 2000.*

The TFTR functions with a graphite limiter. Typically the limiter becomes filled with deuterons and other foreign material, and then acts as a mirror to reflect ions that land on it back into the plasma. This results in the undesirable effect of cooling the plasma. In the recent experiments, Princeton scientists preconditioned the graphite, leaching out impurities over a two-week period preceding the major experiment, by bombarding it with long-pulse helium and low-density deuterium discharges. As a result, ions were allowed to pass through the graphite. This was a significant contribution to the high temperatures they were able to reach.

Using the preconditioned graphite limiter, an experimental "operating window" was found where powerful neutral beam heating at an appropriate tokamak current level caused the tokamak to undergo a transition to a state of enhanced energy confinement, similar to that achieved with magnetic-edge/plasma-control devices—known as magnetic divertors—in the ASDEX tokamak in Garching, West Germany, and the Doublet III tokamak at GA Technologies in La Jolla, Calif. The high-temperature regime produced with these divertors is known as the *H*-mode. For the first time, the Princeton experiment was able to produce the *H*-mode in a divertorless tokamak.

In the parallel high density experiment on the TFTR, high-speed, frozen deuterium pellets were injected to achieve high density at the center of the plasma. These pellets, which are shot at speeds of 1,250 meters per second, deeply penetrate the ohmically heated TFTR plasmas. By depositing their deuterium fuel near the center of the discharge, the pellets reduce the effect of particle recycling at the plasma edge. An $n\tau$ was achieved of 1.5×10^{14}, cm^{-3} sec. This is an order of magnitude higher than the high-temperature experiment and falls short by only a factor of 2, of the $n\tau$ level that will typically be required for a burning plasma in a practical fusion reactor. The temperatures in this experiment were about 15 million degrees. This is also half an order of magnitude higher confinement than was achieved in the Alcator A and Alcator C experiments at the Massachusetts Institute of Technology, which had reached center temperatures of 20 million degrees. (See Table 2 for a summary of results on major tokamaks.)

These pellet experiments relied only upon ohmic heating, and future plans call for the use of radio frequency heating. Ultimately the intention is to combine the use of pellet-injection technique, intense neutral beam injection, and radio-frequency heating, so as to advance the $n\tau$ value and the central ion temperature simultaneously toward the reactor objective.

One problem to be resolved is that, beyond a certain density, it has not been possible to get the neutral beam into the center of the plasma column.

Future Plans

Although energy breakeven—the ability to realize more energy from a fusion reaction than is required to operate the machine—is a great milestone, one of the most important achievements beyond breakeven is the condition in which a plasma, once ignited, will continue to burn. This is like achieving a chain reaction with fission fuel. The projected next step in the Princeton program is to build a compact ignition device to produce ignited D-T plasmas, in order to investigate the physics of the equilibrium-burn state.

Such a device, first proposed by Italian fusion scientist Bruno Coppi and since modified in detail, will use copper magnets to achieve extremely high plasma densities by pumping up the magnetic field. It is not planned as a model for a practicable fusion device and will do only short-pulse physics experiments, but is a useful device for testing how a plasma burns. The compact ignition device will take two years to build and could reach ignition within four to five years. The plan is to build such a machine at Princeton that would be operational in the mid-1990s. Coppi's original proposal was for a $20 million device, but this proposal has been increased to a cost of $300 million.

Two years ago, various designs were proposed for a next-generation TFCX, an engineering test reactor type of device that would have cost $1.5 billion, compared with the $300 million for the compact ignition device. The TFCX would have tested ignition regimes but also would have had reactor features such as a test configuration of a blanket module (used to extract energy from the tokamak). In one design, it would have had a 5-minute burn time—compared to the projected 2 second scale-up. Unfortunately, the alternative of the smaller device was a forced choice, because of the severe constraints being placed upon the fusion budget.

At present, the fusion community is hoping to avert budgetary constraints by winning the collaboration of the Europeans and Japanese—and possibly the Soviets as well—for the joint development of an engineering test reactor by the year 2000 (this was originally scheduled to be on line in the United States in 1990). They are convinced that technically such a test reactor could be providing practical fusion-reactor operating experience beginning around the end of the 20th century. They confidently predict that this would provide a basis for the emergence of commercial fusion power during the initial decades of the 21st century.

What a Fusion Program Should Look Like

The current policy direction of the magnetic fusion program in the DOE reflects capitulation to the idea that the only way to keep the fusion budget from being cut back further, is to replace an aggressive U.S. fusion program with international cooperation.

Although the Compact Ignition Tokamak (CIT) experiment is budgeted in the DOE program, half of its funding is still lacking. In addition to its start-up cost, the device will need about $150 million for supporting activities.

An alternative approach to the CIT or the TFCX would be to build an engineering test device incorporating both concepts in sequenced phases, beginning with a two-year phase in which short-pulse physics ignition experiments would be conducted. This would be followed by long-pulse experiments. The third phase would be the engineering work, materials testing, and a full Engineering Test Reactor machine—operating with superconducting magnets. Such a device could produce results over a 10-year period and could start operation in 5 to 8 years. This would push the program 10 to 20 years ahead of the present track, allowing a commercial demonstration plant between the years 2000 and 2005.

The cost of such a three-stage machine would only be between $1.5 and $2 billion. Previous design work could be updated over a six-month period, during which the construction site would also be chosen. At the end of six months, hardware orders could be placed.

It is precisely such an aggressive approach that will guarantee international cooperation. Indeed, the Soviets and Europeans will be knocking at our doors, as opposed to the present situation in which the United States is standing hat in hand, trying desperately to save the U.S. program from being slaughtered by the budget cutters.

The Magnetic Fusion Energy Engineering Act of 1980 called for doubling the magnetic fusion program funding within a

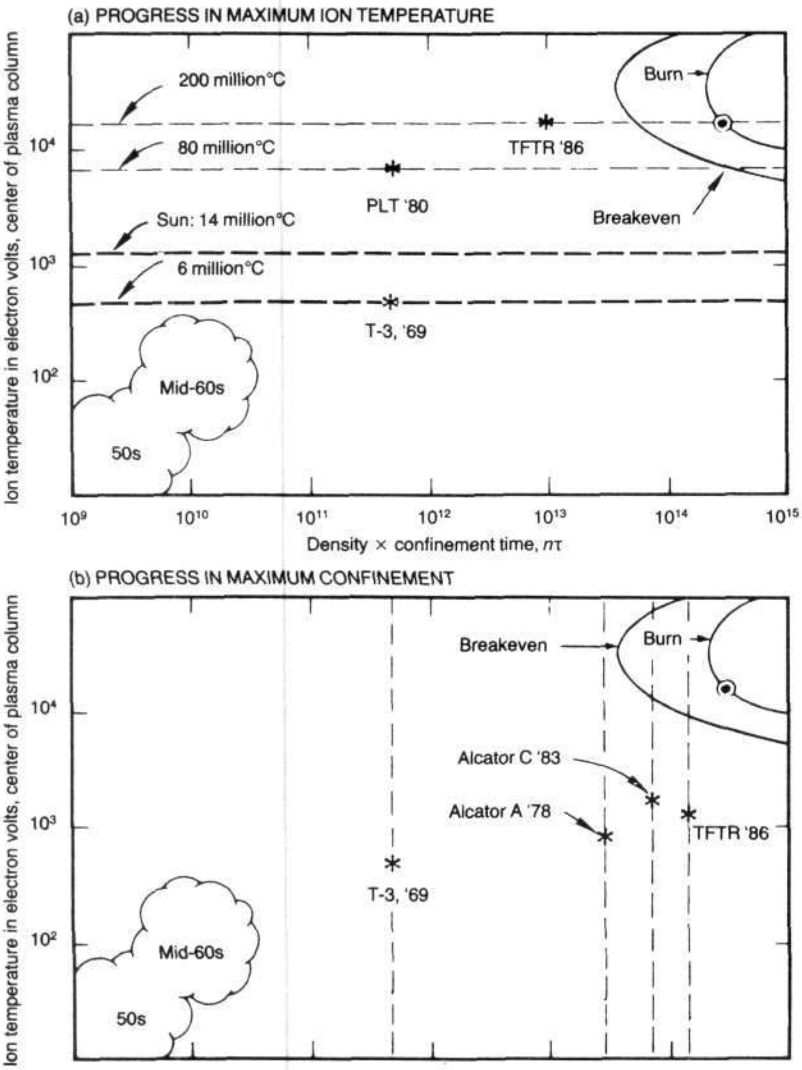


Figure 3
PROGRESS IN MAXIMUM TEMPERATURE AND CONFINEMENT

The achievement of fusion requires a combination of high temperature, high particle density, and sufficiently long confinement time. The Lawson diagrams shown here chart the progress in these quantities. The horizontal axis measures the combined particle density and confinement time. This is an indirect measure of the number of collisions per "shot" on the tokamak. This combined measure is called $n\tau$, *where* n *is the number of particles per cubic centimeter and* τ *is the confinement time in seconds. The vertical axis measures ion temperature at the central, hottest part of the plasma. Ion temperature may be expressed in electron volts or in degrees Celsius.*

In (a) the progress in maximum ion temperature is shown and in (b) the progress in maximum confinement time is shown. The various fusion devices are noted at the points of their achievement. The temperature of the core of the Sun is shown for comparison.

seven-year period (in constant dollars). This act was never implemented, and, in fact, the fusion budget has decreased by about one-third (in real dollars) since the act became law. This being the case, the fusion program needs a far more drastic infusion of funds if it is to proceed at the pace indicated by its technical potentialities.

Just to restore what has been cut out of the budget in the past six years would require doubling the budget this year! This would allow the magnetic mirror machines at Lawrence Livermore National Laboratory, now cut from the program, to operate, and would also allow the first stages of implementation of an Engineering Test Reactor. The program could easily absorb a 50 percent increase each of the following two years.

One example of the stupidity of the present situation is the trade-off concluded in late August by the DOE Magnetic Fusion Advisory Committee to fund the smaller university mirror machine experiments for a few million dollars at the cost of across-the-board cuts in the fusion alternate concepts program. There have already been near-fatal cuts in the alternate concepts programs, university programs, and technology development. For example, the gyratron effort is stopped, no development work is being done in neutral beam technology, and advanced radio frequency heating technology has ground to a halt, along with the ideas for a full electromagnetic spectrum of heating techniques.

Furthermore, in order to achieve commercial fusion, it is obviously foolish to persist in converting the energy to steam in order to operate a turbine; this is ridiculously inefficient. What is needed is direct conversion. In this regard, the tandem mirror is an interesting candidate—even though there are now problems in its design—because of the ease with which a charged particle beam can be extracted from it. Work that is being done studying magnetohydrodynamic direct conversion systems and other advanced conversion devices, however, is now being bootlegged—because it has no existing budget line.

Major work will also have to be done on materials questions. One of the advantages that fusion must prove it will have, is that it does not accumulate long-lived radioactive waste. When tritium is used as a fuel, there is some radioactivation—although not comparable in scale to fission—that contaminates and corrodes the materials coming into contact with the plasma. New alloys and other new building materials have to be developed, along with technologies for manufacturing, handling, and constructing fusion reactors. A first step is to take small samples of new materials and subject them to fusion-comparable radiation environ-

TFTR Results Exceeding the Original Design

AN INTERVIEW WITH DR. DALE MEADE

Dr. Dale Meade is in charge of experiments on the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory. He was interviewed Aug. 15 by David Cherry.

Question: The TFTR has set two new records that bring us closer to fusion as a practical energy source. What are these achievements?

In mid-July we set a world record for the highest temperature achieved in a laboratory, 18-20 kiloelectron volts (keV) of ion temperature; that is, roughly 200 million degrees Celsius. This is comfortably within the range in which a working fusion reactor will function, but achieved at a lower density than will be required.

In March, the TFTR set a new record for the Lawson product, $n\tau$, or quality of confinement. It is the product of density and confinement time. By enriching the fuel with fuel pellet injection, and doing this at high plasma density, we achieved an $n\tau$ of 1.5×10^{14} nuclei-seconds per cubic centimeter. Our pellet injectors were developed at the Oak Ridge National Laboratory. The density itself was 3×10^{14} nuclei per cubic centimeter, confinement time was .5 seconds, and temperature was 1.2 kiloelectron volts. If our high temperature and $n\tau$ achievements can be combined, we will easily have breakeven, where the power produced equals the power required to heat the plasma. Putting it another way, the ratio Q of power produced to power required equals 1 (Q or quality factor = 1). That is beyond the original TFTR design.

Question: Is this being done with deuterium alone?

Yes. These are D-D reactions. The combination of deuterium and tritium (D-T) is 200 times more reactive. When we started our tokamak work in 1974, we had rather modest objectives. For example in 1976, people said we should produce 1-10 megajoules of fusion energy per pulse with temperatures of 5-10 keV and $n\tau$ of 10^{13}. Part of the significance of these latest results with deuterium plasmas is this: We believe that if we put tritium in now, we'd achieve the original objectives for the TFTR.

After 1976, we boosted the objectives. By 1979, we were saying the TFTR should reach real breakeven. In the coming year, with deuterium plasmas, we expect to achieve the conditions for breakeven once tritium is introduced.

Question: How will that be done?

One-third to one half of the reactions are going to come from neutral beam ions hitting tritons [tritium nuclei]. To get breakeven utilizing these beam-target reactions, you need 15-20 keV and $n\tau$ of $2\text{-}3 \times 10^{13}$. That's twice the $n\tau$ we now have at this temperature. Without these neutral beams of deuterium, we'd need $n\tau$ of 6×10^{13}. In 1983, the Alcator C got $n\tau$ of 6×10^{13}, without beams.

At present, the TFTR with tritium would produce a Q of 0.25. Within the next year, the four neutral beam heaters will go from half to full power, and we'll get longer pulses, ments for at least five years. This can be partially accomplished with the proposed Engineering Test Device.

Provisions of the 1980 Law

In 1980, President Carter signed the Magnetic Fusion Energy Engineering Act into law. It contains the following provisions, all of which are as apt today, as at the time of their adoption six years ago:

(1) The United States must formulate an energy policy designed to meet an impending worldwide shortage of many exhaustible, conventional energy resources in the next few decades;

(2) The energy policy of the United States must be designed to ensure that energy technologies using essentially inexhaustible resources are commercially available at a time prior to serious depletion of conventional resources;

(3) Fusion energy is one of the few known energy sources which are essentially inexhaustible, and thus constitutes a long-term energy option;

(4) Major progress in all aspects of magnetic fusion energy technology during the past decade instills confidence that power production from fusion energy systems is achievable;

(5) The United States must aggressively pursue research and development programs in magnetic fusion designed to foster advanced concepts and advanced technology and to develop efficient, reliable components and subsystems;

(6) To ensure the timely commercialization of magnetic fusion energy systems, the United States must demonstrate at an early date the engineering feasibility of magnetic fusion energy systems;

(7) Progress in magnetic fusion energy systems is currently limited by the funds made available rather than technical barriers;

(8) It is a proper role for the federal government to accelerate research, development, and demonstration programs in magnetic fusion energy technologies; and

(9) Acceleration of the current magnetic fusion program will require a doubling within seven years of the present funding level without consideration of inflation and a 25 percent increase in funding in each of the fiscal years 1982 and 1983.

It is therefore declared to be the policy of the United States and the purpose of this Act to accelerate the national effort in research, development, and demonstration activities related to magnetic fusion energy systems. Further, it is declared to be the policy of the United States and the

pulses of 2 seconds instead of typically ½ second. Q will go to 0.5 as a result.

To get $Q = 1$, we face the following problem. We use the injection of fuel pellets to get high $n\tau$. The pellets will penetrate a dense plasma, *but not above a certain temperature*. We use neutral beams, beams of deuterium atoms, trained into the plasma to heat it, but neutral beams *will not penetrate a sufficiently dense plasma*.

Question: So, it is the horns of a dilemma.

Yet, we must approach the objective from both directions. For the high temperature regime, we will perhaps improve the density with the injection of smaller fuel pellets. Working from the high density regime where we have a high $n\tau$, the ion cyclotron range of frequencies [ICRF, one form of radio frequency heating—ed.] becomes useful for increasing the temperature. We will be depositing 5 megawatts of ICRF right in the center of the plasma column. Neutral beams do not reach the center of the plasma.

Coming back to the latest results on the TFTR. The common thread in these two regimes—the very dense and the not so dense—is that they both have sharply peaked density profiles along the diameter of the plasma column. We weren't able to get high temperatures until we learned to get peaked profiles using only neutral beam heating. Now, we get them with either neutral beams or pellet injection right to the center.

The new high-temperature results over the past two months have been achieved by first firing many shots at low density to clean impurities from the machine and condition the interior of the chamber. Then, we would get one good shot. Again, many shots at low density, then three good shots. Then, after the same routine, 10 good shots.

Concerning our March results in the high-density regime, density and temperature are now so good that hydrogenic bremsstrahlung accounts for 20 percent of energy loss at the center—it used to be negligible.

Question: By that do you mean that results are so good that the amount of energy being lost by radiation has now assumed significance, where previously it was a negligible proportion of the general energy losses?

Precisely.

Question: What is being accomplished with Princeton's other tokamaks?

The TFTR is on the main line of tokamak development. The Princeton Large Torus (PLT) and Princeton Beta Experiment (PBX), like the Doublet III in San Diego, are on the advanced tokamak line. The PBX is investigating ways of shaping the cross-section of the plasma column to achieve β [confinement quality] of 10 percent. The PBX has already achieved 5 percent. It is now being modified—it will be PBX-M—in order to achieve a theoretical β of 20 percent, but practically, the objective is 10 percent. PBX-M will start operation in April 1987.

The PLT is working on techniques for radio frequency heating to achieve steady-state operation, instead of pulses. It is achieving 5 keV of electron temperature now, using lower hybrid-current-drive of 2.5 gigaherz. Lower hybrid means intermediate in frequency between electron cyclotron and ion cyclotron frequencies. In the heating of ions, we have traditionally used ion cyclotron waves. Now, we are heating with Bernstein waves—the 5th, 6th, or 7th harmonics of ion cyclotron waves, and looking at other forms of radio frequency current drive.

The PLT will shut down at the end of September 1986. If we had the money, it would not!

purpose of this Act that the objectives of such program shall be—

(1) To promote an orderly transition from the current research and development program through commercial development;

(2) To establish a national goal of demonstrating the engineering feasibility of magnetic fusion by the early 1990s;

(3) To achieve at the earliest practicable time, but not later than the year 1990, operation of a magnetic fusion engineering device based on the best available confinement concept;

(4) To establish as a national goal the operation of a magnetic fusion demonstration plant at the turn of the 21st century;

(5) To foster cooperation in magnetic fusion research and development among government, universities, industry, and the national laboratories;

(6) To promote the broad participation of domestic industry in the national magnetic fusion program;

(7) To continue international cooperation in magnetic fusion research for the benefit of all nations;

(8) To promote greater public understanding of magnetic fusion; and

(9) To maintain the United States as the world leader in magnetic fusion.

Carol White is editor-in-chief of Fusion *magazine.*

	TFTR Princeton	JET Culham, England	JT-60 Tokai, Japan	Alcator C MIT	Doublet III San Diego	ISX-B Oak Ridge
1. Date operational	12/82	6/83	4/85	4/78-11/86	1978-9/84	1978-84
2. **Highest combined density & confinement time**, $n\tau$ (seconds × nuclei/cm^3)(× 10^{13})	15	4-5	3-4	6	1.3	~0.07
3. ***Ion temperature at highest*** $n\tau$ (kiloelectron volts)	1.2	1.8	~1.5	1.7	2	—
4. Highest average electron density, n_e (electrons/cm^3) (× 10^{14})	3	0.8	0.5	15	1.2	1.5
5. Longest confinement time, τ (seconds)	0.75	0.8	0.4-0.5	.055	0.120	0.025
6. Highest ion temperature, T_i (kiloelectron volts)	18-20	7	—	2	6	1.6
7. Lowest impurity level, Z_{eff} (avg. atomic number)	high density ~1.0 low density 2.5-3	2-2.5	good	1.2	1.0	1.1
8. **Highest confinement quality**, β (%)	—	<1	—	1	4.6 4.0	2.6
9. **Toroidal field strength at highest confinement quality**, B_t (tesla)	—	—	—	10	0.6 1.3	0.8
10. Highest toroidal field strength used, B_t (tesla)	5.2	3.5-4	4.2	14	2.6	1.6
11. Highest current used, I (megamperes)	2.5	4.8	1.5	0.8	2	0.23
12. External heating, P (megawatts)						
neutral beam (deuterium)	12.5 now, 25 soon	~7	—	—	8	2.5
radio frequency	—	~7	—	1.6 absorbed	—	0.15
13. Major radius of torus, R (meters)	2.48	2.96	3.0	0.64	1.43	0.93
14. Plasma volume (cubic meters)	35	170	54	—	—	—

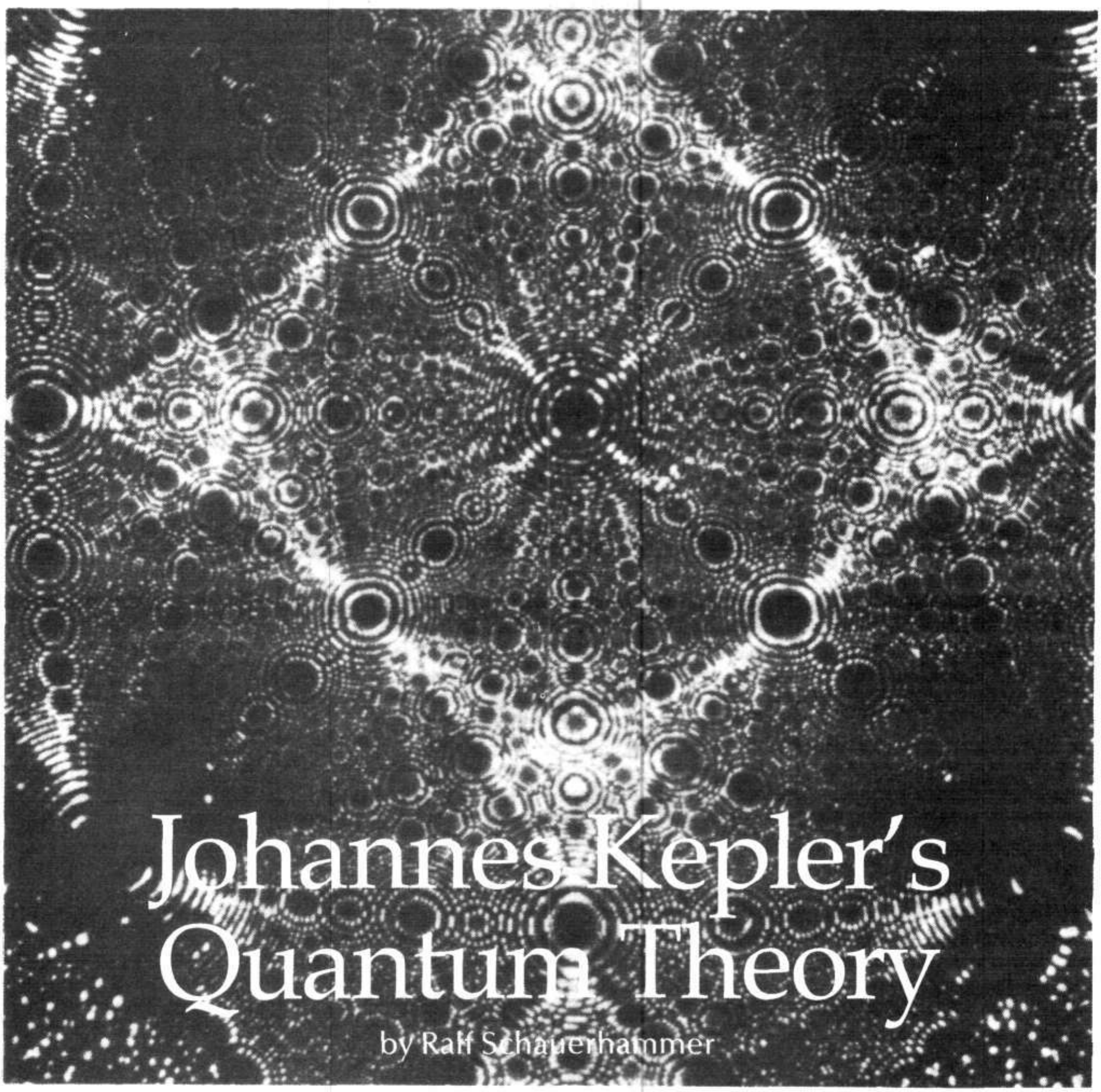
Table 2

PROGRESS ON SOME MAJOR TOKAMAKS

Fusion breakeven—and beyond—will soon be achieved by the "big three"—TFTR, JET, and JT-60—and by the successor to the Alcator C. All of these machines have achieved the necessary Lawson product (combined density and confinement time, $n\tau$; the threshold is 3×10^{13} nuclei-seconds per cubic centimeter), as shown on line 2. None of them simultaneously sustained the temperature of 93 million degrees Celsius (8 kiloelectron volts) that is the other threshold condition for breakeven, as shown on line 3.

The more than 200 million degrees Celsius (actually 18-20 kiloelectron volts) achieved by the TFTR in mid-July, a world record (line 6), exceeds the threshold for breakeven and is suitable for an economical working reactor. But it was achieved at a significantly lower Lawson product (1×10^{13}).

Machines pursuing confinement quality, rather than breakeven, are GA Technologies' Doublet III and the ISX-B at Oak Ridge National Laboratory (lines 8 and 9). Confinement quality, β, essential for an economical working reactor, is the ratio of the energy density of the plasma (density × temperature) to the strength of the magnetic field required to confine it. Beta of 6-10 percent is considered necessary for a working reactor. The highest β so far, 5.3 percent, was achieved on the Princeton Beta Experiment, PBX, described in the accompanying interview.



Johannes Kepler's Quantum Theory

by Ralf Schauerhammer

The discovery of fivefold symmetry in crystals has shaken up the world of physics, but it is a lawful occurrence according to the poetic principle of Johannes Kepler.

Viewed externally, all seems perfectly well in modern physics. It appears that the Copenhagen dogma interpreting quantum theory was irrevocably and eternally established at the 1927 Solvay Conference in Brussels where all the "high priests" of physics of that time gathered. This dogma, in fact, is still the orthodox view today for every physicist.[1]

Position of individual atoms in a sharply curved platinum surface, at a magnification of 500,000.

Natural phenomena, however, are deviating from the Copenhagen articles of faith in increasing numbers, and atoms and elementary particles are occasionally finding themselves involved in some truly blasphemous escapades. It has even come to the point that some physicists now dare to suggest that an entirely new area will soon intervene between quantum and solid-body physics—an unprecedented assertion, since quantum physicists formerly behaved as if they would be able to usurp the other more ancient and honorable domains of physics.

It is, therefore, worth looking into the matter somewhat more closely, and in doing so, we will not omit consideration of the first fundamental work in nuclear physics: Johannes Kepler's short essay *The Six-Cornered Snowflake*, written in 1611.[2] I have read Kepler's essay many times, and on each rereading, I am delighted anew for, exactly as in a work of art, a painting, a symphony, or a drama, new and more profound concepts emerge each time. *Kepler's essay is a work of art in science.* He systematically and rigorously developed hypotheses, and, in that process, came up with results that were in part not rediscovered until 250 years later. But that is not all. There is still another level present, a level characterized by Nicholas of Cusa as "wisdom," that stands above the logic of the understanding and *produces* and organizes this series of scientific hypotheses. This *poetic principle* characterizes the work of geniuses such as Kepler.

Kepler clothes his investigations in the form of a letter to his friend Johannes Matthäs Wackher of Wackenfels, to whom he intends, paradoxically, to give "nothing," punning in German on the Latin "nix," snow, and the German "nichts," nothing. At the very beginning, in the search for the "smallest," Kepler happens on "Epicurus's atoms," which, for Kepler's critical intellectual eye, are "really nothing."

Kepler finally settles on the snowflake as the smallest actual thing. If it is recalled that at that time there were still no microscopes, even the most ingrained empiricist must acknowledge this "object of investigation" for the factual confirmation of "atomistic" hypotheses. Kepler (himself half blind) immediately determines that snowflakes show a well-defined hexagonal geometry.

It must be realized that for Kepler, geometry had a real significance, and that he avoided the practice usual in physics today of mystically jamming mathematical-geometrical models onto phenomena. Kepler was certainly not a mystic, obsessed with playing with geometrical figures, as, for example, the kooky Carl Sagan would have us to believe in his book *Cosmos*. Kepler knew that the geometrical lawfulness of phenomena represents the key to the actual, effective connections within the overall process of nature. Kepler was certain that God must have followed the laws of geometry in the creation of the world, and that man himself can know the universe just because he is capable of knowing this geometrical lawfulness.

When I first read this statement by Kepler, I was quite surprised, since it raises two questions: First, what does this mean for God, who is actually restricted by geometry, and what follows for man, whose knowledge is likewise limited by the laws of geometry?—for only the Keplerian geometrical method makes knowledge of natural law possible. Second, we must ask, what does this mean for geometry, which mediates between the human mind and "God's nature." Only years later, on reading the final chapter of Kepler's *Harmony of the World*, did I somewhat better understand what Kepler meant. In the epilogue on the Sun, he compares the overall harmonic creation of the universe he had previously presented with the thought processes of man, and asserts that the two are in harmony.

That does not mean, of course, that the universe has a huge "science-fiction" brain and can "think." But it does mean that the universe *cannot* be explained mechanically, as something in contrast to man's creative activity of thought. Whoever pursues physics in the mechanistic way—and, since Kant, the majority of physicists have—cannot understand the universe, and ultimately comes to the conclusion that the universe is fundamentally unknowable. Epigones of Kant, such as the physicist Ludwig von Helmholtz or philosopher Emil Dubois, explicitly asserted precisely that unknowability.

The universe is not, however, to be blamed that the hydrocephalic Helmholtz could not know it.[3] Since Kepler's time, the universe has not suddenly become incomprehensible; however, if anyone proceeds as did Helmholtz, on the assumption that the universe must be explained mechanically and, furthermore, that the universe is decaying and becoming more and more entropic, it is only natural that the real *negentropically developing universe* is and will continue to be quite incomprehensible.

How, then, can we apply the geometrical method in the sense of Kepler's snowflake? Geometrical shape is not something self-evident, but rather the expression of the *lawfulness of the process of formation* of the snowflake. Kepler states that the hexagonal form is not to be accounted for by means of the material, but rather *by an action*. He then asks whether it derives from an internal or external lawfulness. Generally, a scientist is only successful if he, like the hunter following a track, can discover the process that produced this track. A hunter must distinguish a hare's track from the hare itself, since it hardly makes sense to shoot the track. Most physics professors fail to make that distinction throughout their lives and thus manage only—at best—to shoot themselves in the foot. The hunter naturally must also distinguish between the boot track of the driver and that of the hare, since it is not a good idea to fire off a load of buckshot at the driver's derriere. For the scientist, the geometry underlying the phenomenon is precisely like the track for a hunter. There are no rabbits with rubber boots in nature. *Geometry is not itself* a natural process, but it is real, *being essentially connected with the action of natural processes.*

This point must be very precisely understood. It implies, for example, that a real understanding of natural processes is *not* possible through "modeling."[4] Just imagine a hunter who sits puzzling before the impression of a boot and produces various models to account for that impression. One model is that a driver went by. However, a group of rabbits appropriately distributed in space and time might have hopped by in just such a way to leave behind an impression exactly resembling a boot print in the snow. That is also a model for explanation of the empirically discovered print, and is far more "interesting" than the first, since it produces important considerations on rabbit-group coherence. (Physicist Ilya Prigogine would be very happy with it.) The hunter can, of course, construct many more such models, and will come to the conclusion that the same track can have been formed in the woods in various ways, depending largely on how one looks at it.

If we look at the geometrical forms in which crystals came into being, we must first rid our minds of these false "model" conceptions. *Crystals* are processes: Although they are as hard and durable as the proverbial diamond mountain on which the little bird sharpens its beak, they *grow*. They are not simply there; they must be formed. If we consider, for example, a jewel, then we must make real to ourselves that we are seeing, not a crystal, but in reality a process that has left behind this beautiful geometrical track. It is fundamentally the same as with the ephemeral snowflake.

Geometry and the Formation of Crystals

In a fluid, a spatial region is formed around a so-called crystallization seed in which all the material is organized in a homogeneous way. The crystal has no "holes" and "gaps," *but fills the entire (interior) space in a homogeneous way.* This apparently simple fact, however, has considerable consequences. For how is a homogeneous filling of space possible? Let us first consider the case in a plane. Figure 1 is taken from Kepler's *Harmony of the World.* If a plane is to be covered in a regular way without any gaps, then we have available from the store of geometrical figures, in addition to the familiar square bathroom tiles (E), regular triangles (D) and the hexagonal tiles preferred by bees in the construction of their honeycombs (F). With other tile forms, for example, regular pentagons (H) or heptagons, difficulties arise. In Figure 2, Kepler shows how, even with various pentagons and considerable imagination, it can't be done. *There remain holes unacceptable for a homogeneous crystallization process.*

Now, let us consider some examples in three-dimensional space. First, we have the so-called simple cubical packing (Figure 3, which corresponds to square tiles). Each sphere touches six neighbors. We can imagine that a tetragonally tiled layer of spheres can be laid exactly on the next. *If the same is done with hexagonally shaped tiles, then* simple hexagonal packing results (Figure 4). It is somewhat denser, and each sphere touches eight neighbors.

Starting with simple cubic packing, a frequently found packing can be produced also with eight neighbors if a further sphere is inserted into each intermediate space between the two layers of four spheres. A cubical, body-centered lattice is formed (Figure 5). Finally, various hexagonally shaped layers can be stacked (Figure 6), exactly as cannonballs were formerly stacked on one another in order to obtain a dense cubical or hexagonal packing. Each sphere thus has 12 neighbors.

The ordering of the 12 neighboring spheres must be examined carefully (Figure 7). *The center sphere is not sur-*

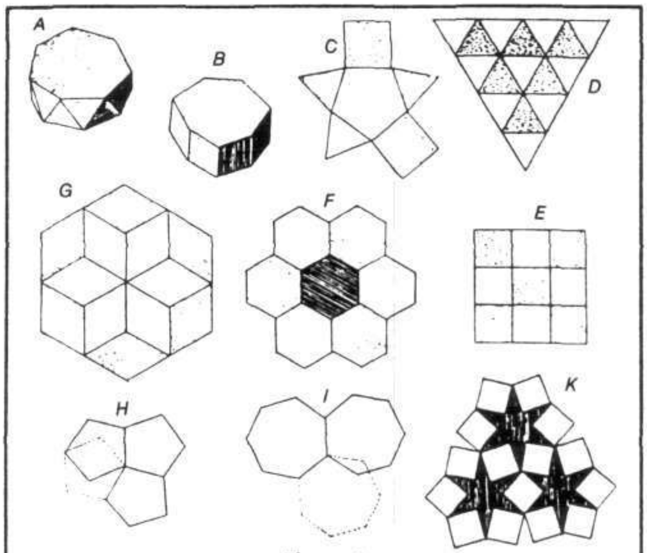


Figure 1
AVAILABLE FIGURES FOR HOMOGENEOUS GEOMETRIC PACKING ON A PLANE
This illustration from Kepler's Harmony of the World *shows the variety of geometrical figures that might be arrayed to cover a plane in a regular way with no gaps.*

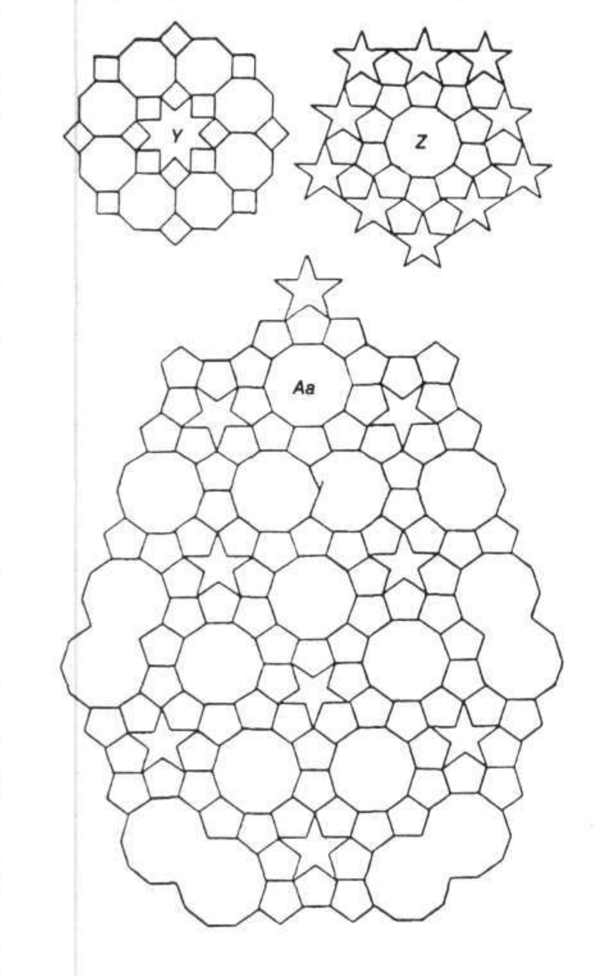


Figure 2
KEPLER'S ATTEMPTS AT HOMOGENEOUSLY FILLING TWO-DIMENSIONAL SPACE
Even with some pentagons and much imagination, Kepler shows here in this illustration from Harmony of the World *that there are gaps in the configurations*

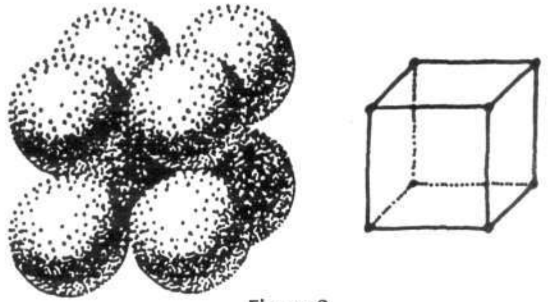


Figure 3
SIMPLE CUBICAL PACKING
There is no sphere located in the center; thus each sphere in an extended lattice has six neighbors.

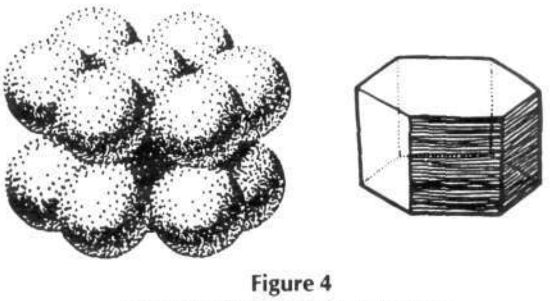


Figure 4
SIMPLE HEXAGONAL PACKING
Each sphere touches eight neighbors.

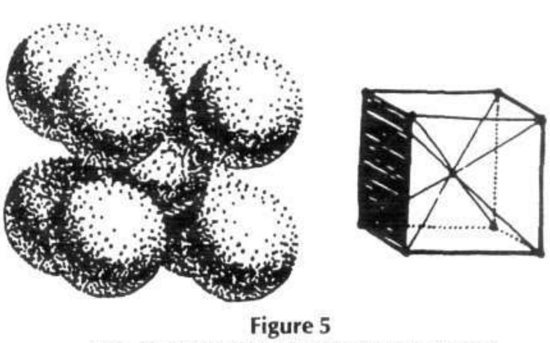


Figure 5
BODY-CENTERED CUBICAL PACKING
Each sphere here also touches eight neighbors.

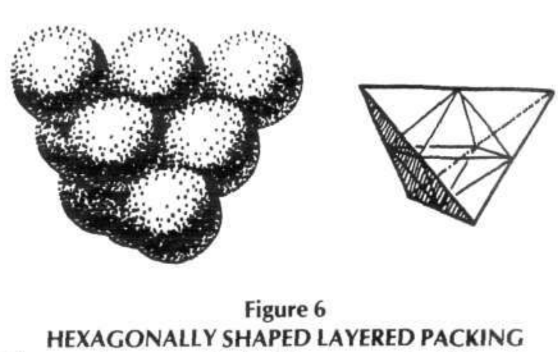


Figure 6
HEXAGONALLY SHAPED LAYERED PACKING
These spheres are stacked like cannonballs in a dense packing where each sphere has 12 neighbors.

rounded at regular distances, for then a small icosahedron would be produced (Figure 8), and the same problem would arise as before. Pentagons can cover no more than a plane. Is it possible to fill space with icosahedrons or dodecaderons (Figure 9), since these are also based on the pentagon or Golden Section?

Kepler was familiar with the properties of all these geometrical figures. He also knew the distinctiveness of the *process that produces pentagons,* in which *the Golden Section* is directly expressed geometrically. Kepler wrote, "On *analogy with this self-developing [golden] proportion,* the faculty of generation, as I believe, is revealed, and so an authentic five-pointed little flag is being carried ahead of that faculty of generation in the flower." It is, in fact, astonishing how often we encounter in living nature the dodecahedron and the icosahedron (which is, of course, directly formed from the connections of the midpoints of the faces of the dodecahedron). Not only higher organized living beings, but the smallest beings of few cells, such as radiolaria (Figure 10), have this form. Even in many viruses, which are located exactly at the threshold between living and dead matter, the proteins of the outer layer (the capsomere) are ordered in the form of an icosahedron.

Although Kepler recognized this principled distinction, he did not simply assert that all living processes show pentagonal geometrical forms while dead processes show hexagonal geometrical forms. He asked: "Is there a distinction between the faculty of form generation for the unfruitful and a second that forms the fruitful, such that the former creates triangles and hexagons, the latter, pentagons?" His answer is explicit: "[This] cause cannot be true so nakedly. For white lilies have three and six petals and are not unfruitful, and the same holds for many flowers. . . . I saw a beautiful piece of silver ore in Dresden from which a dodecahedron protruded, half the size of a hazelnut, sprouting as it were. And according to a description of the spa of Bad Boll, there is a mineral there with the upper part of an icosahedron protruding from it."

Precisely this observation seems to me important for application to the situation in contemporary physics. The previously considered icosahedron does not represent, for example, a virus, but rather a "cluster" of 13 atoms, and thus merely a dead clump of atoms. *Such clusters are formed* when a substance is very rapidly cooled; that is, with high energy-flux densities. They can, for example, be technically produced if a gas under high pressure is allowed to expand rapidly through a nozzle. (Under such conditions, the relative velocity of the atoms, that is, the thermal energy of the gas, decreases rapidly.) Such clusters of atoms are sharply distinguished from the crystals these atoms normally form. Iron clusters of fewer than 25 iron atoms have, for example, a strong catalytic effect that changes sharply with the size of the cluster. If the clusters contain only one or two atoms fewer, the catalytic effect changes radically—by a hundredfold. Such a change cannot be understood "parametrically," but only geometrically.

An interesting recent discovery concerns why the colors of old glass shine so brilliantly. The old masters understand an art today no longer known: They were able to inject the finest clusters of gold or silver dust into the glass. In the terminology of semiconductor technology, they "doped" the glass with such clusters, thereby producing the color and brilliance.

It was also discovered that atoms preferentially form together in groups of 13, 55, 147, 309, 561, and so forth. Immediately, there was talk of "magic numbers," just as there is in nuclear physics with reference to especially stable configurations of nucleons in the nucleus. That is, of course, nonsense: It is not a matter of "magic numbers," but rather of "geometrical numbers."

Another example of pentagonal geometry from inanimate nature, is a carbon cluster. Carbon, of course, plays a dominant role in animate nature. When carbon atoms group together, they mostly form tetrahedrons (Figure 11), that is, four atoms arrange themselves regularly around a single atom in the center. The group of six atoms forming the benzine ring is also familiar. According to the most recent experiments, the form in which carbon in the universe most frequently occurs shows an unmistakable pentagonal configuration, indeed, this is the form of an icosahedron truncated at the edges, the form of a soccer ball (Figure 12). If experimental conditions are created that are typical for the carbon-rich layers in the vicinity of stars, then the majority of the carbon atoms, previously irregularly distributed throughout a gas, group themselves into this configuration. Carbon in this form is possibly a component of interstellar dust, and thus a crucial catalytic agent for the transformation of interstellar molecules.

All these examples are characterized by the predominance of *extremely high energy-flux density* in the formation of these pentagonal figures in inanimate material. A further example—that of the mysterious crystal discovered only about a year ago from an alloy of aluminium and magnesium, for which cooling rates of 1 million degrees per second were necessary—will be discussed below. This example is very appropriate for finding a clue to the distinction between the geometries that predominately produce the Golden Section and those that do not. But before that, we must turn our attention to the connection Kepler made between the human process of knowledge and the process of nature. It will be helpful first to illustrate the way that a totally different and false point of view in physics has become dominant since Kepler's time.

Kant's Garden Path

Two developments were crucial in leading into the present dead-end in physics: First, the definitive propagation of Newton's dogma by Kant and, second, the establishment of the hegemony of the Copenhagen school of quantum theory. In both, the connection between understanding human thought processes and natural processes is of decisive importance.

Kant subjected nature to the rigid laws of Euclidian space and Newtonian mechanics. According to Kant, absolute space exists *a priori,* before any experience and independent of the real processes of nature. This is, naturally, nonsense, and gave Gauss grounds for his biting remarks about that "subtle philosopher." Merely to establish the distinction between left and right, we require a real physical process. We human beings can offer one another either the

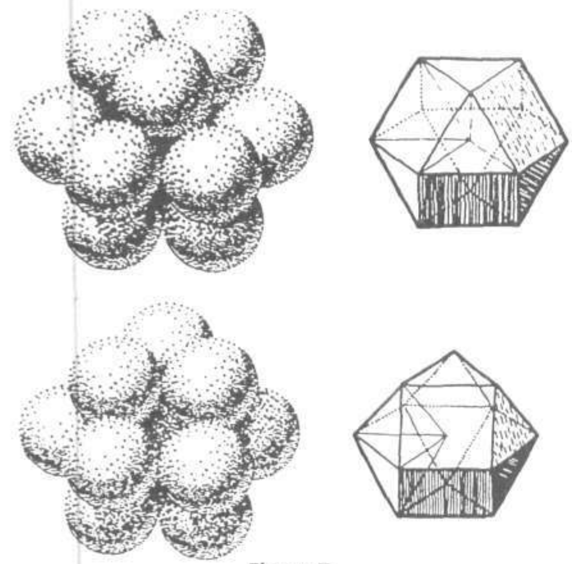


Figure 7
PACKING THAT CORRESPONDS TO BODIES COMPOSED OF SQUARES AND TRIANGLES
The center sphere is not surrounded at regular distances.

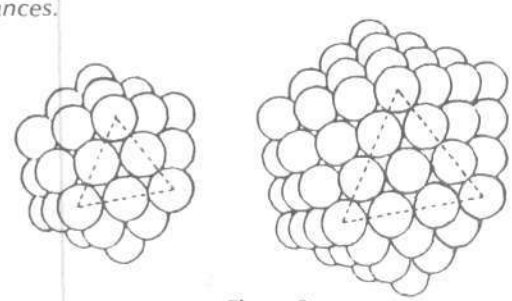


Figure 8
PACKING THAT FORMS AN ICOSAHEDRON
When the center sphere is surrounded at regular distances by 12 neighboring spheres, it produces an icosahedron.

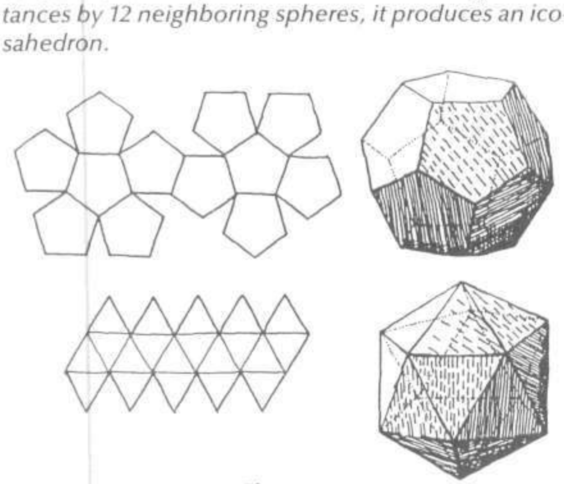


Figure 9
THE DODECAHEDRON AND ICOSAHEDRON
Is it possible to fill space with icosahedrons (below) and dodecahedrons (above)?

right or left hand. Even "inanimate" natural processes show the importance of the distinction between left and right, since, as Pasteur demonstrated, the direction of rotation is *unambiguously* established in real natural processes.[5]

Whoever understands the poet Friedrich Schiller's critique of Kant also knows what mistakes Kant introduced into that branch of natural science today known as "classical physics". That is possible because the supposedly independent and iron natural laws are formulated by men, not by nature. This began originally with Epicurus's atoms, which, according to his theory, behave as hedonistically and irrationally as Epicurus thought human beings should behave, and the same is true of Charles Darwin's theory of natural selection, which (as even Karl Marx ironically stated) merely represents a projection of all-too-human practices onto the animal world. It would therefore be asking far too much to expect that Kant would grant the creative freedom to the process of nature that he took away from human beings.

Consequently, however, the singularity is reduced to a *meaningless mass point*. It would be indifferent to Kant if the planets of the solar system along with the Sun were dissolved into a homogeneous mass soup in absolute space. With Kepler, that is not the case; rather, *the planets are necessary singularities* that were formed in the *previous process of coming into being of the solar system* in precisely the existing harmonic orbital relations. For that reason, the planets could not assume other, arbitrary orbits (which are, according to Newtonian mechanics, "energetically equally well justified"). Other orbits, "dissonant" with the whole, are unstable. *One consequence of this is that the solar system is in reality "quantized."* The planets are thus not free as individuals; rather, they participate in the creative development of the total process.

The connection between singularities and the negentropic development of the total process makes necessary the concept of *the relativistic manifold* of space, as Bernhard Riemann most extensively developed it. This concept is an improved form of Kepler's "geometry" that lay at the basis of God's plan of creation and with which human thought processes harmonize. (Riemann, in fact, was quite conscious of this metaphysical significance of his concept of the manifold.)

It is amusing to see how the dogged Kantian, Helmholtz, in a lecture titled "On the Facts That Underlie Geometry," announced his claim to priority on the subject versus Riemann, 2 years after Riemann's death and 14 years after Riemann's publication of his work "On the Hypotheses That Underlie Geometry."[6] Actually, Helmholtz went through a contorted exercise in order to save as much as possible of Euclidian geometry, which, according to Newton and Kant, is, of course, *a priori* the only geometry possible.

In summary, Kant, Helmholtz, and Maxwell understood neither the importance of singularities, nor the relation of such singularities to the developmental process of the universe, nor the general importance of the geometry (at that time, Riemannian) that mediates this relation. Only 50 years later, singularities began to appear in experiments in such a clear way that the structure of "classical physics" was

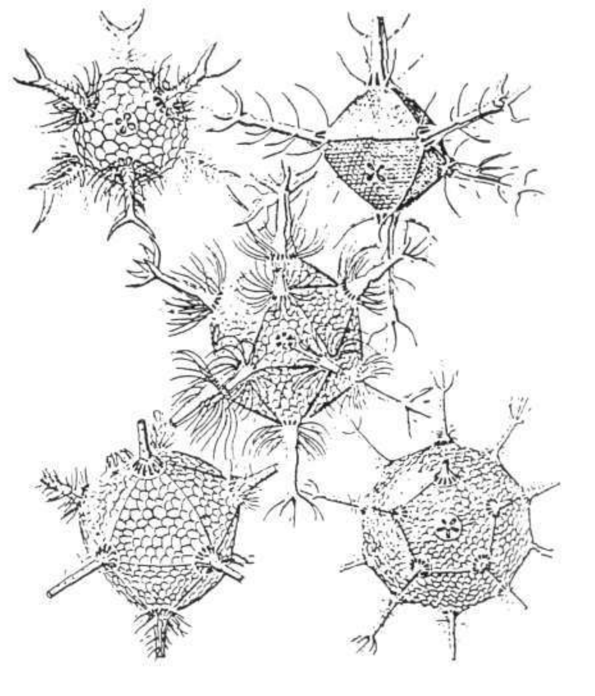


Figure 10
THE ORGANIZATION OF LIVING MATTER
These tiny living radiolaria demonstrate the icosahedral and dodecahedral organization of living matter.

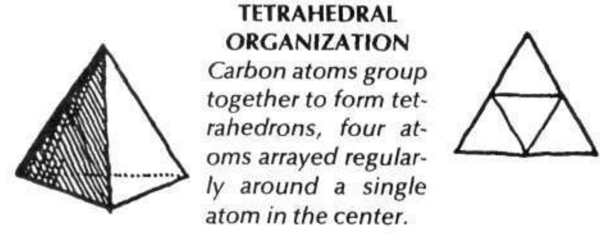


Figure 11
TETRAHEDRAL ORGANIZATION
Carbon atoms group together to form tetrahedrons, four atoms arrayed regularly around a single atom in the center.

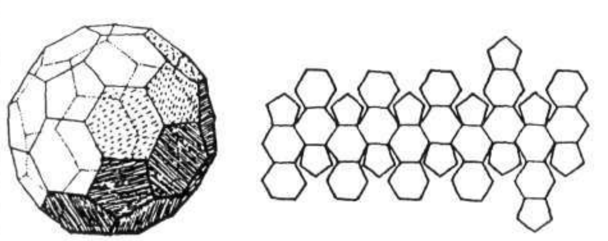
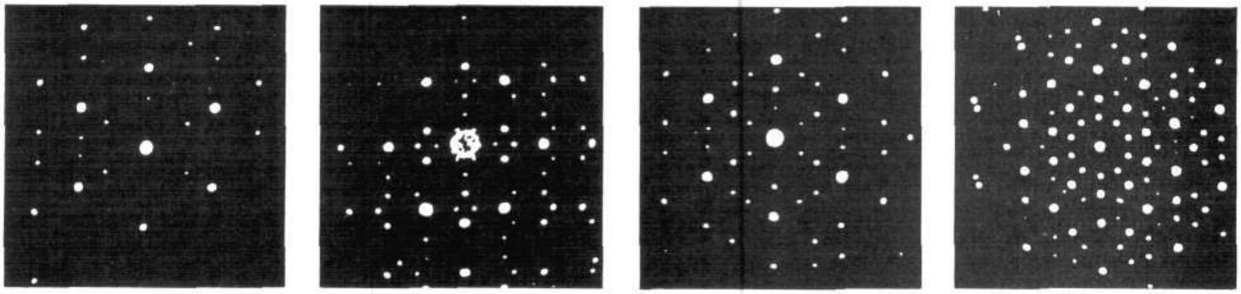


Figure 12
THE GEOMETRY OF CARBON
Carbon appears most frequently throughout the universe in a pentagonal configuration formed by icosahedrons truncated at the edges.



(a)

(b)

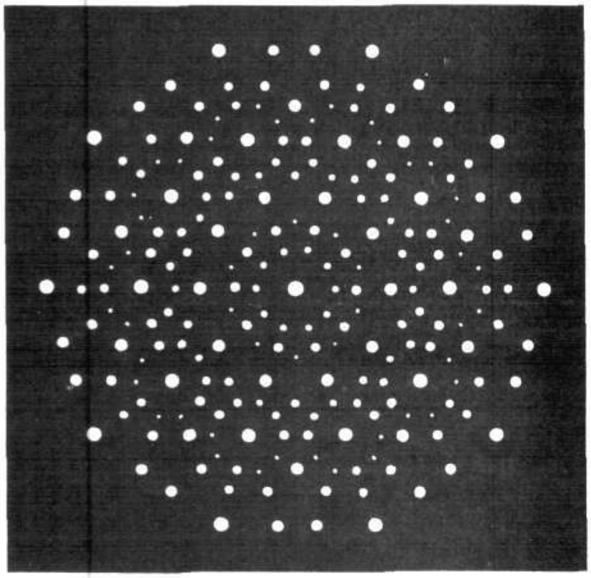


Figure 13
DIFFRACTION PATTERNS OF ALUMINUM-MANGANESE CRYSTALS

Diffraction patterns found by Shechtman and Blech when they exposed aluminum-manganese crystals to Roentgen rays using different angles of rotations. The three patterns in (a) on the left show the familiar hexagonal geometry. The pattern at far right, however, is extraordinary—pentagonal symmetry. The computer-enhanced image in (b) shows this even more clearly.

Photographs courtesy of D. Shechtman

creaking and cracking in every joint. Quanta of action, quantum jumps, photons, and so forth could simply no longer be ignored. A planetary model of the atom was developed, and, behold, this microscopic model allowed only certain quantum states, exactly as did the system that Kepler had already developed for the macroscopic planets of the solar system. Just as the rotational work of the solar system produces a line spectrum, the atom emits a line spectrum. That can only surprise those who had previously blurred real singularities in an absolute space.

Now, however, something ominous took place. Rather than clearly determining that the "banishing of the individual" makes a complete reconceptualization (in Kepler's sense) of natural science necessary, Niels Bohr explicitly allowed as much of classical physics to stand as possible. Only in one area, the microscopic, did Bohr introduce something new. And what was this something new? It was the previously suppressed singularities.

With Bohr, however, the singularities do not stand in a harmonious relation to the whole, but are completely "anarchistic and liberal individuals." In his "On the Constitution of Atoms and Molecules," the fundamental work of Bohrian physics, Bohr wrote: "The result of considering these questions seems to be that the inadequacy of classical electrodynamics for describing the behavior of systems of an atomic scale is generally acknowledged." Note carefully, Bohr used the word "inadequacy," not "falsity," and *he limited the inadequacy to "systems of an atomic scale."* Leibniz had previously insisted that the scientific truth of a hypothesis proves itself precisely in extreme cases of its application. If it fails there, then it must be considered false!

A hypothesis is either true or false. Whenever a hypothesis is recognized as false (even if only "partly"), and this is not taken as the occasion to push the process of knowledge further and to develop completely new hypotheses valid for the entire universe, then reality is split up for the scientist: He becomes a mere observer, and really is split into a vast number of different "truths."[7] The "partial" maintenance of a false hypothesis is the first step into the sort of madness that is so widely current in physics today. It is as if a physics professor today goes home and finds his wife in an unequivocal situation with one of his assistants, and he doesn't say, "My wife is deceiving me." Rather he asserts that the faithfulness of his wife is inadequate within certain "microscopic system areas . . . but in general, everything is just wonderful."

Since nature is not as irrational as Niels Bohr, "quantum processes" have not allowed themselves to be confined to the domain of an "atomic scale" to which he assigned them. They bustle out with delight into macroscopic areas. In all the effects now seen in lasers, superconductivity, or any crystal, "nuclear quantum effects" crowd lavishly as macroscopic realities before our eyes, saying: "Don't you ever want to explain the process of nature as a unified development process? Do you perhaps think that the universe produces singularities without reason? Why don't you use the method that Kepler applied?"

Applying that method is exactly what we intend to attempt here, by means of an example that recently caused great excitement among solid-body physicists and crystallographers.

Revolutionary 'Quasicrystals'

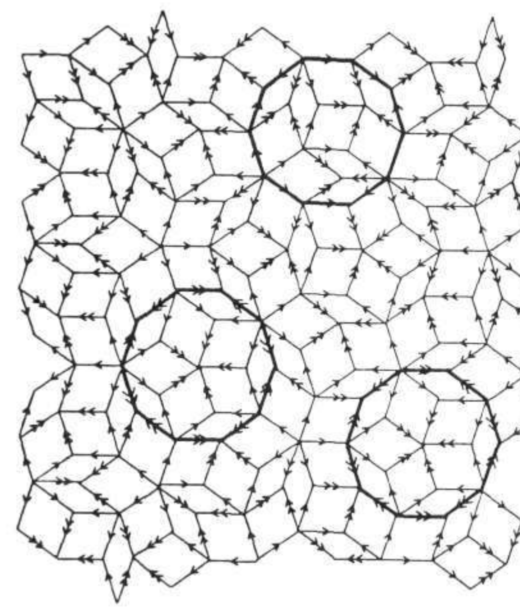
Every natural process is a self-reflexive process of reproduction, and crystals demonstrate the simplest reflexive process of this sort. Exactly as in the picture of the "bath tiles" in Figure 1, one after the other individual cell of the lattice repeats itself alongside the others, and then the next, and so forth. Yet this process cannot continue indefinitely. Every actual crystal becomes "irregular" at a certain limit (which depends particularly on the speed of the crystallization process). So-called displacements are produced, or the crystal is finished. This fact is very important. The universe as a whole is not a crystal, nor could it ever be one! Why not?

The "displacements" in crystals represent singularities of the second order that are produced by the crystallization process itself. Space was changed by the regular crystallization process. Any electron that ever participated in a process of superconduction could tell us quite precisely that there exists a qualitative distinction between empty space (the vacuum) and a portion of space filled by a crystal. After a while, the crystallization process produces a change that makes it impossible to continue the process in its initial form. A singularity of the second order (displacements, and so forth, appear) must mediate this process. As mentioned, velocity is decisive for the "density" of singularities of the second order. This being said, we can consider an extremely rapidly occurring crystallization process.

Approximately one year ago, American researchers D. Shechtman and I.A. Blech at the National Bureau of Standards performed experiments with alloys of aluminum and manganese. When they examined the electron diffraction pattern of the crystals produced under conditions of rapid cooling, they were as astonished as the surprised beginner who has just unintentionally succeeded in covering a bathroom wall with pentagonal tiles. The results were so good that no established physics journal would publish them out of fear of ruining its reputation. What the two scientists could finally publish in June 1985 in the magazine *Metallurgical Transactions* were the diffraction patterns in Figure 13. What do these patterns of bright light imply, and how could these patterns be formed?

Now, anyone is familiar with diffraction patterns who has not been too intensively involved in physics courses and who has, say, while relaxing in a meadow, sometime squinted his eyes at the Sun. The eyelashes of the half-closed eyes produce lovely patterns of rainbows from the white sunlight, a phenomenon already familiar in the breaking up of light by a prism. In less pleasant weather, the Sun can be replaced by a street light, which we observe through the finely woven material of an umbrella. Although perhaps not so romantic, this works just as well. Instead of a spot of light, each streetlight is seen as a small star. The number of rays from the star is dependent on how the umbrella material is woven. For each direction in which the regular cross threads run, two rays of the star located opposite to each other are produced. If the streetlight looks like a six-rayed star through the umbrella, then the umbrella material has three different directions of weave.

If we wish to determine the directions of symmetry of a crystal, we must replace the light source with a source of



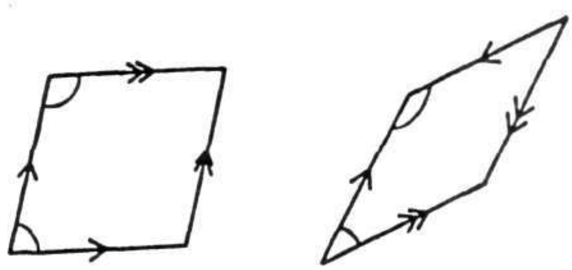


Figure 14
CONVENTIONAL VIEW OF QUASICRYSTAL FORMATION
Using two different rhombi whose area proportions have Golden Section relations, a crystal pattern can be formed that has pentagonal symmetry. This is a one-level manifold.

electron beam or Roentgen radiation. In place of the umbrella, we put the crystal body, which is then turned in different directions. Diffraction patterns are then produced, from which the planes of symmetry of the crystal can be inferred. We see here six-rayed stars in three directions, thus a triangular symmetry. From another direction of view, we see a simple mirror-image symmetry. But then we also see something that a decent crystal is simply not allowed to do: Considered from two directions, we find ten-rayed stars, and thus a pentagonal symmetry.

This presents a difficult problem. The elementary cells of the crystal seem to consist of nothing but icosahedrons. How can we imagine that? One possibility is found in the alloy of aluminum, manganese, and zinc. There, clusters of icosahedrons join together in a body-centered cubic lattice and fill the remaining space with 60 further atoms until a closed packing is produced.

Through more exact investigations, however, it could be concluded that the aluminum/manganese alloy already had a pentagonal substructure nested within a standard elementary cell. The pentagonal symmetry is present throughout. Normally, that means that with low energy-flux density, the aluminum/manganese alloy forms bricklike (orthorombic) elementary cells. If the energy-flux density of the crystallization process is increased beyond a critical point, the process undergoes a qualitative change.

It must be a double process, a close connection between two processes that have different characteristics. Thus the 200-year-old conception of crystals was demolished, as can be seen simply from the hapless technical expression "quasicrystal." We can, however, be happy about the fact that the question Kepler raised at the end of his essay on the six-pointed snowflakes is raised here again: What is the essential basis of those processes brought to light by the different geometrical forms?

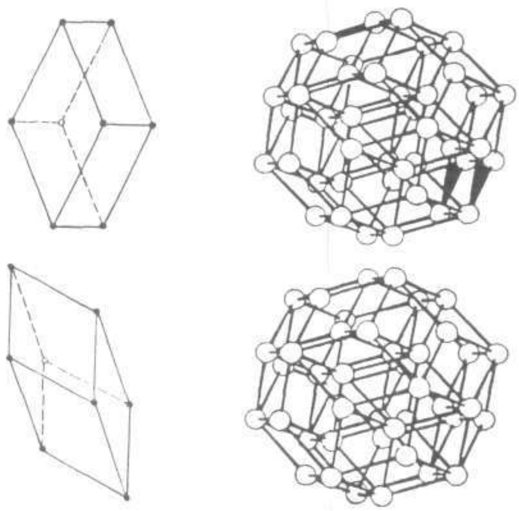


Figure 15
A THREE-DIMENSIONAL QUASICRYSTAL
A corresponding pentagonal pattern arises in three-dimensions using two rhombus bodies from Figure 14. This adds another degree of freedom, creating a two-level manifold.

A crystal, as previously understood, is a one-dimensional manifold, determined by the elementary cells. The attempt is made to explain the "quasicrystal" as constructed from two different elementary cells. In this way, we can imagine in the plane, for example, a closed covering with pentagonal symmetry from two different rhombi (Figure 14), whose area proportions exhibit the Golden Section. Translated into space (Figure 15), a corresponding pentagonal pattern arises from patterns appropriately composed of two rhombus-bodies. A "quasicrystal" represents, therefore, a two-dimensional manifold. A new degree of freedom has been added.

We can imagine this process as a superfast crystallization process, which runs so rapidly that the singularities of the first and second order come together within one process—simple multiplication and expansion in a negentropic process, which displays the "authentic little flag" of the pentagonal geometry of its singularities.

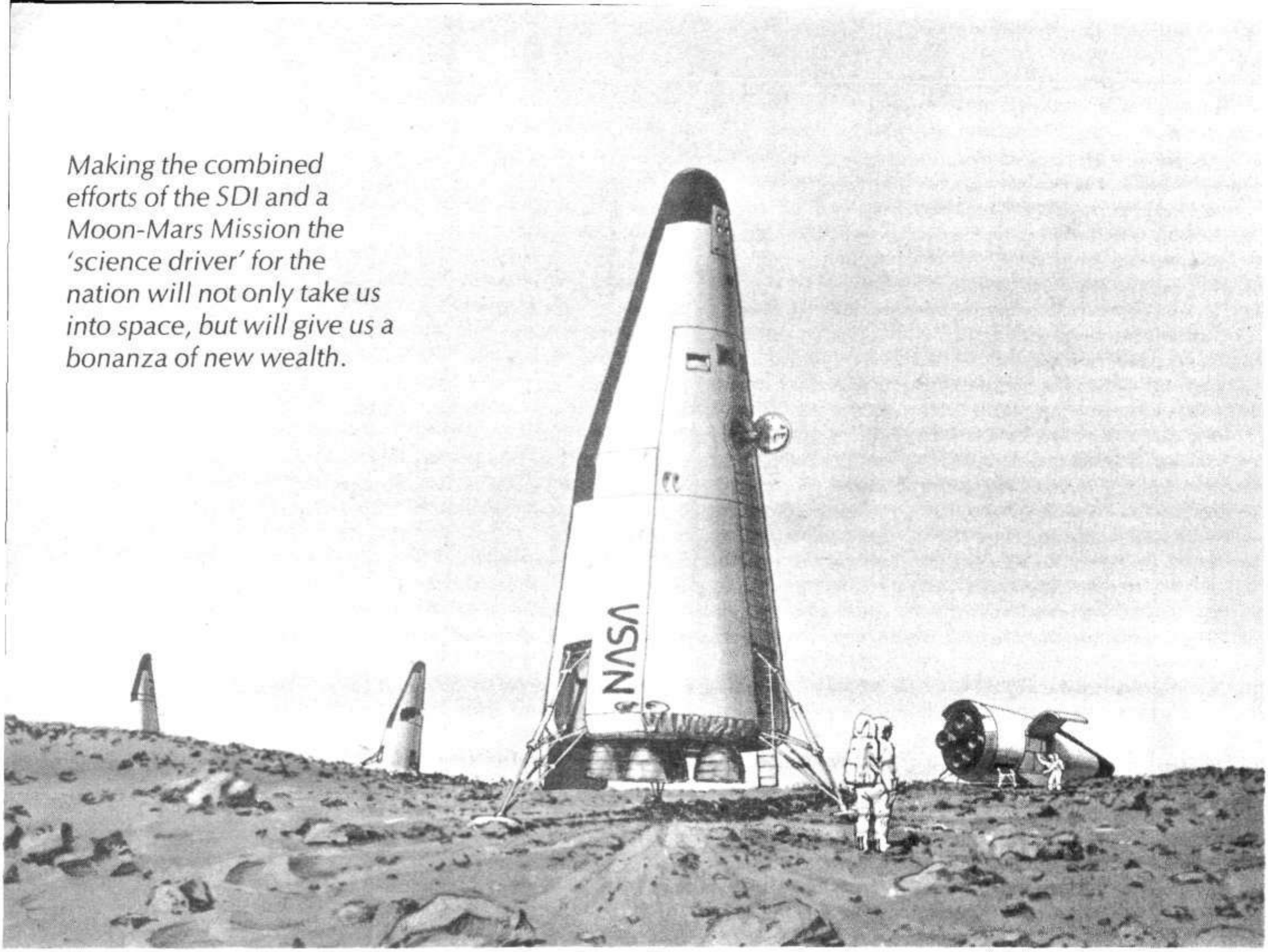
The self-evident particles of "classical physics," which are, at best, formally connected by continuous waves, cannot explain this process—and quantum physics with its "anarchistic" singularities even less. I believe, however, that we are about to rediscover and develop Kepler's nuclear physics of the snowflake. Kepler's "six-sided snowflakes" today have once again taken on a great weight.[8]

Ralf Schauerhammer is the managing editor of the German-language Fusion *magazine. His article was translated into English by John Chambless.*

Footnotes

1. To give but one example from many, we refer to the following statements, with which Prof. Alfred Gierer, director with the Max Planck Institute of Developmental Biology in Tübingen, began his article, "Body and Soul in Light of Physics," in the science page of the daily *Die Welt* Dec. 28, 1985: "Physics as the foundation of natural sciences is the science of lawful processes in space and time. With the development of quantum physics in the 1920s, the fundamental laws of physics can be regarded as completed. . . ."
2. Typical of the half-education propagated by the popular science magazine *Bild der Wissenschaft* is the fact that in the December 1985 edition, Kepler's essay on the snowflake was mentioned merely in passing, and in a manner that clearly indicated that the author had understood nothing whatsoever of the work apart from its title.
3. According to the surgeon, Professor Sauerbruch's autobiography, *Das War Mein Leben.*
4. Decisive is the bowdlerization of natural science into pure description, previously criticized by Georg Cantor (that is, "explanation" by the production of "models," as it would be put today). The problems of modern physics, especially the wave-particle paradox, spring from that epistemological fallacy, as it was already shown in Maxwell's works. See the German-language *Fusion,* No. 2, 1985, p. 37.
5. Warren J. Hammerman, "Louis Pasteur: Father of Today's Optical Biophysics." *Fusion,* September-October 1986, p. 19.
6. Helmholtz wrote there: "By the way, I must confess that even if the publication of Riemann's investigations preempted priority in regard to a series of my own results, it is for me. . . ." and so forth.
7. This problem is especially clearly expressed in Heisenberg's 1942 work "Ordnung und Wirklichkeit" (Order and Reality), where he stated—consistently following Bohr's logic—the necessity of different realms of reality. Thus, any criterion for the development of scientific hypotheses is lost. See also the German-language *Fusion,* No 5, 1985, p. 57.
8. For additional material on Kepler's "Snowflakes" and especially situating it within Kepler's works as a whole, see the magazine *Ibykus,* No. 8, 1984, p. 7.

Making the combined efforts of the SDI and a Moon-Mars Mission the 'science driver' for the nation will not only take us into space, but will give us a bonanza of new wealth.



Except where noted, illustrations here are paintings by Carter B. Emmart depicting a manned Mars mission as conceptualized by space scientist Jim French.

The Science and Technology Needed to Colonize Mars

by Lyndon H. LaRouche, Jr.

Rarely mentioned in news media accounts so far, forces around President Ronald Reagan are now working industriously to elaborate what could be seen by future generations as the crowning achievement of Mr. Reagan's Presidency: the commitment of the United States to establishing a permanent colonization of the planet Mars, 40 years from now.

Such a mission-assignment for the United States is fully feasible today, on the condition that we recognize that about 40 years of step-by-step work will be needed to bring us to the point that we can build the first self-sustainable Earth-like artificial environment under "domes" on Mars. We are presently developing each and all of the new technologies needed to accomplish that, although it will require about 40 years of scientific development and engineering to bring us to the point of applying those technologies to this specific task.

It is also economically feasible. For every penny spent on the research and development work of the NASA-manned landing on the Moon, we gained between 10 and 20 cents of income, perhaps even more, from the application of those technologies to our civilian economy. Civilian use of new technologies we shall be developing in connection with the Mars-colonization mission, will increase the average productivity of labor by at least tenfold over the coming

A Mars lander with a biconic design. The blunt side of the lander will maximize the use of Mars's atmosphere both for aerocapture in Mars-orbit and aerobraking to slow the vehicle down for landing. The first colonists are shown unloading supplies (in the background) from a cargo lander, after they emerge from a crew lander (foreground).

30 to 40 years, perhaps two to threefold by approximately the end of this present century.

The Mars-colonization mission is not only feasible, both technically and economically; it is urgent that we undertake this project, both for scientific reasons, and also for economic reasons. There are certain classes of technical and economic problems now developing on Earth, which we shall not solve on Earth without help from some of the scientific and economic by-products of a Mars-colonization project.

Above all, it is time that we begin work on that project.

The purpose of this present report, is to assist both policy shapers and the general public in understanding the most basic features of a 40-year Moon-Mars-colonization mission-assignment. We describe the most basic features of the project itself. We also describe the way in which such a project will affect life on Earth during this 40-year interval. The objective of the report is to provide the reader with an integrated view of both the project itself, and its impact on our lives back here on Earth.

The Technologies Needed for Regular Travel Between Earth and Mars

By about the time our astronauts first landed on the Moon, the United States had worked out most of the technologies needed for establishing an industrial colony on the Moon. Had the NASA program not been scaled down repeatedly, beginning with the 1966-1967 cutbacks, the United States would already have today, a functioning industrial colony on the Moon. With approximately 10 years of effort, beginning today, we could rebuild our space-mission capabilities to the point that we could begin such a colonization of the Moon.

For several reasons, the colonization of Mars can not be accomplished with the technologies we had either developed, or were working to develop, at the beginning of the 1970s. Essentially, the difference boils down to the fact that Mars is a far greater distance from the Earth than the Moon is. We need more advanced technologies to overcome the several kinds of effects of that great distance.

Therefore, setting the date for colonizing Mars had to wait, until we had begun to master four kinds of new physics breakthroughs: controlled thermonuclear fusion, as the primary source of energy used, lasers and other forms of coherent electromagnetic pulses as a basic tool, new developments in biological science of the kind now emerging around optical biophysics, and much more powerful, more compact computer systems to assist us in handling these new physics technologies. During the past dozen years, we have made some spectacularly promising breakthroughs in the four areas just listed. At an easily foreseeable rate of continued progress in these four areas of technology, all the conditions for establishing the first permanent colony on Mars could be met approximately 40 years from now.

For example: to bridge the long distances between Earth and Mars, we need continuous acceleration for about half the journey, and continuous deceleration for the second half. For the sake of the health of the passengers, it would be desirable to maintain the equivalent of a standard gravity on the surface of the Earth during the flight; the easiest way to do this is to fly the spacecraft at the appropriate constant rates, of both acceleration or deceleration. The proper way to achieve such continuous acceleration, is by use of controlled thermonuclear fusion, preferably using modes of fusion we call inertial confinement.

On the surface of Mars, we shall require a great deal of artificial energy. We shall consume much more energy per person than in the most developed industrial regions of Earth today, simply to maintain an agreeable artificial environment. The basic industries we develop on Mars, to produce essential materials from the natural resources available there, will operate at much higher temperatures than are used in any basic industries on Earth today. For these uses, we require energy generated at very high energy densities. This requires what we call today the second-generation level of controlled thermonuclear fusion, which should be on-line about 25 to 30 years from now.

The most common industrial tool we shall use on Mars is advanced forms of what we call lasers and coherent particle beams.

To master the problems of biology, both on Mars itself, and in long interplanetary flights, we require development of what we call today *optical biophysics*. Work in this area has been under way in the Soviet Union for decades, and, has begun to take off in the Western countries more recently.

To handle the new kinds of industrial processes used, both on Mars and in interplanetary flight, we require systems which use much more powerful computers than exist today, computer units which can perform the equivalent of a billion floating-point arithmetic operations in an average second, and also computer units which can perform what are called nonlinear calculations at the speed at which the controlled processes are reacting. The first kind of improvement in computer systems is already in progress, and first steps are now being made on the second problem.

So, one of the reasons we must allow 40 years for the beginning of permanent colonization of Mars is that decades are required to develop these four sets of technologies up to the level they are fully reliable for use at great distances from the nearest repair shop on Earth.

There are other reasons we must allow so long a period of time. Before we actually start building the first permanent habitation on Mars, we must complete a series of preliminary steps. The best way to view these steps is to look backward from a point in the imagination, about 40 years ahead. At that point, we shall have assembled in orbit above Mars, all the gear we need, to be taken down to the surface of Mars to begin building the first permanent habitation. Let us consider some of the steps which must be completed, before we have reached that point of readiness to begin the permanent colonization.

We start with the assembly of all this gear in Mars-orbit, and trace our steps backward, to indicate at least some of the major steps of preparation.

In The Orbit of Mars

Before beginning to construct the first permanent colony on Mars, we shall have made a significant number of interplanetary flights from Earth-orbit to Mars-orbit, and return. These flights will haul the materials needed to begin the colonization from something like a great railway freight-classification yard, in an orbit perhaps about 22,000 miles above the surface of Earth. The spaceships will haul this material from Earth-orbit to Mars-orbit, and return for another load.

Let us suppose that we use one of Mars's moons, Phobos, as the destination to be reached by those spaceships carrying freight. We might prefer to use a large orbiting, manned station, rotating to provide the personnel inside a reasonable gravity effect. The first thing would be to construct such a manned station, on which technicians and scientists would serve a tour of duty, before catching a return flight to Earth-orbit. The primary missions of the station will include the functions of serving as a spaceport and providing warehouse-management for the freight being parked, entrusted to their supervision, in Mars-orbit.

Let us turn our attention to those space vessels carrying the freight and personnel. Each will be very large, much larger than today's ocean supertankers. They will not fly on long solitary flights; since the United States began working on a manned Mars mission, at the beginning of the 1950s, it has been understood that the ships will fly in flotillas, each commanded by its captain, and the flotilla under the immediate, overall command of a flag-officer, of the rank equivalent to naval commodore or admiral. The minimum number will be about five in each flotilla. Physical communication among the ships, during interplanetary flights, will be provided by fast-flying "space launches."

We shall probably launch 5 or more flotillas during the time required for 1 flotilla to complete the journey from Earth-orbit to Mars-orbit. This suggests a minimum of 10 to 15 flotillas in various stages of outward and return journeys during the time any one flotilla completes its round trip: probably as many as 100 such giant space vessels in service during the period of buildup for the initial colonization of Mars.

Where shall we construct approximately 100 such giant space vessels? Most of the weight of the ships' components will be produced in industrial colonies on the Moon. Also, the greatest part of the weight of the freight carried to Mars-orbit will be manufactured on the Moon. Much of the preassembly will be completed in Moon-orbit, and the final work of assembly and readying done, possibly, in Earth-orbit.

The components supplied from Earth's surface, and personnel will probably reach the space terminal above Earth in two stages. In the first stage, the flight from Earth's surface will occur in transatmospheric aircraft, craft which lift up through the atmosphere as airplanes, and then shift to spaceflight for the remainder of their outward journey. These transatmospheric craft will carry passengers and cargo to a relatively low-orbit terminal, where the passengers or freight are transferred to space ferries, for the remainder of the journey to the space terminal.

Trace the developments leading up to 2026-2027 backwards in time, to the present. The result looks something like the following. The indicated dates are estimates provided solely for purposes of illustrating the conceptions involved.

Phase 1: Lift-off From Earth

(a) We must first build a space terminal, a permanent, expandable space station, above Earth. We shall also build a system of lower-orbit stations, as the place where both the transatmospheric craft and the space ferries dock to exchange passengers and cargo. We must build fleets of transatmospheric "shuttles," and "space ferry" shuttles. Complete this phase during 1995-2000.

(b) With the completion of Phase 1A, we must prepare the first steps of colonization of the Moon. This is done in a manner resembling the more ambitious preparations for the beginning of permanent habitations on Mars, but with very much less effort than for Mars. Complete during 2000-2005.

We construct the first permanent habitation on the Moon, approximately 2000-2005.

Phase 1 is done entirely with materials and technology supplied from the surface of Earth.

Phase 2: Industrialization of the Moon.

(a) Establish a Moon-based industrial power grid. Do this during a span of time which precedes and follows the establishment of the first permanent habitation there: about 2000-2010.

(b) Establish a self-sustaining supply of a major part of required foodstuffs and materials from the Moon, as the first step of agroindustrial development of the Moon, approximately 2005-2015.

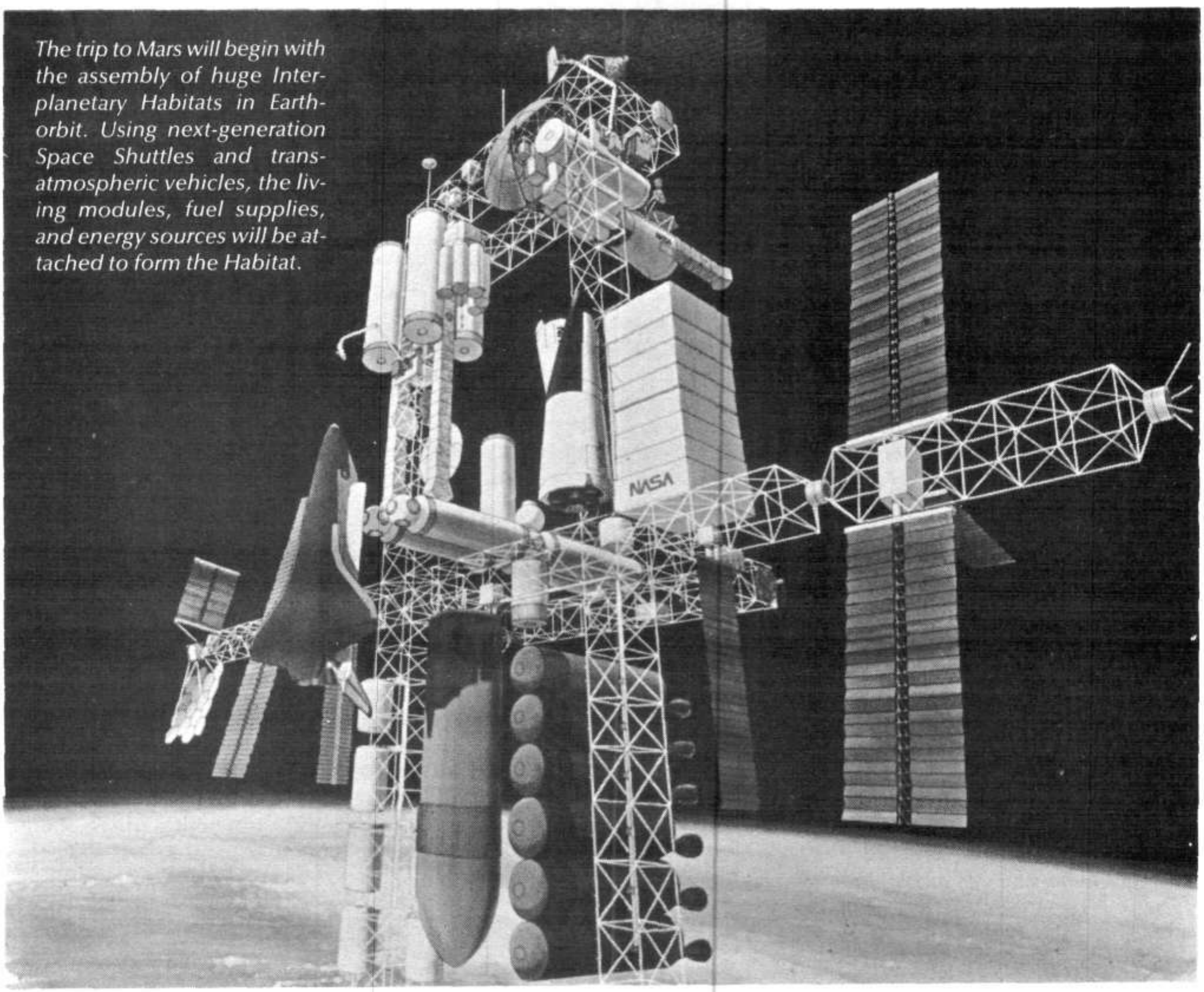
(c) Develop the first steps of space export-oriented primary materials production on the Moon, about 2005-2015.

Expand and improve the permanent habitations on the Moon at a pace ahead of industrial requirements: 2005-2015.

Phases 1 and 2 of the operation are based on perfected technologies available during the years 1995-2010. By about 2015, the industrial economy of the Moon is a significant space exporter, producing types of basic space-use ceramics materials and products beyond anything yet produced on Earth today.

Phase 3: Manned Exploration of Mars

(a) *Unmanned survey of Mars: 1995-2005.* Place a system



The trip to Mars will begin with the assembly of huge Interplanetary Habitats in Earth-orbit. Using next-generation Space Shuttles and trans-atmospheric vehicles, the living modules, fuel supplies, and energy sources will be attached to form the Habitat.

of permanent, unmanned satellites in orbit around Mars, and drop linked sensoring stations to the Mars surface. This will aggregate to a complete astrophysical observations complex, as well as a Mars survey.

(b) Place the elements, for assembly, of a future manned orbiting station in Mars orbit, circa 2005.

(c) *A series of manned visits to Mars-orbit in flotillas of approximately five exploration vessels.* During this phase, a series of craft is assembled in Mars-orbit for descent to Mars's surface: 2005-2010.

(d) Manned visits to Mars surface: 2010-2015. Manned flight to Mars-orbit is based on technologies perfected during 2000-2005. Manned visits to the surface are based on technologies perfected during 2005-2010.

Phase 4: Build Interplanetary Space-Fleet

Assemble approximately 100 such vessels during 2015-2025.

Phase 5: Launch Powered Flights of Flotillas to Mars

(a) Build the Mars-orbit space terminal: 2020-2025.

(b) Begin delivery of materials for constructing the permanent habitation on the surface: 2020-2025.

(c) Complete delivery of materials and personnel to begin main descent to Mars surface for constructing permanent colonization: 2025-2026.

Phase 6: Descend to Construct on Mars Surface: 2026-2027

The foregoing listing merely illustrates the conception of the phase approach required. Our leading points are to show that:

(1) the colonization of the Moon and Mars is an indispensable, integral feature of a Mars colonization mission;

(2) the steps required compel us to proceed in rather well-defined, pretimed phases;

(3) 40 years is a reasonable lapse of time for completing all the essential phases, not too tight a schedule, and not too loose a schedule.

This summary will now serve as background for discussion of the other key points to be considered. Next we shall consider some of the leading reasons we must colonize Mars; and then, we shall consider the benefits this will mean for people who stay behind on Earth, both during each decade of the coming 40 years, and later.

The Scientific Objectives

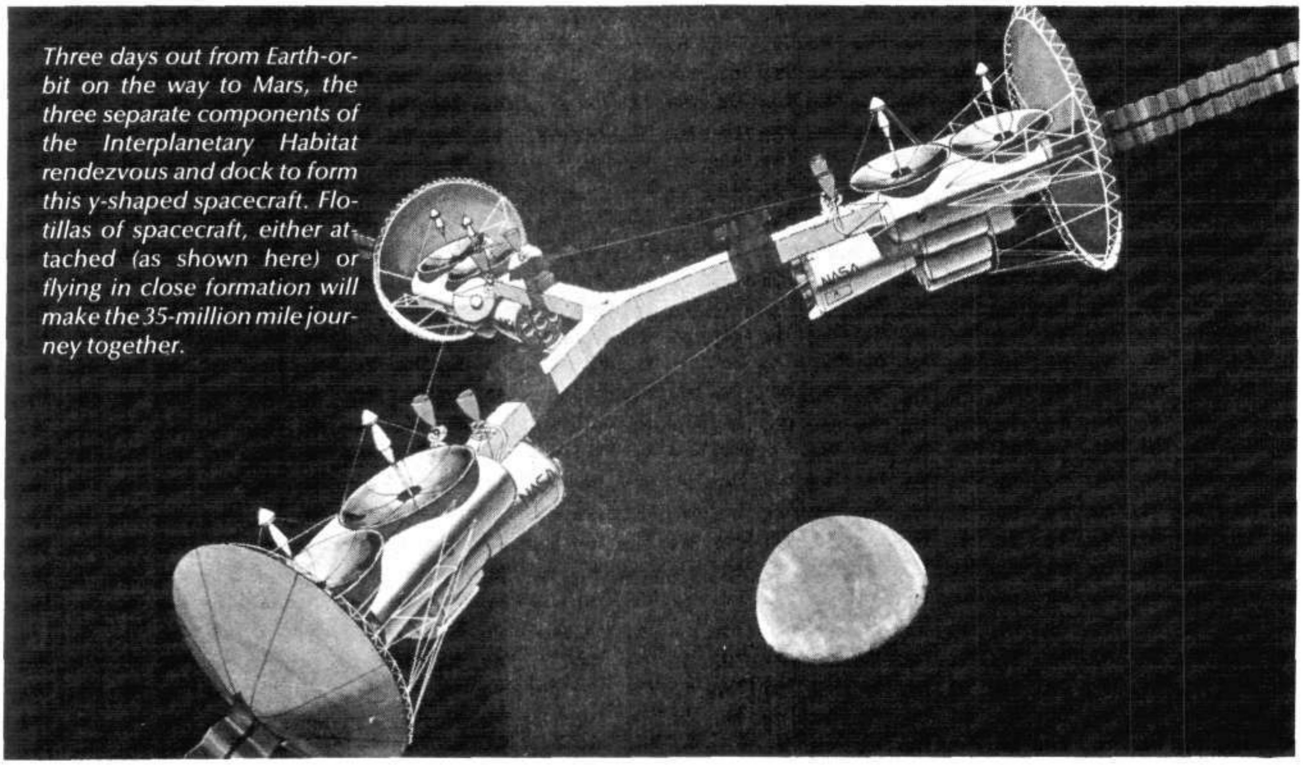
The astronomers are the first to tell us why we must go some distance away from Earth's orbit. The Earth's atmosphere prevents us from observing the full spectrum of radiation from the stars and galaxies, and we have reached near to the limit of what we can discover about our larger universe by Earth-based observatories. We can do a little better with telescopes and radiotelescopes in near-Earth orbit, but for many important measurements, the area in the vicinity of the Earth's orbit is a very dirty and noisy place. We must be able to measure the full range of the spectrum of electromagnetic radiation in space, from the very long wave to the very, very short: from every distant star, galaxy, and other phenomenon to be observed.

Building observatories as far out as Mars orbit, and beyond, will make young astronomers very happy, but our purpose for spending these many billions of dollars is obviously not merely to give astronomers some special sort of personal pleasure. The point is, with aid of such observatories, our astrophysicists will be able to answer many questions very important for life on Earth, questions which can not be answered without information from such complexes of space-based scientific observatories.

As physical science progresses, what was accepted as the best physics yesterday seems to break down around the edges. Usually, when this first occurs, the physicists mumble the ugliest curse word in their scientific vocabularies: "anomalous." At first, they look at the embarrassing experimental results suspiciously, thinking someone must have played a mean prank upon them. Sooner or later, some physicists warn: "It's no good calling these embarrassing experimental results 'anomalies.' We have to face scientific facts; there is something wrong with our existing scientific textbooks."

The history of "anomalies" is the history of fundamental progress in science. Modern science began with the work of Nicholas of Cusa. In 1440, Cusa published a book, *On Learned Ignorance (De Docta Ignorantia)* which accomplished, chiefly, two things. Cusa presented a discovery which modern science calls the Principle of Least Action, and which mathematicians refer to as the *isoperimetric theorem* (see Appendix). Cusa proved that geometry, as then taught, contained a fundamental error, and that this error had a bad effect on our thinking about physics. In the same book, Cusa presented a way of thinking about physics which set the stage for the later work of such leading figures as Leonardo da Vinci, Kepler, and Leibniz. Every step of fundamental progress in experimental science since has centered around discovering mistakes, called "anomalies," in generally accepted scientific doctrines.

By about the middle of the 19th century, with the work of Karl Gauss and his collaborators, science developed a more effective way of looking at this problem of "anomalies." It was established as a rule, that to settle any fundamental principle of physics, we must move away from the everyday scale of experimental work, and study the way in which the universe behaves at its extremes, the very, very large and the very, very small. In other words, we can not say that any physics principle is true experimentally, until we have proven that principle by means of astronomical observations and also on the size-scale of molecules, atoms, and subatomic behavior.



Three days out from Earth-orbit on the way to Mars, the three separate components of the Interplanetary Habitat rendezvous and dock to form this y-shaped spacecraft. Flotillas of spacecraft, either attached (as shown here) or flying in close formation will make the 35-million mile journey together.

It has also been recognized, off and on, since the work of Leonardo da Vinci, that we must also prove principles of nature *in a third region of physical experiments and observation:* living processes. Today's progress in optical biophysics is reminding us of that, once more.

In brief: The practical importance of astrophysics for life on Earth is that without the special kind of knowledge of laws of the universe we gain from astrophysics, we are blocked in scientific progress on the scale of everyday practice. Astrophysics, microphysics, and optical biophysics, are the frontiers of all scientific progress on Earth today.

To explore the behavior of the stars and galaxies, we must measure the full range of radiation from those sources. We must measure not only the visible light, but also microwaves and radio frequencies, the very large infrared spectrum, the ultraviolet, the X-ray region, and so forth. The farther from the Sun we make those observations, the better. What we are searching for is "anomalies" in our present textbooks' physics. We are searching for the kind of evidence, which compared with work in microphysics and optical biophysics, will enable us not only to uncover those "anomalies," but to solve them.

The rate at which science progresses on the surface of the Earth depends very much on these kinds of coordinated investigations.

A considerable amount of benefit can be gained from unmanned observational stations placed in various locations around our solar system. More and more, we are faced with the fact that there must also be manned laboratories and manned observatories in space, as well.

So far, most of our space exploration has been based on these kinds of objectives. This will continue to be a large part of man's work and life in space for the foreseeable decades ahead.

Once we move to place observatories and space laboratories at interplanetary distances, the idea of permanent colonies in space pops up. Once we think of putting a few dozen scientists and technicians at interplanetary distances, we are already raising the question of space colonization.

The logic of the problem is simple enough. To support a few dozen scientists and technicians in the "front line" missions of research in space, we must have a much larger number of people there to maintain the life-support systems on which those scientists and technicians depend. As soon as one has sketched the table of organization for the persons necessary simply to maintain those life-support systems, we realize that once we have decided to put a few dozen scientists and technicians into front-line space missions, we might as well put a few hundred such scientists and technicians out there. The size of the life-support staff needed to sustain a few dozen scientists, would actually support hundreds with relatively little more effort.

Once we have decided to put observatories and laboratories a significant part of the distance toward Mars-orbit, we see it is much better to go all the distance, and take advantage of the fact that Mars is the most convenient place to establish a logistical base for the more remote stations.

Once that point is settled in our minds, we must estimate the minimum population on Mars necessary to maintain all functions indispensable to life support on that planet. Even with continued logistical support from the industrial base on the Moon, we are in the range of a city-sized population in our initial Mars colony. We must stop thinking in terms of the word base, as we might say "Antarctica base"; the word we must use is permanent colony, a chiefly self-sustaining, permanent colony on Mars.

We might look at the project in this way. Think of it as recruiting several thousand scientists, and supporting research technicians, to staff the major U.S. laboratory in space research. However, instead of establishing this university-like research center in the middle of Arizona, we place it on Mars. To provide the goods and services the scientific teams and their families require, we develop a small city around the research center, analogous to the case of Los Alamos.

This population is composed of human beings, not robots, and also not fellows clomping around in space suits in some Hollywood science fiction sort of space opera. Without a human ecosystem, many of them would go mad, or nearly so. Building an atmosphere on Mars so that the colonists could bicycle or hitchhike around the planet's highways, might be a bit farfetched for the foreseeable future; cities and farms in Earthlike artificial environments, under large domes, is the more likely prospect for the foreseeable future. Within such domes, human activity and environment must be as Earthlike as possible. Think of a similar center placed in the middle of the Sahara Desert: pretty bleak and unlivable outside the oasis under the air-conditioned dome.

An Illustration

To make a bit clearer, the kind of work which requires large colonies of scientists in space, we describe some of the relevant features of one type of work to be done.

To analyze and measure radiation from very distant astronomical objects, as accurately as today's leading scientific questions require us to do, we must construct what we call lenses of very large aperture, floating in space at some distance from Earth. These *lenses* measure a great variety of kinds of radiation from distant sources.

Such supergiant astrophysical lenses are not the solid sheets we ordinarily associate with giant telescope mirrors. They are built up out of a kind of mosaic of many individual sensory devices, each separated from all of the others by rather large distances of interplanetary solar space. The total number of such sensory devices would be distributed over an area many thousands of miles in diameter, and even much larger. The radiation sensed by each and all of these component devices is coordinated, as "information," by a supercomputer, a computer of capacities way beyond anything presently in use. The bigger the area of the "lens," the more precisely we may focus on very distant objects and regions of galactic and intergalactic space. The principles involved are very basic principles of known electromagnetic optics.

Ask a mature young astrophysicist dealing with anomalous cosmic ray and other radiations from the Crab Nebula region, or fast-rotating binary-star complexes, or "black hole" regions, what he would really like for Christmas, something which is technologically thinkable today, something which would be of great practical value for exploring the most important kinds of anomalous phenomena with precision. While he is thinking about this, interrupt him with a hint: "Imagine a lens with an aperture on the scale of the Mars orbit." He will respond with statements to the effect: "That's technically possible; you have just described every astrophysicist's dream."

What we shall accomplish by about 2027, will be far more modest than that, but we shall be moving in such directions.

This is not science-fiction fantasy. This merely describes, on a larger scale, what we are already doing today. We are already using this kind of technology. The importance of very-large-aperture lenses of this sort in interplanetary space is not only a very well-defined technologic requirement; there is a well-defined need for such observatories in terms of leading problems of present-day physics. Any good physicist can write out a list of specifications for building and operating such devices in space, as well as writing out a list of some of the observations which are indispensable for settling certain fundamental anomalies of physics today. This list of requirements for improved technologies is fully covered by the technologies we have indicated as needed, and developable, for starting a permanent Mars colony by 2026-2027.

There are fundamental principles of physics, which recommend developing such observational instruments along one of the solar system's available Keplerian orbits. The physics significance of Keplerian orbits, is that they are what are sometimes called force-free pathways, or better named "Least Action" pathways. We must use this principle of "neo-Keplerian" physics (Kepler's work as corrected by Gauss et al.), to ensure the desired stability of the lens's mosaic, to minimize the perturbations in the lens-object's relative position with respect to the other elements of the mosaic. Earth's orbit is one of those accessible to us during the coming decades; the Mars orbit is a happier choice.

The kind of observatories which justify, and which require, Mars-colonization belong more or less to the family of such instruments we have just described. Thus, we are dealing with thousands of elements of each large mosaic, each of which requires either direct, manned intervention, or robotic intervention under human control within that locality of interplanetary space.

Similar considerations apply to manned laboratories, and semiautomatic laboratories in interplanetary space. A whole range of industrial and other production and research projects, most of currently known practical importance for life on Earth, are involved.

So, within the span of the foreseeable future, about two to three generations ahead, we must anticipate tens of thousands of scientists and engineers working in interplanetary space. Much of this work has a more or less well-defined urgency for settling questions which are important to life on Earth itself. To support tens of thousands of scientists associated with such projects, either permanently in space, or on extended tours of duty there, requires colonies in space with populations on the scale of important cities on Earth today.

All of this requires powered spaceflight, preferably at accelerations and decelerations with the effect of one Earth gravity, or higher accelerations in craft modified to reduce the effect on the passengers and crew to that of one Earth gravity. It requires the conditions which can be provided only by 40 years of the kind of development we have outlined here.

The Spiritual Imperative for Conquest of Space

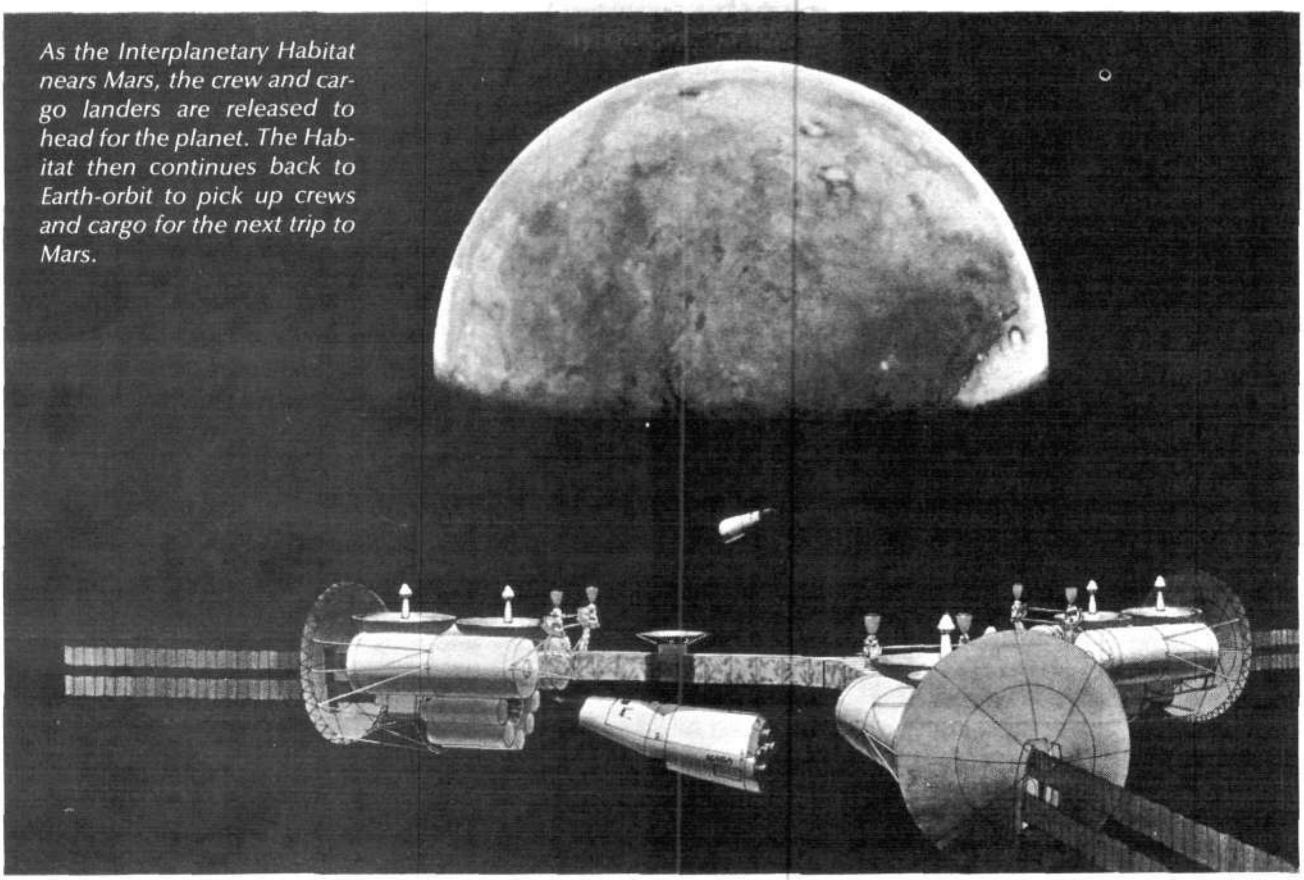
Empiricists generally, and behaviorists in particular, have a definition of "human nature," which is very simplistic, very wrong, and very morally degrading. They insist that "human nature" is based essentially on irrational sorts of hedonistic impulses, or "instincts." It is not accidental, that the behaviorist psychologists base their research into "human nature" on close observations of monkeys and other beasts. They are flatly wrong; human beings are not beasts, at least not the sorts of individual one should wish to have as a neighbor, or to marry one's daughter.

Human beings are absolutely distinguished from beasts by virtue of the fact, that every normal newborn infant has what is sometimes called "the divine spark of reason." This spark, if developed, enables each of us to develop the power of creative reasoning, the quality of reasoning typified by the work of the best scientific discoverers. Such persons are potentially of great benefit to both contemporary society and future generations: One new, useful idea, discovered by such an individual mind, is of benefit to all mankind. This benefit is partly direct. It is also indirect: new, better ideas to come, will start from the most advanced discoveries of preceding scientists.

This same spark of reason, gives man not only the capacity for scientific discovery, which no beast can do. This spark of reason is the basis for durable ideas of beauty, and for that quality of lovingness toward other persons typified by Christian love: not bestial forms of erotic "love," but what the classical Greeks called "agape." Everything that is good and beautiful in a person, is a reflection of the development of this divine spark of reason.

It is the potential for development of this divine spark of reason, which places mankind above the beasts, which defines mankind as in the image of the living God. This quality which sets each of us above the beasts, is our true "human nature." The fuller realization of this beautiful potential in ourselves, is our true self-interest.

If this be our "human nature," then what does this nature tell us is mortal man's proper destiny? Can it be anything but the efficient self-development of that capacity for good which is the divine spark of reason within us? To be good, can never be separated from good deeds, from work which



As the Interplanetary Habitat nears Mars, the crew and cargo landers are released to head for the planet. The Habitat then continues back to Earth-orbit to pick up crews and cargo for the next trip to Mars.

is consistent with goodness. Which, then, is the goal: the deeds of which goodness makes us capable, or the goodness which is affirmed by such deeds? The answer to this seeming paradox is elementary: Good deeds are necessary to the fulfillment of the quality of goodness in ourselves; it is by responding to the challenge about us with good deeds, that we strengthen goodness within us. To become good, by aid of deeds which respond properly to whatever practical challenge faces us, is our true self-interest, our true goal.

What we have just said, goes far from everyday thinking today. Ordinarily, only theologians, philosophers, and a handful of scientists who think philosophically, concern themselves with such ideas. For that reason, most readers may have some difficulty, both in grasping the concept we have just described, and in recognizing the practical importance of such ideas in day-to-day life. At this point, we must make the idea clearer, and show the reader the practical importance of such ideas.

The philosophy we have just outlined, is indispensable for any society which has entered the era of exploration and colonization of space. No person could survive extended periods in space exploration or colonization, without adopting this point of view: Without this philosophical outlook, many of them would break down psychologically under the impact of a gradual accumulation of "subliminal" psychological stress.

This will show up, sooner or later, as the major human flaw in the Soviet space program. Psychological problems of this type have already appeared around the edges of the impact of space exploration on sectors of the U.S. population, including some veterans of that program. The difference between us and the Soviets on this account, is that Western culture provides us with the resources needed to overcome the "culture shock" of space exploration, whereas Russian culture, both Soviet "materialist culture" and present-day relics of pre-Soviet mysticism, does not.

Although this philosophical "technology" is indispensable for extended space exploration and colonization, the reality and importance of this principle is rather easily demonstrated by suitable forms of reflections on the recent 2,500 years of European culture. The problem addressed has "always been there"; the conditions of space exploration on a large scale, over extended periods, merely brings this "factor" up front as an immediate practical issue of great importance.

Think back to the greatest heroes of European culture, since Solon of Athens during 599 B.C. Although some aspects of their contributions to our civilization are still of continuing practical importance today, most of the practical things accomplished in their lifetimes have vanished into the dust: used-up, outlived parts of our civilization's earlier history. Yet, however obsolete most of their practical work has become, our civilization would not have progressed as far as it has, in its best periods to date, had these heroes of the past not lived. The question posed to each of us, by the example of these heroes, is: "What is durable, and therefore most important, in our mortal lives?"

Brilliant new discoveries of today, make many ideas of the preceding time obsolete. Later, many of today's discoveries, and great deeds, too, will be made obsolete. So, we are forced to recognize that there are two ways of looking at our mortal lives. On the one side, we place the emphasis upon the concrete actions which seem to make a person important or unimportant during his or her lifetime: the actions which make one appear to be important, or unimportant to most contemporaries. On the other side, we look at ourselves as we look back to the great heroes and devils of the distant past; many of the things which appeared most important to the opinion of their contemporaries have vanished into the dust of past events.

The second view instructs our conscience: What is important in our living and having lived, is our contribution to human progress. The specific acts we perform have importance, of course. But, the aspect of those actions which survives, is the way those actions either contribute to the progress of man's moral and material self-development, or have an opposite effect.

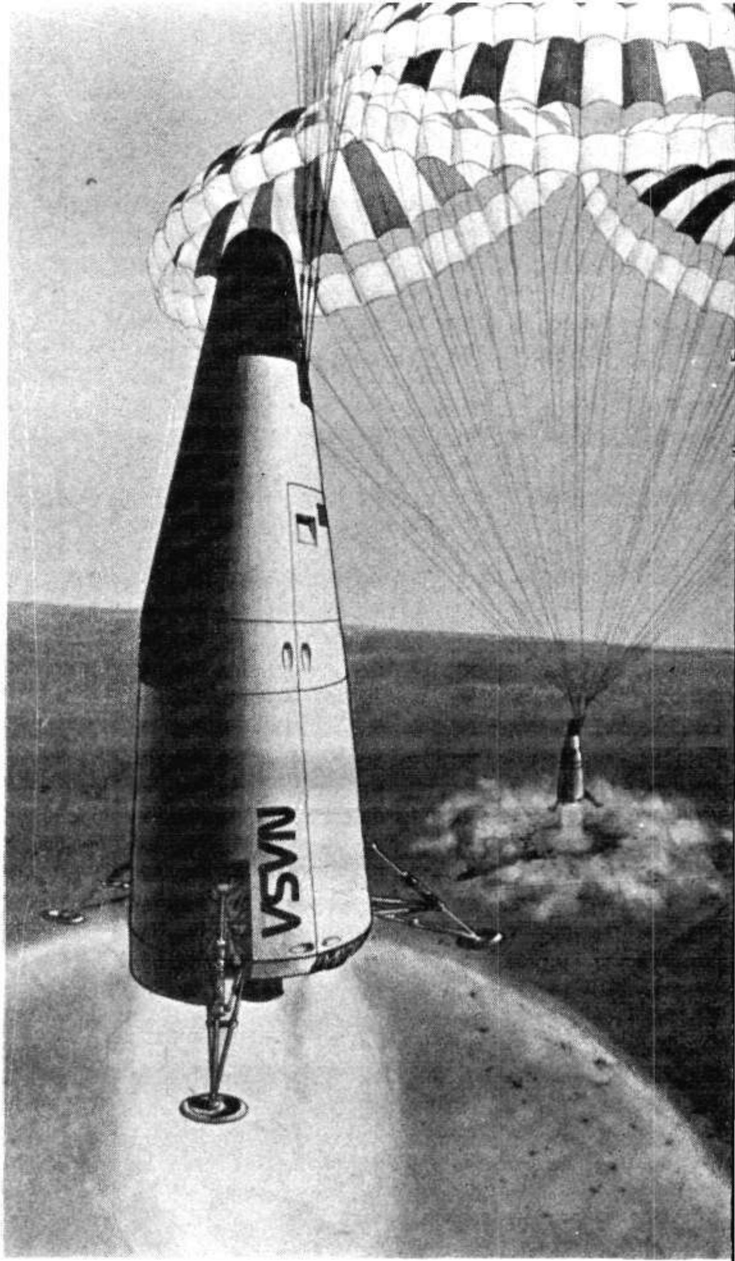
The simplest case, is the obscure parents engaged in the sustenance and loving rearing of a child. For that child to develop, the child must be sustained materially, of course. Therefore the physical care of the child is an essential part of a moral act. However, the essential thing, is the development of that child's character. The very least contribution made by the development of the character of a child by its parents, schools, and so forth, is the child's capacity and resolution, as a later adult, to the building of the character of his or her own children and grandchildren. In this way, the most ordinary activities of parental life, even by an illiterate mother confined to the limits of ordinary life in the household, the extended family, the local community, have a moral outcome which extends to far-distant generations.

From this historical vantage point, this historical way of looking at individuals of both the distant past and the present, the most essential aspect of a good and important action by a living person, is that person's moral character and scientific intellectual development. It is the ability to choose between right and wrong, and the ability to react to challenges in a way which is efficiently consistent with goodness, which enables an individual, or an entire nation, to choose and to perform the kinds of actions which will be rightly judged as beneficial by later generations.

Let us call this combined development of the moral character, and science-like intellectual development, the pursuit of the good. This quality of goodness, as developed in the individual and the nation, is that person's, that nation's potential for responding to contemporary challenges in a way which will have enduring value.

As we have indicated here, so far, at least implicitly so, there are limits to our power to foresee the practical work which will confront our grandchildren and great-grandchildren. Each decade ahead, the exact nature of that work becomes less and less concrete, less precisely exact. Even the most developed scientists can not look much more than 50 years ahead in forecasting the general levels of technology, and related problems, which might confront our grandchildren and great-grandchildren.

How, in that case, can we know whether the outcome of our generations' work will be ultimately good or disastrous? Our capacity to pose suggested answers in practical terms, is a limited one. We find ourselves on sure ground, only if we make our more fundamental goal, the enrichment of the moral character and science-like intellectual development of the coming generations. If we can accomplish that, we are preassured that our grandchildren and great-grandchildren will have a greater moral and scientific capacity than we today; therefore, they will be better equipped to perpetuate the good into the 50 years following their lifetimes, than we.



Unlike the Moon, Mars has a thin atmosphere, which will allow the use of landing parachutes to slow the landers, in addition to retrorockets. At right is the first cargo lander; at left is a crew lander.

To make this point clearer, consider the case, that we make the United States a great economic and military power, unchallengeable, on either count, by any nation or combination of nations on this planet; yet, we neglect the development of the moral character of our children and grandchildren. In that case, as we see in the fallen nations

and empires of the past, those grandchildren and great-grandchildren will destroy this nation with wrong choices.

That has been precisely the root of our undoing over the postwar period to date. Our postwar State Department turned our foreign policy away from the nation-building perspective we developed during the war years under President Franklin Roosevelt. We allowed the subversion of the morals of the nuclear-family household, the rock on which the development of the child's character depends. We allowed the immoral subversion of our educational systems. We tolerated the spread of the rock-drug-sex counterculture during the past quarter century. Although, into the middle of the 1960s, we continued to be the world's greatest economic and military power in history, over the past 20 years we have frittered both away, through our neglect of the moral character building of our children and grandchildren. It is those so-mistreated children who are now taking the lead in destroying the institutions upon which our nation's future depends.

Our essential task is twofold.

First, on the practical side of policy shaping, a wise nation lays the foundations for what will be bequeathed, materially, to our posterity, 50 years or so ahead. The ordering of the leading practical goals of our nation to be consistent with, and sparked by the Moon-Mars colonization mission-assignment, essentially fulfills the practical side of our obligations to posterity's general welfare.

The Moon-Mars colonization mission, illustrates the point, that what the world and our nation will be, 50 years from now, will depend upon what we do, or fail to do, during each of the five decades between now and then. To build a house, or an industry, the basic economic infrastructure and the foundation of that house or industry must be constructed first. To operate a farm, wasteland must first be developed as fertile land. It would be impossible, 50 years from now, for our posterity to do the kinds of things a successful Moon-Mars mission makes possible, unless, during each of the next five decades, we accomplish the step-by-step tasks needed to make this possible. That, our posterity can not control; that is our moral responsibility to the future generation of this nation, which no one but we can do.

Second, whether our grandchildren and great-grandchildren will build upon, or destroy what we have bequeathed to them, depends chiefly upon the development of their moral character. Provided we have bequeathed our posterity a good material foundation, the rest depends upon their moral character.

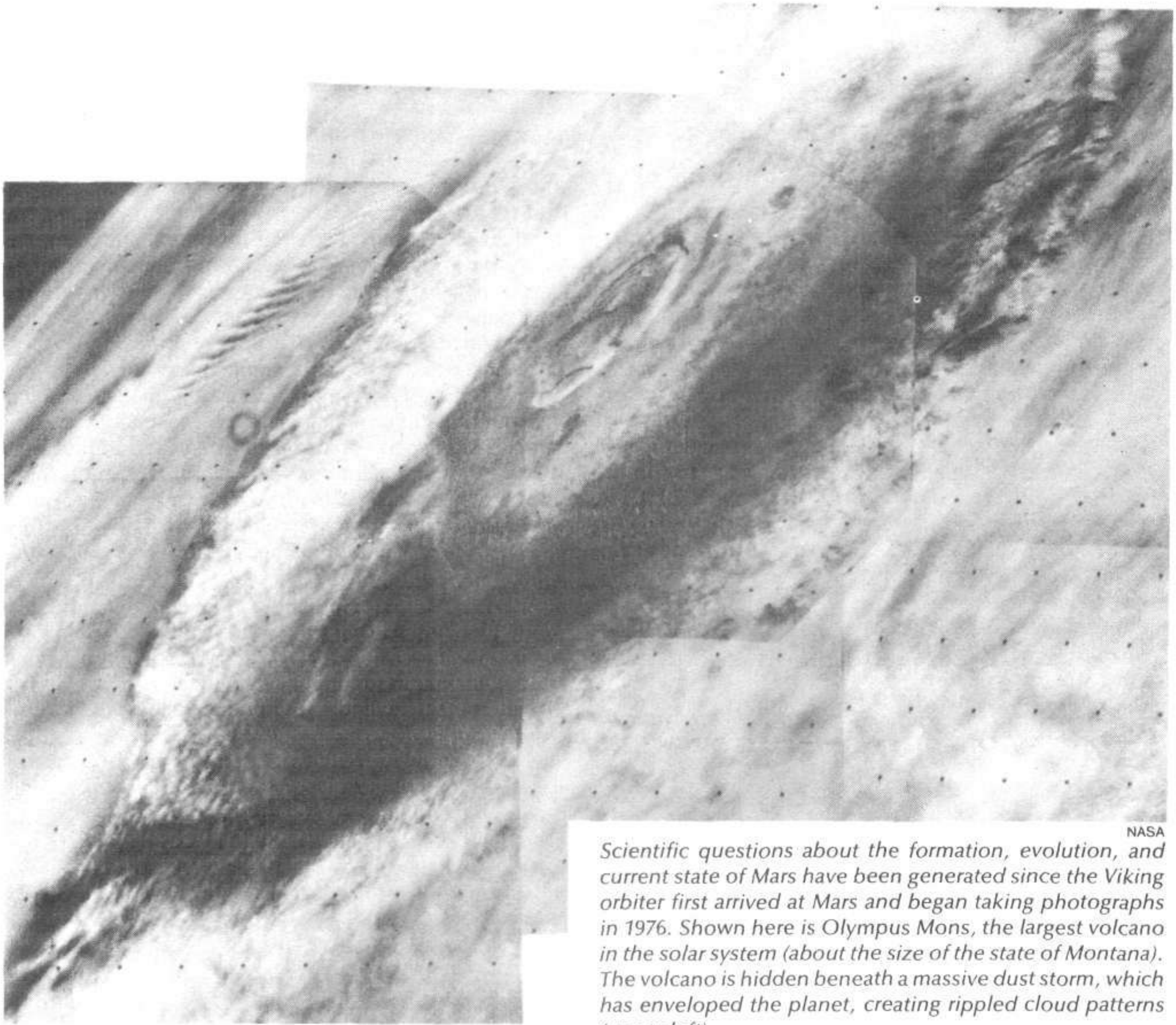
The first, the material basis for the future 50 years ahead, is indispensable, but the second, the development of the moral character of our posterity, is what is essential, what is fundamental.

The practical question on which we are concentrating here, is: How should we think, in order that we may place the essential and the indispensable both in the properly coordinated perspective? It is the development of good moral character and science-like intellectual development of the individual and the national culture, which has permanently efficient effect. The meeting of the practical tasks of present-day society, is indispensable to the perpetuation of the good; however, if the development of the moral character and science-like intellectual development of the individual and the culture is consistent with the principle of the good, then each generation will tend to make the right choices of leading practical tasks.

We must think of a process of the self-development of the good within our national culture. In this process, it is the development of the good which is fundamental, and the practical tasks merely the indispensable activity of goodness.

Our potential capacity to act and think in this way, is bequeathed to us as the essential thread of Augustinian culture. The work of the great Jewish reformer and collaborator of St. Peter, Philo of Alexandria, contributed nourishment to the elaboration of Christianity, as our Judeo-Christian heritage is summed up in an integral way by the work of St. Augustine. This culture incorporates the Socratic method of Plato, while correcting the crucial theological defect in Platonic paganism.

The center of Augustinian culture, from the special, limited standpoint of European civilization's statecraft, is the way in which Augustinian Christianity defines the human



NASA

Scientific questions about the formation, evolution, and current state of Mars have been generated since the Viking orbiter first arrived at Mars and began taking photographs in 1976. Shown here is Olympus Mons, the largest volcano in the solar system (about the size of the state of Montana). The volcano is hidden beneath a massive dust storm, which has enveloped the planet, creating rippled cloud patterns (upper left).

individual. We define the individual as being in the likeness of the living God, in respect to that divine spark of potential for creative reason in the person. This divine spark defines each person as a universal existence, both spiritually and from the vantage point of practice of statecraft.

This universality is most readily portrayed from the standpoint of reference to the individual scientific discoverer. Although each scientific discoverer depends upon the contribution of his or her entire society, past and present, to the development of his individual powers: each particular scientific discovery is the work of an individual human mind. As this discovered idea for practice has impact upon all humanity, present and posterity, so that discoverer is a universal being by virtue of the development of his or her individual character, as an individual character.

As we have indicated already, the same universality of the individual personality, applies also to the simple parent who shapes a positive outcome of the development of the child's character. It applies to all who use the development of their moral character, of their science-like intellectual development, as an integral part of whatever work they perform.

If the individual, developed in this moral way, is conscious of this kind of universality as his or her personal identity, and as the essential center of his or her personal self-interest in life, we are thus presented with the kind of person morally, philosophically prepared for the work of space exploration.

The Military Analogy

The astronaut traveling for extended periods into deeper interplanetary space, experiences a stress akin to that of the soldier in combat. He is far removed from what his rearing as child and adolescent defined as acceptable circumstances, committed to a hostile and deadly strangeness. This sort of effect upon the astronaut is projected back upon the nation and Earth-bound civilization which that astronaut represents, just as the fate of the combat soldier has profound impact upon the population of his nation. Just as the nation participates in a war far from its shore, through its combatants, so the nation participates psychologically in the astronaut's space exploration. It is not merely the astronaut who is working in space; we, as a society, are in space. We, as a society, experience the essential cultural impact more immediately confronting the astronaut traveling at a remote distance.

War is war, and space exploration is just that; however, the psychological experience varies among definable psychological types of soldiers, and, similarly, definable types of space explorers. The analogies between war and space exploration, and in the comparison of psychological types of combatants in warfare, shed important light on the proper moral philosophy for a space-exploring society. It sheds light directly on the penalties of a poor choice of philosophy, and also sheds light, implicitly, on the beauties of society's participation in such exploration.

The killing of human beings is, by its nature, bestial, and therefore bestializing in tendency of effect upon he who kills or merely prepares to kill. In the worst sort of psychological type of combatant, "coming up ugly," mobilizing the feral beast from the lowest, most infantile depths of one's personality, predominates. In the opposite psychological type, the killing exists only as the indispensable act in service of a moral purpose; this is the combatant-type closer to the mind-set of the astronaut. The latter psychological type is a combatant far from home, distant from home physically and psychologically. Whether as soldier or as astronaut, the adversary is attacked impersonally; this type of soldier does not kill for "personal reasons," but for reason of love of duty to the higher moral cause of his nation, the motive which has brought him to the theater of warfare. His motive is the essential, to which the indispensable is fully subordinated psychologically, philosophically.

The contrast between the two psychological types of combatants is illustrated by the way in which General Douglas MacArthur combined his magnificent display of principles of mobile development during World War II and the war in Korea, and the consistency of this military excellence with his approach to the administration of defeated Japan. The same point is illustrated by contrasting General Patton's application of mobile development to the relative incompetence of Field Marshal Montgomery's leadership. The same difference in character shows up as the intrinsic superiority of the character of the U.S. soldier during World War II to the Soviet commander and soldier of World War II and today.

Soviet commanders are excellent professionals, but there is nonetheless a potentially fatal defect of morality and culture in their character, and the character of current Soviet war plans and capabilities as a whole. This same defect must tend to come to the surface in what seems otherwise a brilliant Soviet approach to space exploration. It is that defect, as something similar might appear in our space-exploration policy, which is the point we are moving to stress at this point.

In the literature of chess play, there are many instances of what are called "brilliancies." The uncritical spectators are awed by the brilliantly crushing humiliation of the defeated player. Yet, in each case more closely examined, the "brilliancy" of the victor is more the result of some folly by the loser, than any remarkable intellectual power of the victor. Present Soviet war plans for a crushing military first strike against the United States are aimed at this sort of "brilliancy." Soviet leaders precalculate to the last decimal point, an overwhelmingly crushing first-strike blow, followed by a brilliant military "end-game." Against a capable adversary, this same Soviet "brilliancy" would be the key to a Soviet defeat as decisive as Hannibal's crushing of the Romans at Cannae. The most vulnerable flank in the Soviet strategic capability, could that flank be effectively exploited, is Soviet psychology and culture. The Soviets are better than Montgomery was, by far; but as Patton would have defeated Montgomery decisively, so the Soviets have a kindred psychological vulnerability.

The Soviets are very good, on condition they have a precalculated overwhelming preponderance of force deployed, and on the condition that their adversary agrees to play by the rules as the Soviets preconceive the rules. On condition that the Soviets move, as planned, from point A to objective B, and that the outgunned adversary accepts battle on these grounds, the Soviets would probably win. If the adversary changes the scenario quickly, to make objective C, D, and so forth more decisive than B, the Soviet war plan is in serious trouble. They can not improvise new dimensions of mobile development as the best U.S. commanders and their forces have done in the past.

We suffered an analogous blunder of military policy in the recent U.S. war in Southeast Asia. Our military forces were deployed according to definitions of objectives and means of warfare controlled by the U.S. foreign-policy establishment. General Giap and others exploited this "Montgomery-like" folly of the U.S. political command, by applying the principle of "mobile development" to a much broader dimension of warfare than operating U.S. combat doctrine could effectively address. From a purely military standpoint, Giap's approach could have been flanked, had our policy been based on bringing U.S. superiority into effective play; however, as long as the United States played by the "set-piece warfare" rules of the game dictated by the U.S. foreign-policy establishment, the U.S. position was effectively flanked by Hanoi's strategy. The superiority of U.S. society and culture was kept out of play: our advantages in effectively deployable technology and our culturally determined disposition for innovative mobile development.

What we have thus identified as the most admirable features of military policy, are also at a premium in space exploration. The superior qualities of combat potentials, for mobile development, of the generally unmilitaristic U.S. society, flow from the fact that our nation was founded upon a republican form of elaboration of Augustinian culture: our emphasis upon the social equality of the individual, a value which may be modified only as one person is developed as of a better moral character and greater science-like intellectual development than another. These are the qualities which best lend themselves to successfully sustained space exploration.

It is the lack of this feature of our historically determined moral and cultural superiority to the Russians, which presents the Soviets with profound psychological problems in extended space exploration. Their present and past culture prevents most among them from developing the kind of philosophical outlook indispensable for withstanding the psychological stress of extended space exploration.

At present, broadly speaking, Americans lack those psychological potentials for space exploration which existed during the 1960s and earlier. Through the influence of those irrationalists, such as the "ecologists" and the counterculture generally, many of our citizens have lost connection with the principles of moral character and science-like intellectual development traditional to the Augustian heritage. We, as a nation, are presently in the process of being self-destroyed by the growing influence of the "ecologists" and the radical counterculture. Over the recent 20 years, we have undergone a "cultural-paradigm shift," away from Augustinian tradition, toward a philosophical outlook akin to that of the Russians.

This recent difficulty is not, however, an argument against space exploration. Precisely the opposite; the psychological demands placed upon our society by bold ventures into space, are precisely the stimulant best recommended to bring us back to ourselves, our moral heritage.

There are many practical things which must be done, urgently, to save our nation. These are the indispensable, which we shall lack the resolution to accomplish, unless our decision-making once again embraces the essential.

Space is there. It is a challenge within man's grasp. It is a challenge which bears upon the improvement of life on Earth. We must respond to that challenge with goodness.

What is the desire of the good person? What else but to discover the laws of creation less imperfectly, to the end that our knowledge, as guide to our practice, deviates less from that will of the Creator expressed in the lawful ordering of this universe. Who can be good, who does not yearn for agreement with the Creator, and, on that account, to lessen the imperfection of one's own understanding of the lawful ordering of creation?

What could be a more beautiful event in the existence of mortal mankind than to step up from the mud of our planet, into space, to accept whatever challenge we discover to be awaiting us there? To think of such a task as imminently before us, is to experience an awesome sense of beauty within us.

On this planet, especially during the recent 20 years, increasing portions of the populations of even Western Europe and the Americas are afflicted with cultural despair.

"There is no future," say the doomsaying "ecologists." Believing the "ecologist" propaganda, the young person seeks momentary escape in the here and now: Drug usage proliferates, destroying growing ratios of our youth, on this account. That same stink of irrationalism and cultural pessimism, which spawned the Nazi upsurge in Weimar Germany, spreads among our nations, spoiling the very will of our nations to survive.

We must turn the mind's eye of the young upward, to the heavens, while we point: "There lies the future of mankind."

In that respect, the conquest of space is a prize beyond price.

The Economic Benefits of Space Colonization

The economic benefits of space exploration are of two classes. The less significant of those two classes of benefits, is products imported to Earth from space. The principle benefit, is the improved technology Earth gains through knowledge derived from the process of space exploration.

We consider the first class of benefits briefly, to get this out of the way. We are then free to concentrate our attention on the vastly more important, and more complex kinds of benefits, of the second class.

Bringing any sort of heavy cargo from space to Earth's surface, is an idea best suited to the unscientific mind of the Hollywood space opera writer. The cost per ton of interplanetary flight, and the costs of bringing cargo from Earth-orbit, down through the atmosphere to our planet's surface, mean, that we shall never use mines on the Moon, on asteroids, or Mars, or anywhere else outside the Earth, for materials of production back here at home.

The only products sane people are likely to bring from space to Earth, are products which have a relatively immense value per pound of weight. The often-discussed growing of industrial crystals in the low gravity Earth-orbit, is typical of the limited classes of products we shall actually import from space laboratories. Otherwise, we shall import some scientific samples for our laboratories and teaching institutions, and perhaps a few small souvenirs.

Forget the idea of building giant mirrors in space, to catch large globs of sunlight for broadcast to the Earth's surface. There are some interesting engineering problems posed by discussing such a possibility, but, economically, the idea is a very silly one. "Solar energy" for industrial or residential use, is not "free." Collecting the energy is the most expensive way to obtain energy, in dollars per kilowatt, yet imagined, vastly more expensive energy than that from fossil fuel or nuclear plants. Currently, we spend more energy in producing and maintaining solar collectors, than the total energy we obtain from such collectors during their entire useful lives. The idea that industrial solar energy will ever be economically competitive with other forms of industrial energy, is an unscientific pipe dream, fit only for Hollywood scriptwriters; the energy-density cross section of solar energy, as measured in kilowatts per square meter, per hour, means that no possible solution will ever exist for this economic problem.

That does not mean that solar collectors are useless; they are useful to the degree they are very light and portable, and can be used therefore where other sources of energy are not available. Until we establish an industrial power grid on the Moon, for example, they would have worthwhile functions as a supplementary part of total energy sources used by the advance exploration and construction teams.

However, even in such exceptional cases, we could never rely significantly on solar-energy collection. The essential features of colonization of the Moon include getting oxygen and hydrogen from rock, for supplies of synthetic air and water. To accomplish this economically requires energy feedstocks of very high energy-density cross section, by industrial standards. We must rely on fission and fusion modes of generation of energy, and a heavy reliance on energy-dense tools such as lasers.

Generally, in tons, Earth will export a great deal into space and obtain very little import from space in return. Production in space will be for export. We shall mine the Moon, to produce most of the weight of our space fleet, and most of the weight we bring for early stages of Mars-colonization. Most of this mining and production outside the Earth will be done for a few elementary purposes:

(1) to reduce the cost of transporting weight from Earth's surface to Earth-orbit;

(2) to limit the drain on Earth's primary resources;

(3) to provide local supply for colonies in space.

The chief export from space to Earth will be knowledge. That knowledge will be worth vastly more to the inhabitants of our planet than any physical objects we might import from other planets and moons. That knowledge will be worth vastly more than the Earth's total investment in space exploration.

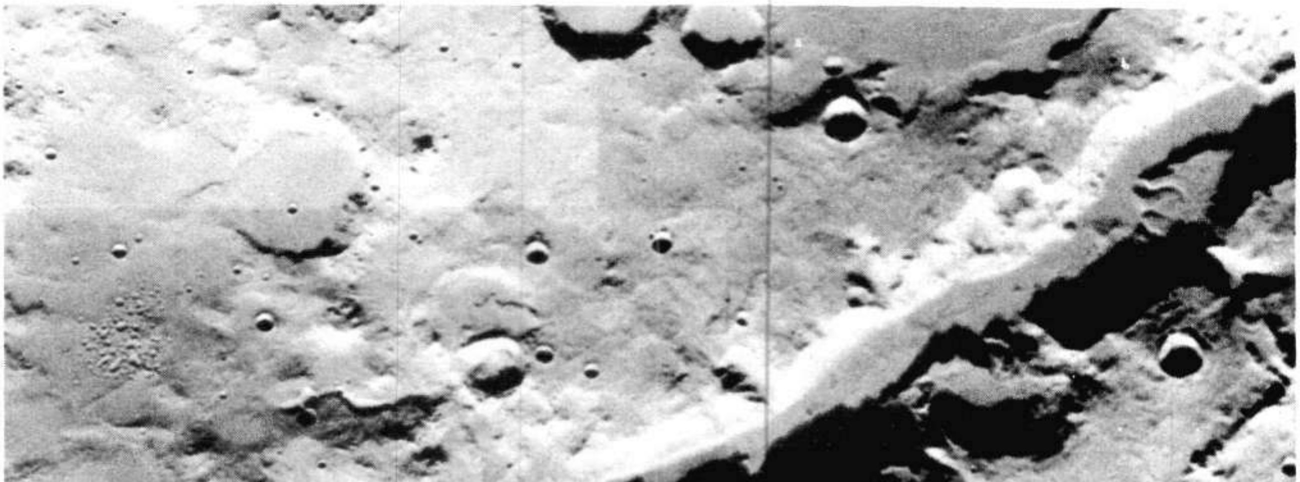
The "payback" on the investment will come in two forms.

During the next 40 years, the chief "payback" will be the most rapid rate of growth of productivity on Earth in human history. If we start now, the productivity of the United States will more than double present levels by the end of this century. By 2027, the average productivity in the United States will be at least 10 times what it is today.

All of those increases in productivity, or at least nearly all of them, will be the result of development of branches of physical science already being developed on Earth today. By forcing ourselves to develop these technologies, as the schedule of the Moon-Mars colonization program forces us to solve one problem after the other, we create inventions, based on those technologies, which will greatly increase the productivity of industry, and will also result in great improvements in quality of products bought by businesses and households.

Once our space observatories and laboratories have been functioning for a while, a new element will be added to increase productivity on Earth. This will begin to happen about the end of the present century, provided we follow approximately the schedule of steps suggested earlier in this report. By aid of our work in space observatories and laboratories, we shall make discoveries bearing upon the fundamental laws of our universe. Many of these will be discoveries we could, perhaps, never have made, except by aid of such space exploration.

So, whereas most of the increase of Earth's productivity, during the first 20 to 30 years of the program, will come



NASA

The channels on Mars were once believed to be the handiwork of intelligent beings, but the evidence indicates that the catastrophic release of flowing water carved out these rifts. The largest of the Martian channels, similar to the one seen here, would stretch from New York to California.

from developing the established frontiers of science, between 20 and 40 years ahead, the impact of new discoveries made by aid of space exploration, will tend to become a dominant feature of technologic progress on Earth.

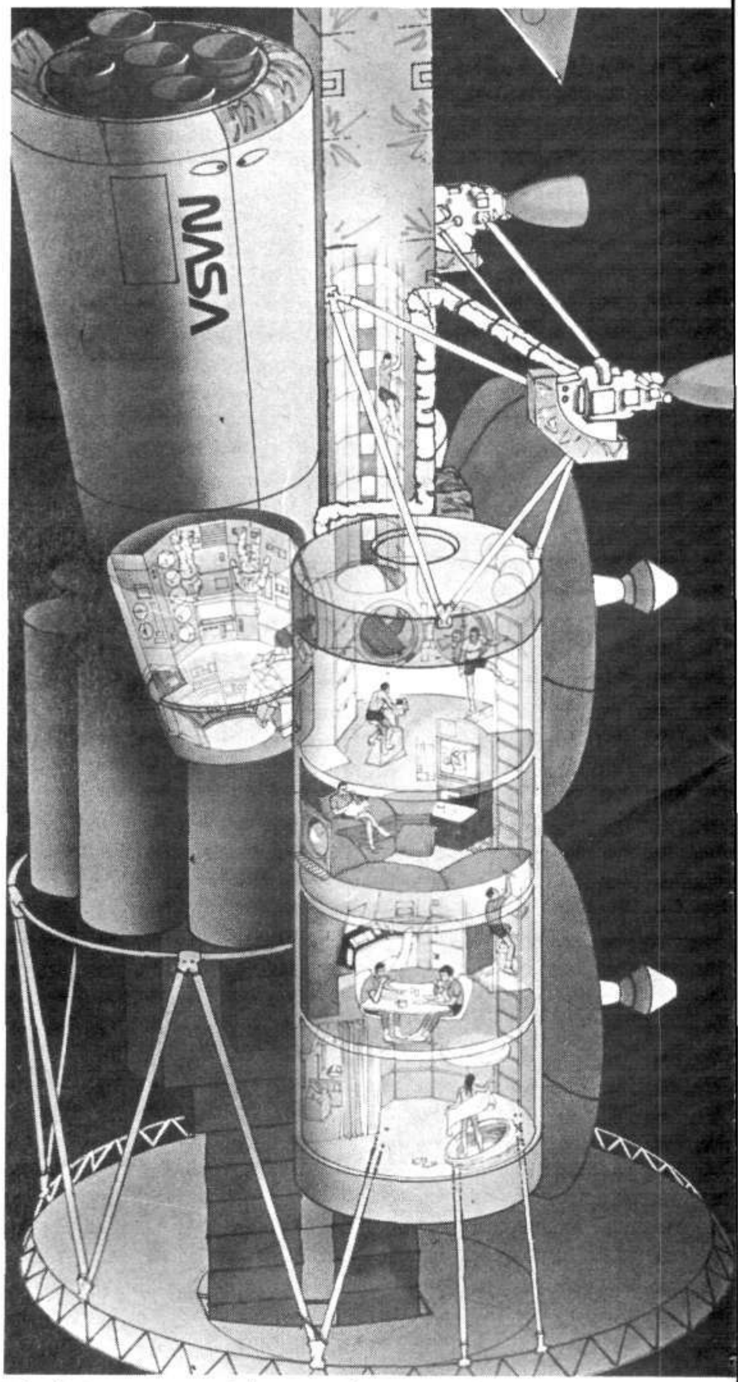
By between 50 and 60 years from now, the main source of scientific and technologic progress on Earth will be space exploration. We shall become a "space civilization," as distinct from an Earth-bound civilization. Sixty years from now, perhaps not more than a few million pioneers will be actually working in space, but we shall be a "space civilization" nonetheless. Our culture on Earth, our new ideas, will be meshed with, and dominated increasingly by, the ideas generated in connection with space exploration.

However, for at least the next 50 years, the way new technologies will increase productivity will be determined by the same principles of economic science that described human progress since the Golden Renaissance in 15th-century Italy and France. Even 100, or 200 years from now, economic science will change very little in respect to fundamentals, because the way human beings assimilate technologic progress to cause increase of productivity, will change very little.

In other words, we may be fully confident that if we base the Moon-Mars mission-assignment on the right economic policies for today, those same policies will be the right choices for 40 to 50 years from now.

The problem to which we must turn our attention now, is the fact that very few so-called "economists" know anything at all about economic science; in fact, they know much less than the leading economists of the United States knew during the first half of the 19th century, and even much less than the founders of our republic. The problem here is what is taught as "economics" in our universities today is not really economics, but what should be called "money theory." Even in our basic industries today, management knows much less about economics than the managements of the 1940s, 1950s, and 1960s. Two decades ago and earlier, operating managements of our leading corporations were, like the management's of Japan's industries today, either trained engineers, or men with an equivalent kind of knowledge accumulated in coming up the ladder from the production floor. Today's economists and "new breed" of Harvard Business School-type managers, are specialists in buying and selling, but have very little knowledge of, or interest in, the economy of agricultural and industrial production.

The practical problem involved, as it affects the Moon-Mars mission-assignment, is this. Almost none of our professional economists, or the other policy shapers they influence, has any comprehension of the kinds of institutionalized economic and monetary policies the United States would be obliged to adopt, either to get out of the present collapse of agriculture and industry, or to construct the kind of space program indicated. There are still a few senior officials, either retired or nearing retirement, in our aerospace industry, or in military ranks, who remember from firsthand experience, how and why the 1960s aerospace program succeeded as brilliantly as it did. Then, even into the 1970s, a very significant portion of our relevant governmental and industry officials, and large numbers of engineers and other relevant professionals, had the kinds of knowledge and experience needed to put the Moon-landing program into operation and ensure its timely success. Today, those are a rapidly dwindling, tiny minority within the policy-shaping establishments.



The living quarters of the Interplanetary Habitat, where the space pioneers will spend several months in travel. This module includes a fully equipped laboratory as well as recreation facilities. At lower left is a biconic crew lander, recognizable by its five engines (the cargo landers have only four engines).

This is reflected in the most obviously incompetent features of the reports issued by the Rogers Commission. Putting the question of sabotage to one side, the fact remains that "NASA no longer has the depth of professional competence it had even a few years ago, to say nothing of the early 1970s. Over the past 10 years, NASA, our aerospace capability generally, and our nation's vendors to both aerospace and military services, have been gutted of human and material resources. Like our aging commercial air services, exhaustion, obsolescence, and savage cost cutting, have brought us to the point that a spiral of major disasters must be expected. Whenever a once-proud capability is run into the ground, as our aerospace program has been gutted, so, sooner or later, everything that could break down will break down."

Despite the experts included in the Rogers' Commission, the Commission's efforts to lay the blame upon almost anything but sequence of cutbacks in government aerospace budgets (or the inexperience of the acting NASA official in charge), makes the report as a whole essentially incompetent. The problem lies not within NASA, but in what shifts in government policy have done to ruin NASA's capabilities. The worst thing about the Rogers' Commission report, relative to the matter immediately at hand here, is that the toleration for that Commission's point of incompetence, as we have indicated that incompetence, indicates a policy-shaping mind-set around government. As long as that defective mind-set persists, no old or new program, either in aerospace or many other vital programs, will end up in anything but a cascading accumulation of disasters.

It is therefore urgent that the shaping of policy for a Moon-Mars mission-assignment be based on instructing the policy-shapers in the relevant ABCs of economic science. We shall not present anything so comprehensive as even a crash course in economic science here; we shall merely identify some very basic principles, and shall indicate how the principles bear directly on the policy governing the mission assignment.

'Physical Economy'

As Treasury Secretary Alexander Hamilton and the later American economists understood more clearly than anyone else in the world, "economics," or "political economy," consists of coordinating two very distinct processes. The one process is called "physical economy." This deals with the production of goods and services, and their physical distribution. The second process, the flow of credit, indebtedness, and currency is the monetary process. What Hamilton first named as "the American System of political economy," locates essential reality in the processes of "physical economy," and prescribes that monetary processes must be brought into conformity with the criteria of physical economy. The opposing doctrine of political economy, that of the London and Swiss adversaries of the United States in the American Revolution, the so-called "free trade" dogma, demands that the physical economy be subjugated to a "free trade" notion of the monetary process as such.

The first, the American System, measures economic performance, broadly, by the yardstick of increase of physical output per capita, and by the role of what Henry C. Carey described as "the economy of labor." The "economy of labor," represents a reduction in the amount of labor required to produce a standard market basket of producer or household commodities, measuring those market baskets in terms of only physical goods plus a very restricted list of essential services. This "economy of labor" is accomplished through technological progress in an energy-intensive, capital-intensive mode of investment in basic economic infrastructure, agriculture, and manufacturing.

The second, the monetarist system, ignores the effect of lowering prices below the actual cost of production of such goods, in favor of investors' buying such goods at the cheapest price, to sell them at the highest possible margin of money profit. Instead of measuring economic growth in physical output per capita, monetarists measure growth in terms of money income of sellers of final commodities, including money income from any form of commerce not prohibited as illegal. According to monetarist theory, the Gross National Income of the United States could be caused to leap upwards, by legalizing prostitution and trafficking in dangerous narcotics, even if this accelerated the collapse of agriculture and industry.

The monetary policies of the American System were first introduced to the 17th century Massachusetts Bay Colony: The commonwealth declared a monopoly on the issuance of currency, and used the loan of this currency issue to promote trade and investment in physical output. During the 18th century, this policy for the Americas was promoted by Cotton Mather and Benjamin Franklin. These monetary policies were followed in the U.S. government under the Federalists and the American Whigs, including President Abraham Lincoln's economic mobilization of the early 1860s, which transformed the United States into both a major military power and a leading agroindustrial power.

The principles of physical economy were discovered by Gottfried Leibniz. These principles were introduced to the United States through Leibniz's English ally, Johnathan Swift, and, later, through Franklin's close association with Leibniz's circles in Europe. The first elaborated application of these principles of physical economy as U.S. government policy appeared in Hamilton's December 1791 Report to the Congress, "On The Subject of Manufactures." This latter was the leading governmental policy statement establishing the American System of political economy.

This writer is the world's leading living exponent of the American System of political economy today, and is also responsible for the only advance in the science of economics (physical economy) since the 1870s. The author's discovery has great and direct bearing upon the implementation of a Moon-Mars mission-assignment. What the author discovered, as a by-product of refuting the Wiener-Shannon and von Neumann dogmas of "information theory," was the means for measuring the cause-effect connection between the introduction of an advance in technology and a resulting increase in the productivity of labor. We now sum up those features of economic science which bear directly on the successful implementation of a Moon-Mars mission-assignment.

Over the recent 140 years, it has become the commonplace assumption, that primitive human society was of the form called a "hunting and gathering society." In such a mode of existence, an average of 10 square kilometers of the Earth's land area would have been required to sustain the life of an average individual, in a wretched state of existence, and at life expectancies significantly below 20 years of age. This would have permitted a maximum human population of our planet of approximately 10 million individuals.

Today, the Earth's population is approaching 5 billion individuals. Three-quarters of this increase has occurred since the 15th century Golden Renaissance, and that increase chiefly as either a direct or indirect result of policies of scientific and technologic progress, including notions of public-health measures, set into motion during that Renaissance. This is an increase in potential population density, of nearly three orders of magnitude, above the level of that "primitive society" to which today's "ecologists" would return us, by aid of the most massive genocide imaginable.

Essentially, the measure of economic performance of societies is measurement of some rate of increase of the potential population density. This improvement is the result of changes in human behavior of a type associated with technological progress. For this progress to occur, investment in productive employment must occur in an energy-intensive, capital-intensive mode.

If this progress does not occur, then continued existence in a relatively stagnant level of productive technology means a marginal depletion of a significant portion of the spectrum of required primary resources. This depletion causes a rise in the average cost of production of a standard market basket. As a result, the potential population density falls. When potential population density falls below the actual population density to a significant degree, part or most of the population affected is wiped out by the logic of famine and epidemic disease.

Hence, some minimal rate of technological progress, in an energy-intensive, capital-intensive mode, is indispensable to sustain even the equilibrium of an existing economy (society). There are certain general restrictions, which define the minimal preconditions, either for economic growth, or even for merely sustaining economic equilibrium. We identify these interrelated requirements now, as briefly as possible.

Statistically, economic analysis must begin with a measurement of standard market basket contents of both household goods and producer goods, relative to an existing level of technology. For all conditions of change, the amount of productive labor required to supply a standard market basket, per capita, of both household goods and producer goods, must be decreased, and the quantity and quality of the contents of such market baskets must be increased with technological progress.

Any analytical solution in economics practice, which fails to satisfy those market basket conditions, is a false solution.

On condition that that requirement is satisfied, the following, additional, interrelated preconditions for sustainable technological progress must also be satisfied:

(1) The quantity of usable energy supplied, both per capita and per hectare, must increase. This is measured, alternately, better, as an increase in the usable energy throughput per capita unit of potential population density (increase of energy intensity, in first approximation).

(2) There must be a trend of rise in the average temperature-equivalent of primary energy stocks supplied to basic production (increase of energy intensity, in second approximation).

(3) There must be a decrease of the ratio of the labor force (households) employed in rural production, relative to urban employment in infrastructure and manufacturing, on condition that the society's per capita output of food and fiber increase (capital intensity, in first approximation).

(4) There must be a decrease of the ratio of the labor force (households) employed in urban production of household goods, relative to production of producer goods, on condition that the per capita market basket of household goods is improved in quantity and quality (capital intensity, in second approximation).

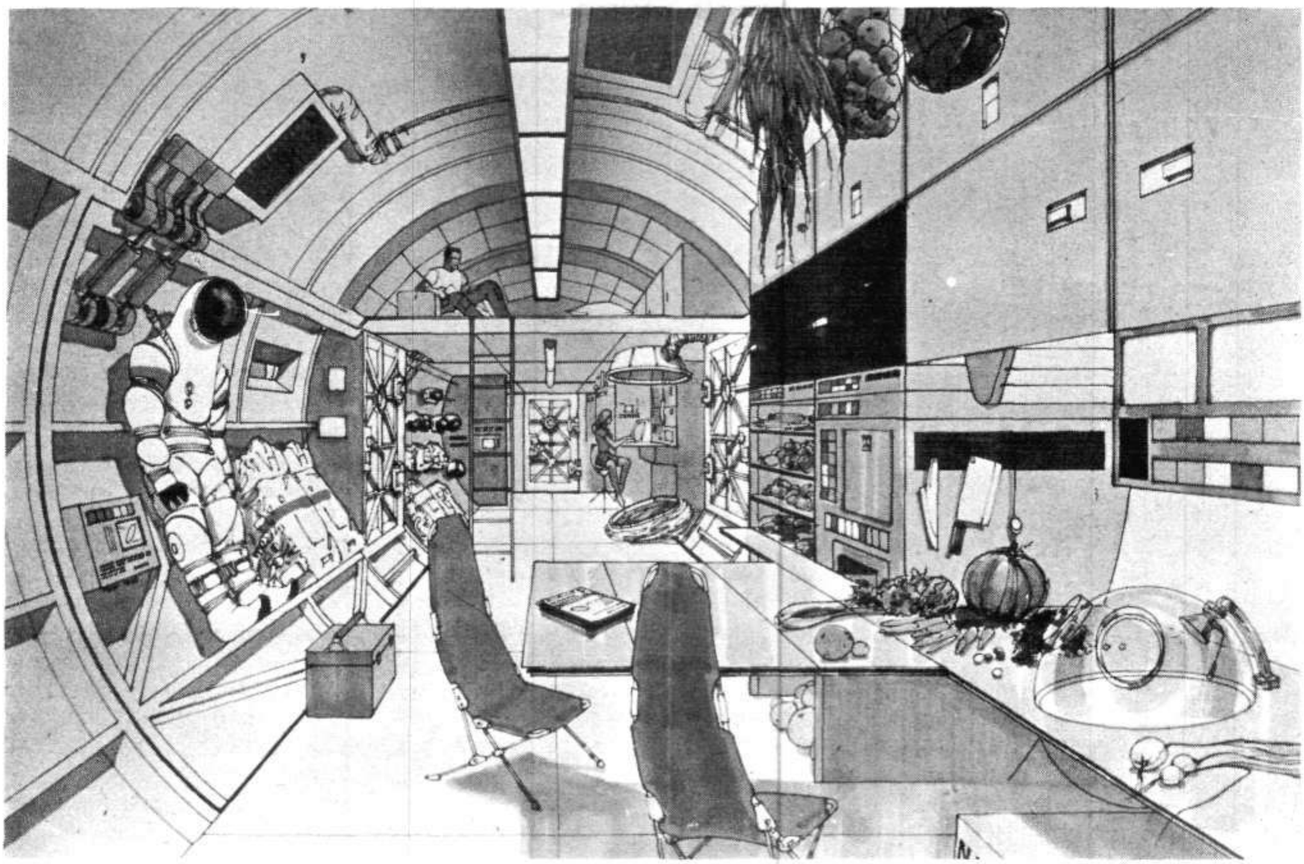
(5) Technology as Leibniz first defined "technology" must be advancing.

These requirements circumscribe the process in which technological advances are introduced to the productive process. Given: that the U.S. economy is committed to net growth of productivity, through technological progress in an energy-intensive, capital-intensive mode. Given, also: the set of restrictions we have just specified. To isolate the linkage between the Moon-Mars mission-assignment and rapid rises in productivity "spilling over" into the economy from this program, we must focus attention on the implications of the fifth of the numbered constraints listed above.

To proceed into that point, we should begin by reemphasizing, that the term "economic science" must be restricted in definition and usage, to signify "physical economy" as founded by Leibniz. In conception, "physical economy" means the mathematical-physics view of an interdependent process of production and consumption. As the foregoing list of restrictions implies, this mathematical physics leans strongly in the direction of thermodynamics. The proper definition of "technology," a conception first explicitly supplied by Leibniz, is the central conception of "physical economy."

The author's own original discoveries in economic science, are focused upon further elaboration of Leibniz's conception of "technology." It can be shown, that the author's discoveries can be reduced, formally, to a retrospective application of relevant work of Gauss, Dirichlet, Weierstrass, Riemann, and Cantor, to supply an enriched elaboration of Leibniz's original definition. It is also relevant to stress, that the conception of "technology," so elaborated, is totally incompatible with the notions of "information theory" associated with Wiener-Shannon and von Neumann, and also incompatible, in a directly related way, with the statistical ("reductionist") definition of "negentropy" associated with the work of Boltzmann.

This report will not summarize as much of the proper definition of "technology" as bears directly on essential policy features of a Moon-Mars mission-assignment; we



The two-story living quarters on Mars will be created in the emptied cargo landers. Because the Mars atmosphere is not breathable, the crew will have to don space suits (at left) to go outside.

shall not explore the full implications of the distinctions just identified, but only as much as is directly relevant to the matter immediately at hand.

Leibniz's elaboration of economic science began, in 1672, in a short paper entitled "Society & Economy," in which the theme is the most general restriction we have identified above as a constraint acting upon the interrelated five, numbered restrictions. His continuing work in the elaboration of economic science, placed the emphasis on study of the general characteristics of heat-powered machinery. This inquiry was adjunct to Leibniz's assistance in the development of the first steam-powered engine (that of Denis Papin), and was referenced to Leibniz's proposals for reform of mining, transportation, and manufacturing, through introduction of generalized used of the coal-fired steam engine. Leibniz's catch phrase for this reform, later called "the industrial revolution," was that by employment of such heat-powered machine, "one man may do the work of a hundred" others employing then-prevailing methods.

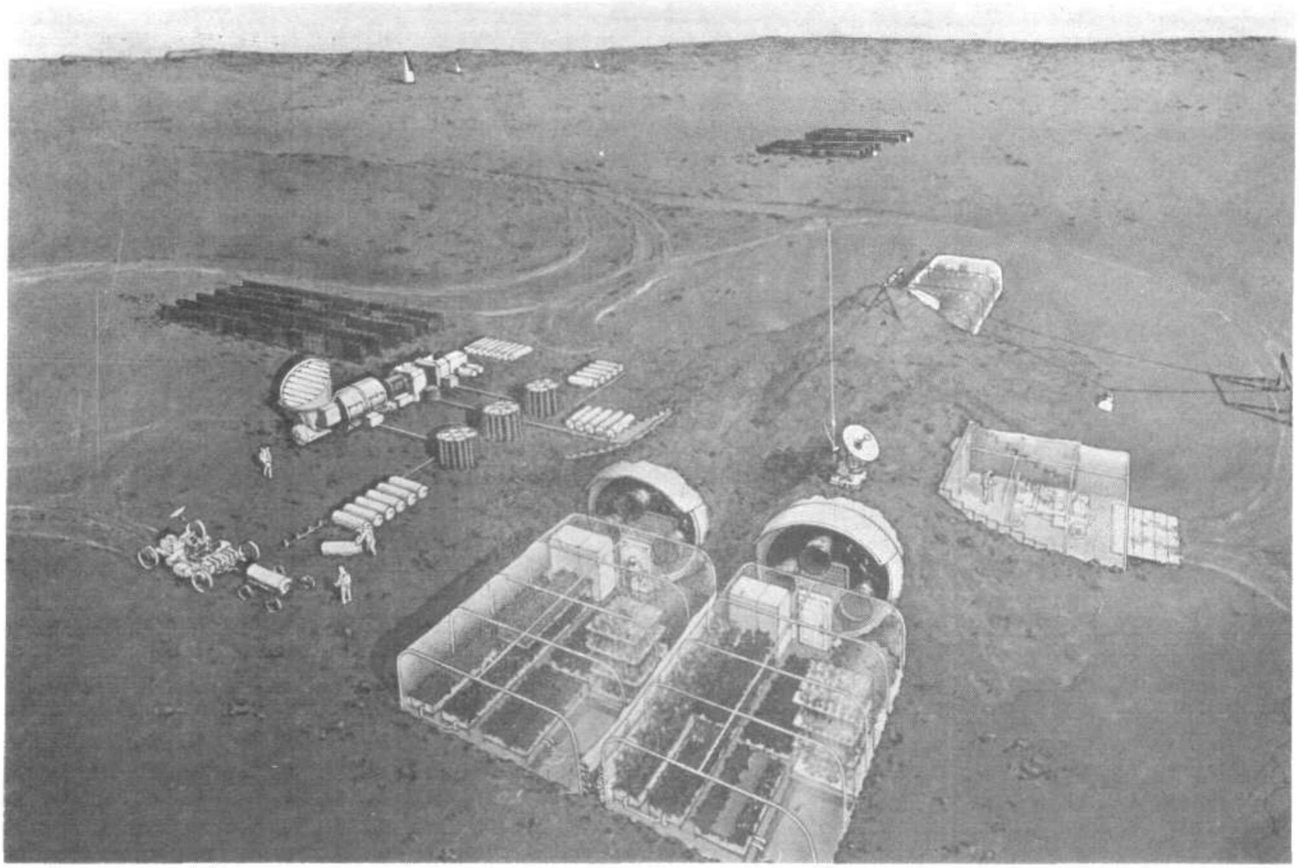
Broadly, given a species of heat-powered machinery, productivity of the operative increases as a function of the increase of the amount of heat supplied to power the machine. This is made more general, by adding that by increasing the energy-density cross section and relative coherence of the energy supplied, productive powers of labor are also increased as a function of this factor. It is within this setting, that Leibniz's conception of technology appears.

For brevity, assume the hypothetical case, that two heat-powered machines are employed, alternately, by the same operator, to produce the same kind of work (product). Assume the very special case, that the two machines consume the same amount of coal energy per hour (at the same energy-density cross section for the input energy), but that the operator produces greater output with one machine than with the other.

This illustrative case could be refined for greater exactness, but the point can be illustrated sufficiently well for our present purposes with aid of the case as stated.

The only accountable difference between the performance of the two machines, is a difference in the internal organization of the machines. The idea of such a difference being an efficient cause of increase of productivity is the raw meaning of the term "technology."

The idea of "technology" is made more precise in the following way. Let us discover a way in which we can measure better and relatively poorer forms of internal organization of heat-powered machines, from the standpoint just given in our illustration. The standpoint from which this measurement can be accomplished, is Leibniz's geometrical principle of Least Action. Actually, to do this as precisely as we require, we must resort to the related work of Gauss, Dirichlet, Weierstrass, and Riemann, on the matter of construction of "nonlinear" continuous functions. The indicated further refinement with aid of Riemann's contributions,



An outside view of the living quarters. The two former cargo landers are buried under the Martian soil as protection against radiation. One engine in each has been removed to function as an airlock connecting the living quarters to the greenhouse. In the greenhouse, which is an inflatable structure, the crew will grow high-yield protein-rich crops from seeds brought from Earth. The rectangular structures (top right) are two nuclear reactors and their radiators, which will power the settlement.

we need not elaborate here; it is sufficient to identify the point that such a necessary qualification exists.

The working point is, that there exists an ordering principle of physics, by means of which we can define one degree of internal organization of processes as of a higher order than another; furthermore, that this ordering principle is in functional correspondence with an efficient increase in the productivity of operatives.

The function which defines that efficient correspondence between higher degrees of organization and increase of the productive powers of labor, is the strict definition of "technology."

The practical problem, on which the connection between scientific progress and increased productivity of labor depends, is the need to uncover a common principle, which, on the one side, describes those scientific conceptions we call discoveries, and which, on the other side, describes the changes in organization of machinery or analogous processes resulting from introducing scientific discoveries to production in the form of improved technology. This means that, on the one side, we must be able to reduce the relevant aspect of the scientist's mental processes to the same form as technological improvements in organization of machinery. For our practical purposes here, we can limit ourselves to a description of the connection.

For such cases as Nicholas of Cusa, Leonardo da Vinci, Pascal, Leibniz, Monge, Gauss, Riemann, and other prominent cases, we know that the organization of their scientific thinking was consistent with what we call today a "constructive geometry," sometimes also named a "synthetic geometry." The 19th-century elaboration of such a geometry, chiefly by the work of Gauss, Dirichlet, Weierstrass, and Riemann, is indispensable for mapping the mind's scientific-thinking processes in more than broad, descriptive terms. A scientific discovery, involves the generation of one or more "singularities" to a previously established geometrical model. Such mental processes belong to the class of solutions to "nonlinear" continuous functions, as developed by Dirichlet, Weierstrass, and Riemann.

We may take a shortcut at this point. We have indicated that the mental concept we call a scientific discovery can be treated as a special class of geometric "models." We have indicated, that there is a congruence between this mental model of a scientific idea, and the changed internal organization of the machine resulting from the application of that scientific idea, "technology," to the improved design of the machine.

In other words, the proper sort of rigorous mathematical thinking in physics, is a reflection of what the physicist's mental processes actually do in generating a new discovery. It is merely indispensable to construct that mathematics in the proper way: in fact, a Riemannian synthetic geometry. (Mathematical models based on a deductive-axiomatic arithmetic or algebra, do not supply such a representation.) We are reporting, that the proper mathematical-physics model of the physicist's thinking, is a model of the relevant changes in organization (technology) of the improved machine resulting from this discovery.

To some this might seem rather exotic, at first glance.

A bit of common sense helps to dispel that impression. Practical thinking is practical, only to the degree that the ideas generated cause the hands of the thinker to restructure their behavior to the effect predicted by the idea. To accomplish this result, the mind must think in terms of structured cause-effect interactions between the thinker's hands and the process he is attempting to control. This sort of structure, we call "geometry," the kind of geometry that satisfies that requirement, is what is known variously as a "constructive" or "synthetic" geometry.

In an idealized case, a manufacturer dissatisfied with the productivity obtained with a certain design of machine, calls in an ideal creative thinker familiar with such machines. The thinker studies the internal organization of the machine's processes. The thinker absorbs the idea of such organization into his mental processes, in the form of an idea of organization. He manipulates that geometrical image in his mind to the purpose of discovering a relevant sort of improved internal geometry for a machine of that class. He returns to bring the revised design of the machine's internal organization into geometrical conformity with his idea. The idea can be compared broadly to a blueprint of the new design. In fact, when a designer constructs a blueprint, he is putting that kind of thinking on paper, geometrically.

The introduction of science to production, as improved technology, is of the form of creating a physical model of a mental conception.

This is precisely what is done in experimental physics. As Professor Felix Klein demonstrated most effectively, all really good experimental physicists think geometrically, not algebraically. So, for such a physicist, an experimental hypothesis is already more or less in the form of the physical design of an experimental apparatus. Such a physicist walks into the university's toolmakers' shop, and works with the chief toolmaker to build an apparatus consistent with that idea.

Later, improved experiments will be in the form of changes in the structure of the first model. The correspondence between the geometrical form of scientific thinking, and the changes in organization of the apparatus, is more or less transparent to insightful observers of this process.

In the case of technological progress, the physicist walks into the industrial machine shop, and works closely with the engineers and toolmakers there, to construct a new variety of machine tool or other capital equipment of production. The logic of this is the same as for the case of the scientists working with the toolshop at the university, in building an experimental apparatus.

This improved machine tool, or other capital equipment, when introduced to the production floor, becomes the means by which scientific progress is translated into technological progress, and increased productivity, on the production floor.

This view of the process of introducing improved technology, guides us to the right economic policies for the Moon-Mars mission-assignment:

(1) Accelerate fundamental scientific research in all relevant areas.

(2) Expand budgets and staffs for construction of experimental apparatus.

(3) Greatly increase operating capital throughput in the machine tool sector of industry.

(4) Stimulate preferential flow of retained earnings, invested savings, and lower-priced credit, into capital-intensive investment in production in relevant areas of industry.

(5) Foster accelerating rates of turnover in production of machine tools and other capital goods of production, and provide a premium incentive for high rates of technological attrition in designs of these investment goods.

National Economic Policy

This policy has a significant resemblance to exactly what the United States did, especially between the years 1939 and 1943, in cranking up the U.S. economy to levels at which we could sustain the war effort. There is nothing accidental in the similarity.

The leftists—especially the leftists—used to insist, that it was the war which stimulated the long-delayed 1939-1943 U.S. recovery from the Great Depression of the 1930s. The leftists based themselves on monetarist thinking; they often leaned toward a British Fabian's blending of John Maynard Keynes and Karl Marx, of the sort taught at Cambridge's King's College. This was the argument, that the market demands for war goods stimulated the economic recovery. This is what has been sometimes described as the "demand-pull" doctrine: that it is the donkey of "market demand" which pulls the cart of investment and expanded production after it.

Following the postwar recession, there was a recovery which coincided with the Korean War. Later, following the 1957-1959 recession, there was the "post-Sputnik recovery," which lasted through 1966. In each case, most of the labor union economists stuck to their Keynesian donkey's dogma, that "war demand" expanded the market for produced goods, which stimulated recovery.

Monetarists have never understood: It is productive investment which generates "demand." If left-wing monetarists stick to past performance, they will accuse us of reviving the unfortunate Herbert Hoover's "trickle-down" myth: that if wealthier people become richer, some of this money will "trickle down," eventually, to the rest of the population.

What we are recommending is not Herbert Hoover, nor the Paul Mellon who engineered the U.S. side of the 1931 banking crisis from his post at the Treasury Department; quite the opposite, the approach taken by Franklin Roosevelt and his advisors at the end of the 1930s. Create a high rate of taxation in upper income brackets, but with a very big investment tax-credit loophole: supply generous investment tax credits for technologically progressive, energy-intensive, capital-intensive modes of productive investment. Make large volumes of credit available, at specially low borrowing costs, for such forms of investment. "Arms spending, or no arms spending," the U.S. economy will take off in a vigorous recovery from any recession, any time.

It was such measures, plus some approximation of the same sort of measures, which Roosevelt used to crank up the economy during the 1939-1943 interval. Once the obstacle of his 1940 reelection campaign was past, our economy was well on the road toward a "take-off" point in the recovery.

True, as early as 1936, and clearly by 1938, Roosevelt knew the United States was going to support Britain in a war with Nazi Germany; during most of his second administration, Roosevelt was planning the U.S. participation in that war. True, politically, Roosevelt was able to push through his economic-recovery reforms at the end of that second term, because he was supported by influential anglophiles and others, who intended that the United States should mobilize to intervene in World War II, and soon. Apart from this political factor, the war had nothing to do with the economic recovery as such. The same economic reforms would have worked far more successfully without the wartime accumulation of pent-up monetary inflation, if there had been no war.

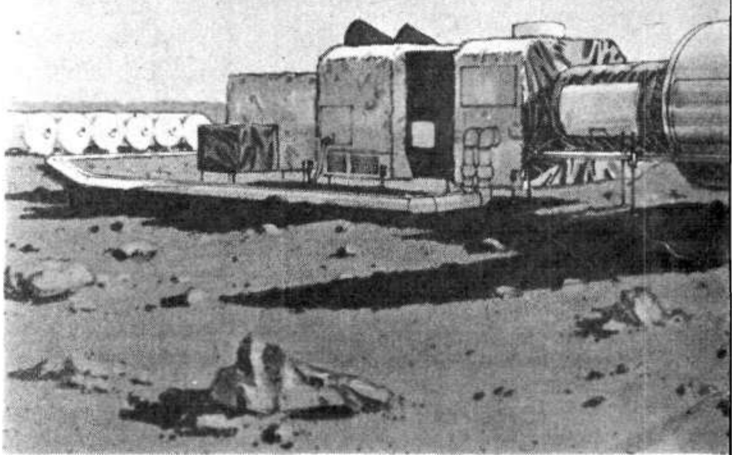
It was "investment push," not "war demand pull," which caused that recovery.

In considering the policies for the Moon-Mars mission-assignment today, it is useful to put the period of the U.S. economy, 1931-1966, into general perspective.

Under the policies of Coolidge and Hoover, the U.S. economy of the late 1930s seemed to zoom upward in an orgy of prosperity, although agriculture was collapsing into disaster, and industry was becoming shaky at the foundations. The collapse of the effort to reorganize the German war-reparations debt through the proposed "Young Plan," set off a chain reaction through the world's financial markets. The 1929 stock market crash was chiefly a symptom of this development, as well as a result of the follies of Paul Mellon and President Hoover. During 1931, with the collapse of the Vienna Kreditanstalt and the subsequent collapse of the British pound, the world's financial system toppled, and the U.S. economy slumped into a deep depression, followed by a slow erosion over the rest of the 1930s. What were viewed wishfully as the partial economic recoveries of the mid-1930s, were actually based on using up the stored investment in physical wealth built up during the preceding decades. There was no actual economic recovery until after the 1939-1940 turning point.

During the interval 1939-1943, the U.S. economy went through an accelerating recovery. This began by mobilizing every scrap of usable junk machinery, and recruits from the unemployment lines, often working in formerly abandoned or semiabandoned buildings. After 1940, this "scrounging" phase of the mobilization shifted into a retooling phase, which reached an approximate peak during the 1944 election campaign.

A closeup of the "atmosphere mining" facility in the first settlement. This gas extraction system takes in Mars air and extracts from it oxygen and nitrogen for the living quarters, as well as liquified oxygen stored under pressure at low temperature in the tanks (left) for later use as fuel for the vehicles.

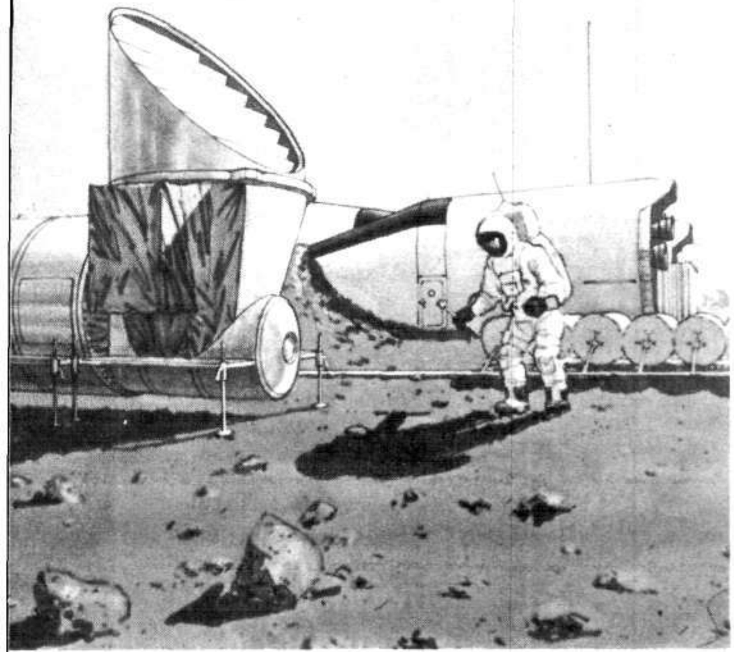


It was the retooling implemented during the war, which gave our economy the industrial structure, which, in turn, carried us through the middle 1960s—with some ups and downs in between.

Generally, except for the short-lived, post-Korea, 1955-1956 consumer-credit bubble of the first Eisenhower administration, every recovery from a recession appeared to be based on an arms-buildup drive. On closer inspection, what actually happened, was that we resumed some aspects of the investment stimulants which the 1939-1943 buildup built into the design of the 1946-1966 National Security system.

Beginning 1966-1967, the doctrine of "postindustrial society" was embedded into our national policy structure. It was at that point, that the 1946-1966 National Security policy began to be thrown away. The new doctrine of "postindustrial," or "technetronic" society took over Washington, at an accelerating rate, from that point onward. Today, underneath an increasing thin and unstable veneer of "prosperity," U.S. infrastructure, agriculture, and manufacturing are already in approximately the same state of exhaustion as during the 1930s Great Depression.

What we should have learned from this experience of the past 60 years of ups and downs, is consistent with what economic science teaches us. During every period the U.S. government has returned to the American System of political economy, or even a reasonable approximation of it, our economy has prospered. During every period we have adopted Adam Smith's policies, we have experienced a new depression as a result. The 1815-1818 depression, the 1830s depression caused by Jackson's and van Buren's policies,



the depressions of the 1850s, the long depression of the 1873-1886 period, the depressions of the 1890s, 1905-1907, the early 1920s, and the Hoover depression, were each caused by "free trade" policies of government. The vigorous growth under President Washington, the recovery of the 1820s, the economic upsurge of the 1860s, the wartime recoveries of this century, and the "post-Sputnik" recovery under President Kennedy, were each caused by our government's total or partial adoption of American System policies.

The aspect of the American System which must be stressed, to produce a true economic recovery today, and to get the Moon-Mars mission-assignment into gear, can be simplistically, but fairly described in the following terms.

Imagine that any major national economy, such as the United States', can be seen as like a giant agroindustrial enterprise. Our economy is a mixture of government operations and private enterprises, but the economic activities of these diverse enterprises interact so interdependently, that the fate of each depends to a very large degree on the policies of practice and performance of the others.

The principal features of this "consolidated enterprise" are the following:

(1) Construction and maintainenance of basic economic infrastructure, by a combination of federal, state, and local government and public utilities. This is the foundation upon which agriculture, manufacturing, and the household economies are based.

(2) Output physical goods, other than the product of public utilities, chiefly by agriculture and industry.

(3) Output of certain special categories of services, including science, engineering, medicine, and teaching, essential to maintain and improve the technology of production and the productive potentials of the labor force.

That is the economic output of our economy, the only thing which should be counted in statistics measuring national product and net national income. In addition to this economic output, our national economy carries a very large, and expanding "overhead burden." From the standpoint of physical economy, this "overhead burden" is sorted into the following primary, functional subclassifications:

(1) *Economic "overhead expense."* Those administrative expenditures which are incurred for reasons other than direct management of production itself, or in physical distribution of goods, but which bear directly upon the organization of productive investment.

(2) *Institutional "overhead expense."* Those selling and administrative costs and expenses, which are necessary to maintain essential governmental or entrepreneurial organization's functioning as institutions.

(3) *Waste "overhead expense."* This includes unemployment, revenues of redundant labor-intensive services generally, usury, immoral activities, and crime.

In our present, misconceived system of national income accounting, the marginal money income of each and all of these activities is treated equally. In other words, the "value added" attributed to income from "overhead expense" activities, is treated as income in the same degree as income from production of national output of goods and essential services!

It is for that reason, at least chiefly so, that our government reports rising national income during a period that infrastructure, agriculture, and manufacturing are collapsing at major depression rates, a collapse which has continued at an average of between 2.5 percent to 3 percent from 1981-1985, and at an accelerating rate since late 1985.

One of the most important financial ratios in any private enterprise, is the ratio of overhead expense to costs of fixed and operating capital employed for production of physical output plus essential services. If this ratio rises significantly, the firm is a sick one. The same is true of our national economy, as measured in national income accounting terms of reference.

In 1946, about 60 percent of our labor force was employed in production of physical output, roughly a ratio of overhead expense to production of 2:3. Today, a shrinking 25 percent or less of our labor force is employed in production of physical output, approximately a ratio of 4:1. Our economy is very, very sick.

Employment of operatives remained essentially stagnant in absolute numbers over most of the past 15 years, until the onset of a recent, rapid drop. During that period, the productivity of labor has dropped, and the market basket content of per capita household income has dropped. The decline in productivity of labor is most prominently caused by the following trends of the 1970s and 1980s:

(1) The accelerating collapse of basic economic infrastructure, especially since the New York City crisis of 1975.

(2) Erosion of net capital stocks of agriculture and industry, since the 1970-1971 monetary crises, and accelerated by the 1974 petroleum crisis and the introduction of Volcker's

policy of "controlled disintegration of the economy" in October 1979.

(3) A governmental and central-banking policy of forcing disinvestment in energy-intensive, capital-intensive modes of production of goods.

(4) A shift in composition of employment of operatives, from highly skilled occupations, to low-wage employment in unskilled occupations, with emphasis upon wasteful or wastefully redundant labor-intensive services.

(5) An accelerating collapse of both the skill levels and skills potential of the labor force, caused by a breakdown in education and by the influence of the counterculture.

It's no way to run a railroad.

The cause of this sickness lies chiefly in the past 20 years' policy trends in government, central banking, and the moods of the business consensus. It is on these three points that the government must act. Relevant policy trends in government and central banking must be sharply, dramatically reversed. Government must exert leadership to the purpose of remoralizing the business consensus on medium- to long-term investment prospects.

Government and central banking must act to reverse the trends in ratio of overhead expense to productive investment, and in the ratio in employment of the labor force. Government and central banking must adopt taxation and credit policies, which sharply constrict flows of public credit, savings, and income into the overhead-expense categories, while increasing massively the relative flows into technological progress in an energy-intensive, capital-intensive mode.

Government must act to organize leading public and entrepreneurial forces of the economy around projects which give structure to a technological breakout. This impact must be directed to the capital-goods producing sector, especially the machine-tool sector. Government must concentrate on its constitutional areas of economic responsibility: military and infrastructure expenditures, and stimulation of the domestic economy through tariff policies and promotion of U.S. high-technology exports.

Apart from infrastructure, such government initiatives of recovery today, are concentrated in the military and aerospace sectors, and in government leadership in biological research and governmental sectors of medical programs, such as the veteran' hospital system.

In the high-technology breakout sector, we are speaking of about 10 percent of total manufacturing and related classifications, of which government expenditure is a small fraction of the total. The case of military expenditures for manufactured goods and analogous categories of procurement, is a good illustration of the process.

Of total military expenditures, perhaps less than 10 percent of the required defense budget is actually consumed in introducing new technologies. Most of the Defense Department's procurement from manufacturing, about 10 percent of total current manufacturing currently, is spent for what are essentially off-the-shelf technologies; only a rather thin, but ultimately decisive margin is actually spent on creating new technologies. Over the recent ten years, most emphatically, this thin margin has been withering away.

The prime aerospace vendors, for example, have been shifted from technology-intensive mode, toward an off-the-shelf technology mode. The ratio of total investment aimed at high rates of technological gain in quality of product, has been withering toward a vanishing point. This is partially a reflection of shifts away from high-technological gain in defense procurement; it is perhaps more emphatically a result of government and central banking taxation and credit policies.

Governmental and banking policies have fostered a tendency to drain off capital stocks, to generate income disbursed either for defense of firms against financial raiders, or for diversification away from production and essential services, into "overhead expense" categories.

A relatively small shift in total income flows through such enterprises, to reverse the present trends indicated, would suffice to put the U.S. economy back into a high-technological-gain mode. Relatively few billions per year, less than the equivalent of 5 percent of the defense budget, will make that difference, on the condition that policies of taxation and credit are shifted back, to foster private investment in a mode of energy-intensive, capital-intensive technological progress. Most of such margins of governmental expenditure will go into the areas of scientific research and the toolmaking industry. It is that relatively small shift in direction, which "leverages" the turn on a large scale. It is shifts in taxation and credit policies, which create the conditions in the private sector enabling that small margin of governmental "leveraging" to produce the needed effects in the economy as a whole.

The general objective is a 5 percent to 7 percent annual average increase in productivity of operatives over the coming 15 years.

We mean "productivity" of operatives as measured in terms of reference to a 1967 standard market basket per capita for producer and household goods. These are rates of growth comparable to those reached during the first half of the 1960s, under the combined impact of the "Kennedy investment tax-credit" and the technological stimulant of aerospace research and development (in other words, rates which are readily achievable by standards of past performance).

This gain in productivity will come principally from three sources:

(1) Increase in ratio of employment of operatives to total labor force: an increased percentage of labor force employed in producing physical output.

(2) Increases in energy intensity and capital intensity of production on the average.

(3) Higher capital turnover in the capital-goods sector of production, combined with higher rates of technological attrition in designs of capital goods.

Despite generous investment tax-credit rates for preferred classes of investment, the government tax-revenue base will be expanded at rates comparable to or exceeding those of the early 1960s. This will be the case, on the condition that favored capital gains treatment is limited to those resulting from useful inventions and physical improvements, and is cut back drastically in other categories of financial gain.

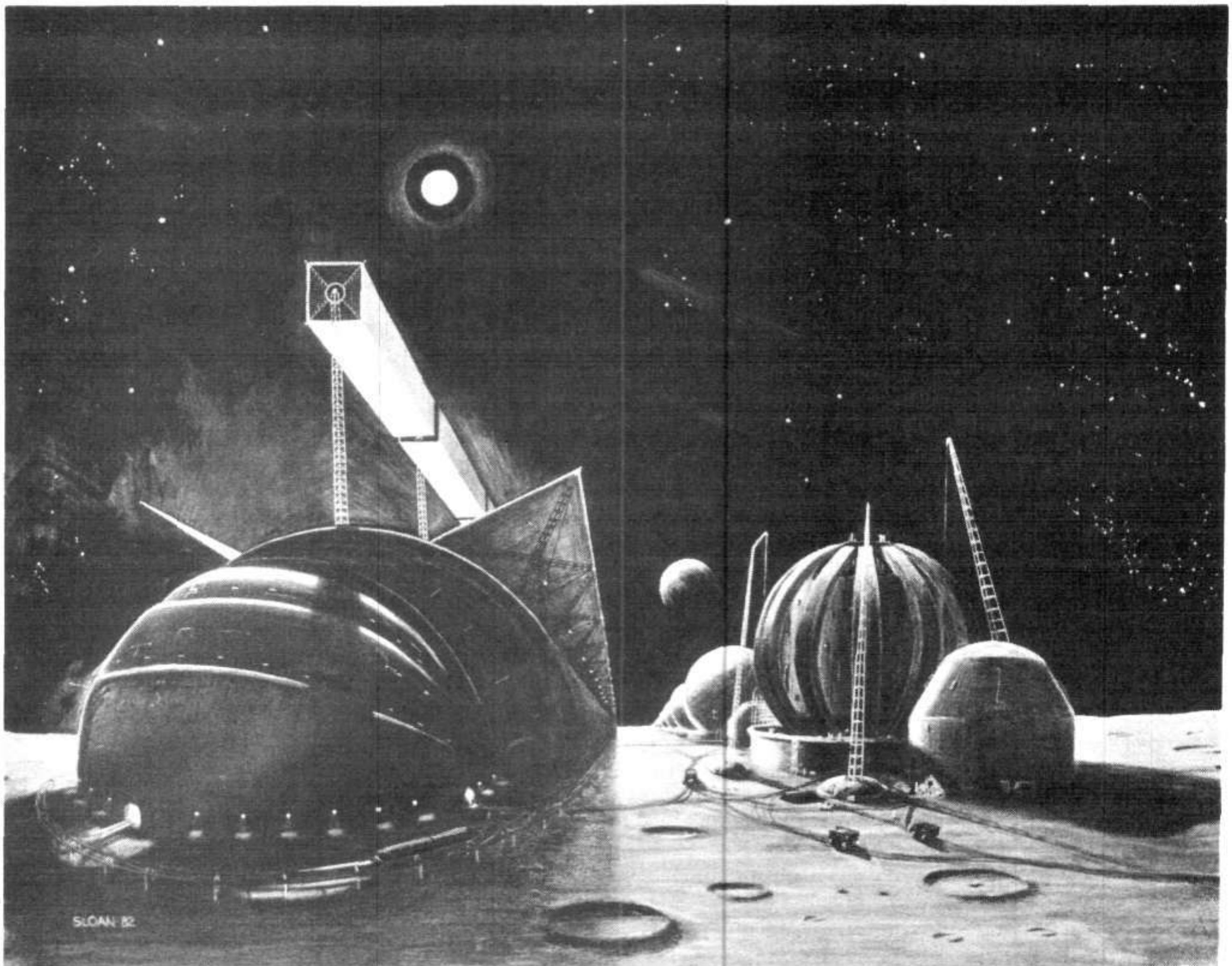
In summary of this point on governmental economic and monetary policies, the problem which appears too massive to be attacked with brute force, frontally, can be solved by a shrewd choice of flanking operations. The flank is that small but decisive aspect of the economic process which is most responsive to a technological breakout.

This is not some wild, untested innovation. It is nothing but the primary lesson of the past 500 years of European civilization, restated as a policy.

The Way a 'Science-Driver' Program Transforms Economies As a Whole

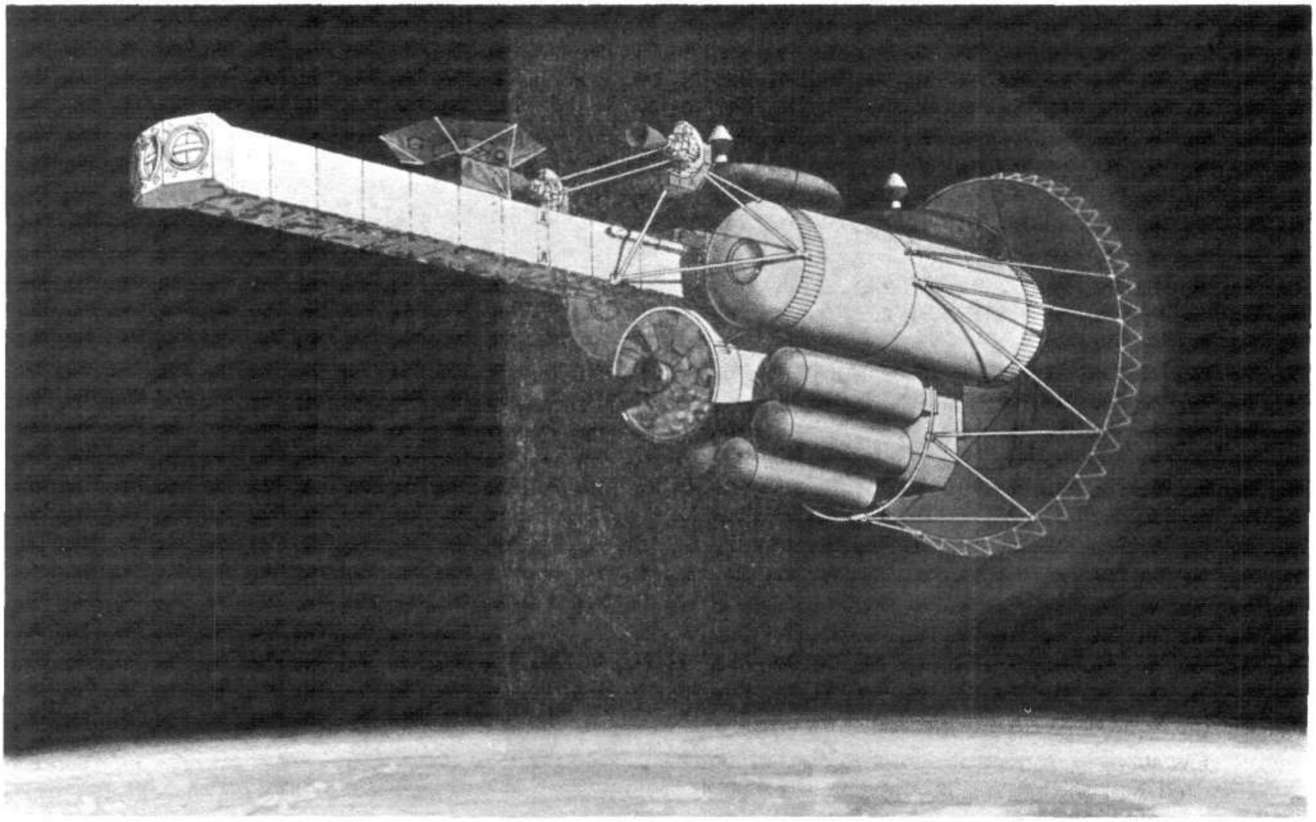
The idea of a "science-driver" approach to rapid growth of entire economies was implicitly rooted in the reforms of Florence's Cosimo de Medici, but was first given elaborated form by Leonardo da Vinci. Medici's approach was introduced to France under King Louis XI. The impact of Leonardo's work was reflected in the policies of Tudor England under Henry VII and, to some degree also, Henry VIII. The next major effort along these lines was successfully launched by France's Jean-Baptiste Colbert. The principles of a "science-driver" approach to economic policy were defined more rigorously by Leibniz, as reflected in Treasury Secretary Hamilton's 1791 "Report On the Subject of Manufactures." The prime modern model of a "science-driver" approach is that initiated by Lazare Carnot during the period he served as France's "organizer of victory," 1793-1795. The further elaboration of Carnot's approach to snatching victory from the jaws of imminent crushing and dismembering of France, was Carnot's collaboration with and sponsorship of Gaspard Monge's Ecole Polytechnique over the interval 1794-1814.

The revival of the U.S. economy during the 1820s, was based directly on the Monroe administration's adoption of the lessons of the 1793-1814 Carnot-Monge program as an enriching feature of a revived American System policy. The



Christopher Sloan

Later settlements on the Moon and Mars will use the more advanced energy source of fusion. This system, designed by space scientist Krafft A. Ehricke, shows a donut-shaped tokamak under construction (right) on the Moon. At left is part of an advanced city, which Ehricke named Selenopolis. Note the transportation system (lower left).



"Our Lord, who placed an insatiable quest for knowledge into the hearts of men, did not intend to set limits to that quest when he said, 'Go out and subdue the Earth.' It is the whole of creation that He entrusted to man and that He offered to the human mind, for the human kind to penetrate it, thus gaining deeper and deeper knowledge of the infinite greatness of his Creator."—Pope Pius XII, addressing a congress of the International Astronautical Federation in 1965. Above, the Interplanetary Habitat returns to Earth-orbit. The shield in front is slowing the Habitat so that it can rendezvous with a Space Shuttle.

transformation of the United States into the world's leading agroindustrial nation during 1861-1865, was based on this same policy. The development of 19th century Germany, from an economic backwater, into the world's leading economic and scientific power, was based on introduction of the combined influence of the American System and the Carnot-Monge program, under the leading sponsorship of the Humboldts. The major "crash programs" of the 20th century, have been based on the institutional impact of these 19th century models.

In that light of history, the proposition before us amounts, in practice, to making the combined, complementary efforts of Strategic Defense Initiative and Moon-Mars mission-assignment, the "science-driver" program which will transform the United States into an economic power beyond the imagination of all but the tiniest handful of scientific workers today, and accomplish a good part of this during the coming 20 years.

In rule-of-thumb terms, what we are proposing is this. We make an inventory of those visible breakthroughs on the frontiers of scientific discovery today. We select a task which urgently needs to be done, and which will make use of each of the benefits of those areas of technological breakthrough. We orient the majority of the scientific and toolmaking establishment of our nation to such a task orientation over the period of the coming 40 to 50 years. In that way, we create manufactured objects which are of great use and economic payback rates in and of themselves, and which also refine and prove every kind of new technology being developed. By producing those specific manufactured objects, we enable our economy to apply those same technologies and their benefits directly to every part of the economy as a whole: We "copy" from advanced technologies developed in the project, for every useful application entrepreneurs might desire.

As a result, we increase the average productivity of the United States by two or more times during the remainder of this century, and more than 10 times over the coming 30 to 40 years. The amount we spend on this effort costs our economy an investment equivalent to a small fraction of our defense budget, something in the order of NASA and related aerospace spending of the 1960s. The payback during the medium term, from the "spillover" into the economy generally, pays back to our government in increased tax-revenue base, more than the investment.

Where does this bonanza of new wealth come from? It comes from the human brain.

Economist Lyndon LaRouche is a member of the board of directors of the Fusion Energy Foundation and a Democratic presidential candidate.

Appendix: The Continuing Controversy Over the Principle of Least Action

Modern European science is divided chiefly into two factions: the currently popular view, which derives physics' mathematics from an axiomatic arithmetic-algebra, as opposed to the standpoint of what English usage sometimes identifies as "continental science," the latter the standpoint of Nicholas of Cusa, Leonardo da Vinci, Kepler, Leibniz, Monge, Gauss, et al. The latter dates approximately from Cusa's 1440 *De Docta Ignorantia,* establishing a true "non-Euclidean," or "constructive" geometry. The former, opposing method dates, essentially from the work of René Descartes, and is aptly described as either Cartesian or neo-Cartesian. All of the important, fundamental or approximately fundamental, differences among leading modern mathematical physicists are defined in a meaningful way, only by aid of reference to the opposition between the indicated two factions.

The Cartesian and neo-Cartesian views start from the action of (arithmetically) assumed point-masses acting in straight-line motion in otherwise "empty" Euclidean space, or in a kindred form of neo-Euclidean space, the latter sometimes misnamed "non-Euclidean." The constructive-geometric view starts from the standpoint referenced by Cusa in the cited work, that matter, space, and time are an indivisible substantiality.

The classic expression of the issue between the two factions, is the attack on Kepler by Newton and others, and the defense of Kepler's approach by Leibniz, Gauss, et al. Kepler derived his three universal laws, and the planetary orbits, solely from constructive geometric principles, without considering the masses of the bodies, or functions of the pairwise interaction of such bodies. Kepler's hypothesis, employed to construct those laws, was based on the preceding work of Cusa, Luca Pacioli, and Leonardo, with special emphasis of Pacioli's and Leonardo's treatment of the significance of the Golden Section in that context. Kepler sought to demonstrate that our solar system had a specific kind of physical space-time geometry, independent of pairwise interactions among masses, and that this physical geometry imparted certain metrical characteristics to action in such space, characteristics relatively independent of pairwise actions within that space. Descartes, Newton, et al., rejected such notions of an efficient physical space-time, demanding pairwise interaction among bodies in Euclidean empty space-time.

Karl Gauss's demonstration for the case of the asteroid Pallas supplied crucial experimental proof that Kepler's conception was correct, and the standpoint of Kepler's critics was absurd. Gauss implicitly demystified the Golden Section's role in Kepler's physics, by basing physics upon a constructive geometry of multiply connected, conic, self-similar-spiral action: The Golden Section is the metrical characteristic of plane projections of conic self-similar-spiral action, and also of Gaussian hyperspherical space upon the "Euclidean" domain as a whole.

Beginning 1850, Clausius, Kelvin, Helmholtz, Maxwell, et al. led a counterattack against Gauss, Weber, Weierstrass, and Riemann. *Maxwell is most explicit on this point.* He attempted to reconstruct the work of Gauss, Weber, and Riemann in electrodynamics, with the qualification of eliminating the idea of metrical characteristics of physical space-time as such, attempting to preserve the Cartesian idea of matter, space, and time. As Maxwell explained in a letter, the object of his work was to disregard "any geometries but our own."

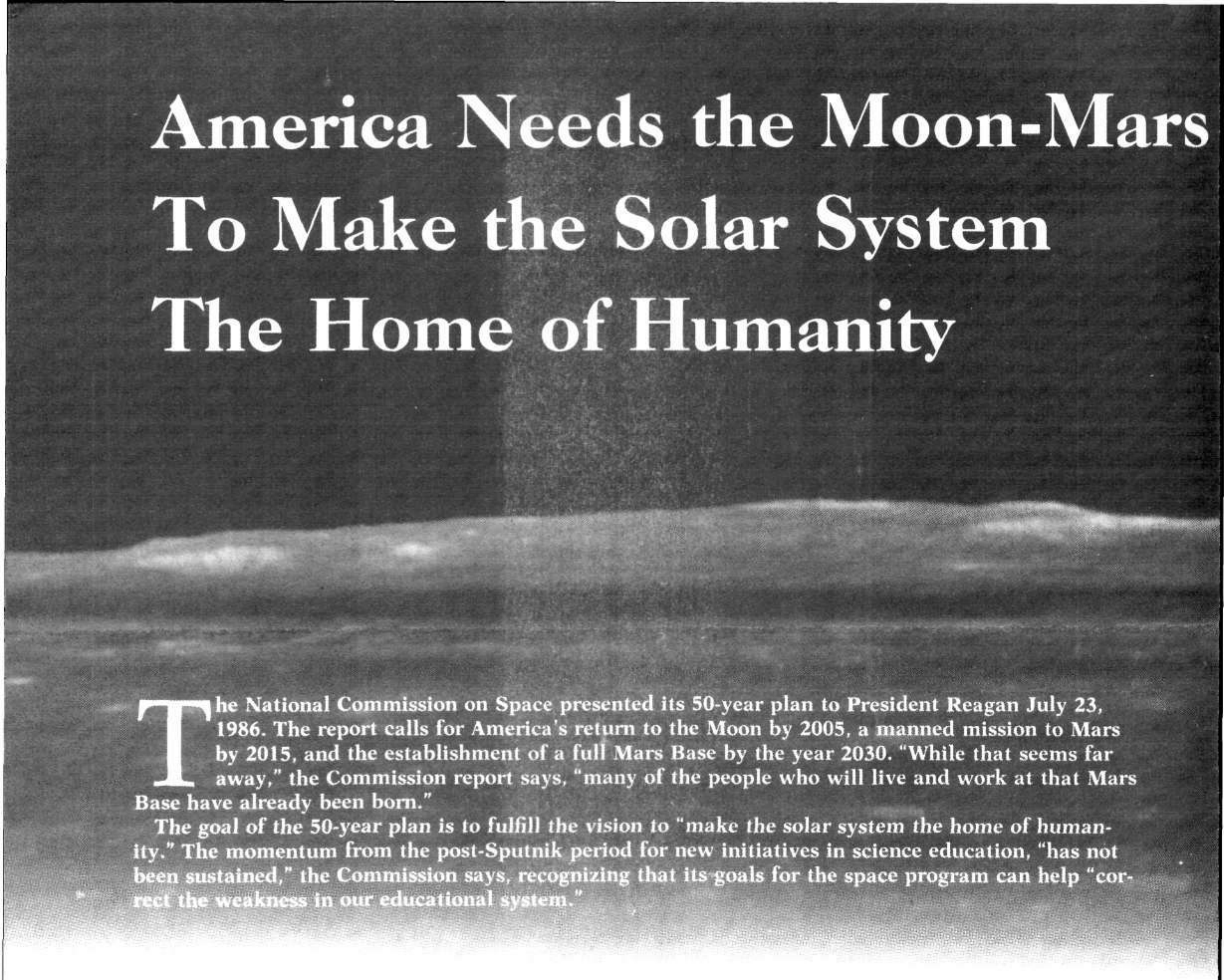
In order to attempt to explain away phenomena which demanded the notion of metrical characteristics of physical space-time as such, Maxwell supposed his "ether." When Michaelson-Morley and other inquiries discredited an efficient "ether," classical mechanics was substantially displaced by statistical mechanics, in the effort to save the appearance of neo-Cartesian geometry. The effort to elaborate a doctrine of special relativity, mimicked aspects of the work of Riemann, without conceding the most essential features of Riemann's method. The failures of a special relativity so conceived, led to the search for a general relativity. Generally speaking, to this date, so matters stand.

The areas of controversy so circumscribed, are at the heart of the "anomalies" of physics to date. These are the most important, most efficient of the practical problems of frontier physics today. The leading practical question associated with these challenges, is the *choice of experimental domain* in which the issues may be tested conclusively. The proper such domain is correlation of analogous anomalies of astrophysics and microphysics, with an eye to related phenomena in the domain of optical biophysics. Hence, a qualitative advance in astrophysical observations becomes indispensable to any general advance in physics.

The central feature of the controversy, and therefore of the related inquiries, is the notion of a Principle of Least Action. The modern history of this principle begins with Cusa's "Maximum Minimum Principle," continuing through the formulation of this as a Principle of Least Action by Leibniz, and the work of Gauss and his collaborators. Least Action is a notion inseparable from the idea of a metrical characteristic of physical space-time as such. Gauss-Riemann Least Action is, therefore, multiply connected self-similar-spiral action.

For example, Kepler's planetary orbits are, axiomatically, relatively "force-free" pathways, Least Action pathways. These are determined, not by multibody interaction, but by the metrical characteristics of physical space-time as such. The speed of light, the quantum constant, the fine structure constant, are interrelated reflections of the same metrical characteristics of physical space-time as such.

The most interesting researches in plasma physics, astrophysics, and optical biophysics, are those which either converge upon or directly touch this area of issues. These define the frontier of the present physics, and will obviously, therefore, define the basis for the new physics beyond today's. The Moon-Mars project's contribution to coordinated astrophysics and microphysics research, will therefore be of decisive importance for the future history of mankind.



America Needs the Moon-Mars To Make the Solar System The Home of Humanity

The National Commission on Space presented its 50-year plan to President Reagan July 23, 1986. The report calls for America's return to the Moon by 2005, a manned mission to Mars by 2015, and the establishment of a full Mars Base by the year 2030. "While that seems far away," the Commission report says, "many of the people who will live and work at that Mars Base have already been born."

The goal of the 50-year plan is to fulfill the vision to "make the solar system the home of humanity." The momentum from the post-Sputnik period for new initiatives in science education, "has not been sustained," the Commission says, recognizing that its goals for the space program can help "correct the weakness in our educational system."

FRANK BAUMGARTNER
Baumgartner Oil and Gas Division
Englewood, Colo.

HERB BETTENCOURT
San Francisco, Calif.

RICHARD BLOCKER
Proprietor
Live Oaks Winery
Gilroy, Calif.

CHUCK BRITZIUS
Chairman
Science, Engineering, Technology Assessment Cttee.
State of Minnesota
St. Paul, Minn.

JOHN BROSTMEYER
Bridgeport, N.Y.

ROBERT J. CARTER
Virginia Beach, Va.

PETER COOK
Washington, D.C.

JOHN D. COX, Ph.D.
President
FutureTech Industries, Inc.
Research and Development
728 N.W. 8 Avenue
Gainesville, Fla. 32601
Tel. (904) 378-3056

JOEL DE JEAN
Dallas, Tex.

ARTHUR W. DICKIE
Grass Valley, Calif.

J. MADISON DRAKE, P.E.
New Orleans, La.

MEINHART EDSON
Anaheim, Calif.

EMILY TAYLOR ELLIS
Union, N.J.

HERMAN ERHARD
San Jose, Calif.

DALLAS E. EVANS
Manned Mars Mission Studies, NASA, 1963-1969
Houston, Tex.

CARL GALLOWAY
Austin, Tex.

A.L. GLIDDEN
Glidden Morris and Company
New Cannan, Conn.

ROBERT GONZALEZ, JR., M.D.
P.O. Box 64407
Uleta, Fla. 33164

KENNETH HADDAD
El Paso, Tex.

DAVID E. HALL COMPANY, INC.
Industrial Sandblasting, Power Plants
Keller, Tex.

TOM HOMATIDIS
Toronto, Canada

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Federal Civil Service (ret.)
Aviation Logistics Systems
Patuxent River, Md.

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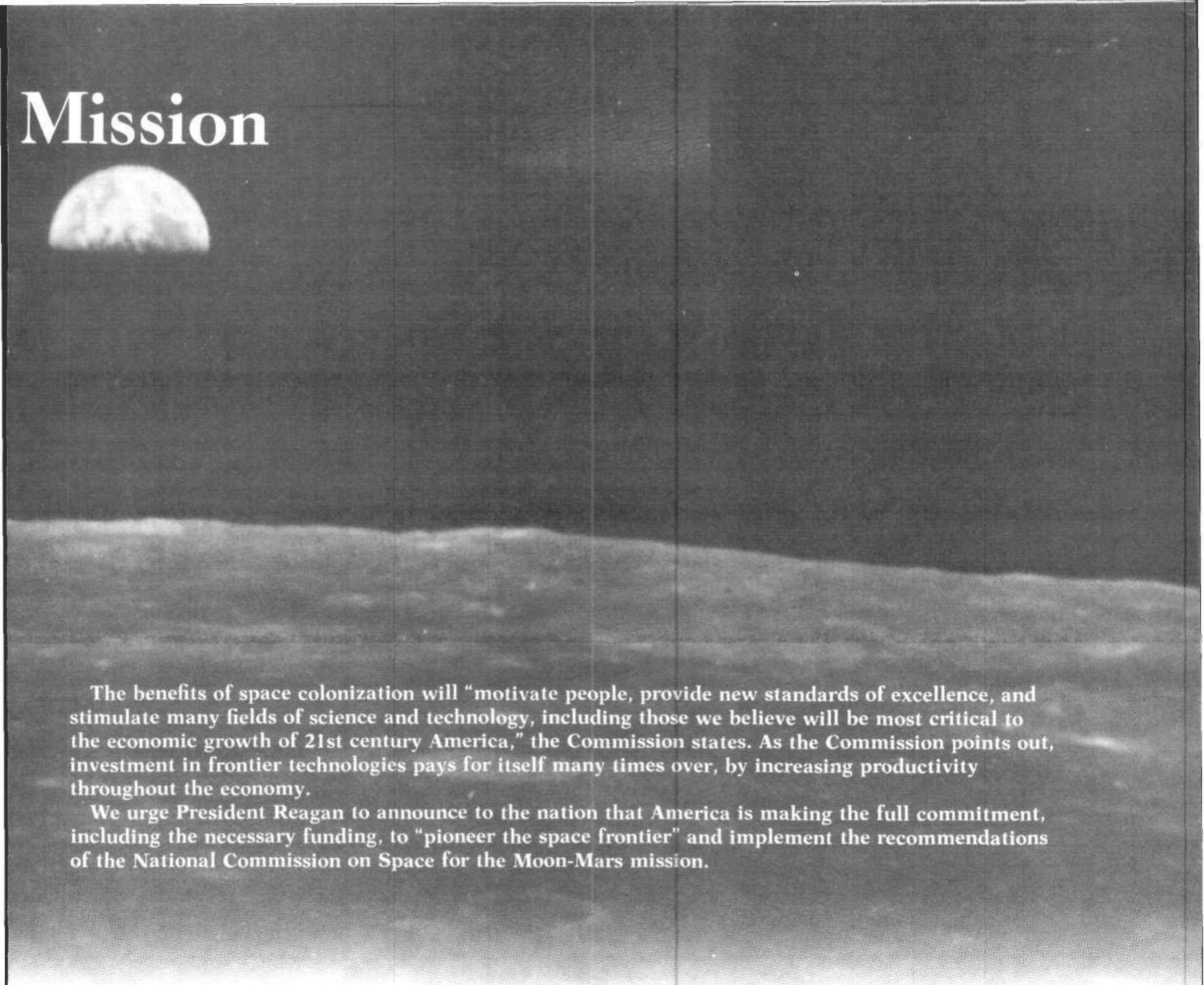
Jersey City, N.J.

BLAKE JAMESON
Electrical Engineer
Tulsa, Okla.



Mission

The benefits of space colonization will "motivate people, provide new standards of excellence, and stimulate many fields of science and technology, including those we believe will be most critical to the economic growth of 21st century America," the Commission states. As the Commission points out, investment in frontier technologies pays for itself many times over, by increasing productivity throughout the economy.

We urge President Reagan to announce to the nation that America is making the full commitment, including the necessary funding, to "pioneer the space frontier" and implement the recommendations of the National Commission on Space for the Moon-Mars mission.

ROBERT KESSLER
General Manager
Avco Everett Research Laboratory
Everett, Mass.

WILLIAM E. KRAI
Haddonfield, N.J.

LLOYD LAMB
Issaquah, Wash.

ANTHONY M. LEE
West Orange, N.J.

WILLIAM M. MCKNIGHT, JR.
Corpus Christi, Tex.

WILLIAM MAYHEW
Jericho, N.Y.

STEVEN MAYS, M.D.
San Antonio, Tex.

WALTER MEINCK
Aerospace Project Engineer
Grumman Aerospace
Bethpage, N.Y.

GLENDON MILLER
Redondo Beach, Calif.

BARBARA MONTANA
Wappingers Falls, N.Y.

WILLIAM MOORE
Dames and Moore
San Francisco, Calif.

DAVID MOSS
San Jose, Calif.

LEONARD NITZ
Sacramento, Calif.

HUGH B. O'DONNELL
Beltsville, Md.

MARGARET PARDUCCI
Parducci Wines
Ukiah, Calif.

BENJAMIN R. PARVIN
Senior Reactor Operator
Hartsville, S.C.

CAROL PENDERGRASS
Torrance, Calif.

PETER RIVA
President
International Transactions, Inc.
116 E. 95 Street
New York, N.Y. 10128

ROBERT W. STEVENS, DDS
Carmel, Calif.

GARY SUEN
San Francisco, Calif.

STANFORD TERRY
San Rafael, Calif.

BRUCE THOMPSON
Aerospace Engineer
Denver, Colo.

J. FRANK THOMPSON
Attorney
Fort Worth, Tex.

DR. JOHN TOMLINSON
Pathologist
Bryan, Tex.

DR. ANDREA M. TRESCOT
Pediatric Anesthesiologist
Washington, D.C.

ANTHONY VIDOVCICH
Mountain View, Calif.

ELSIE WICKSTROM
Cool, Calif.

America Needs the Moon-Mars Mission to

Make the Solar System the Home of Humanity

Is There Life on Mars?

by Marsha Freeman

When the first Viking spacecraft left Cape Canaveral in Florida on Aug. 20, 1975, its primary mission objective was to try to determine if there is life on Mars. As the results began to come back to the scientists on Earth one year later, two instruments said, "no," but one said, "maybe."

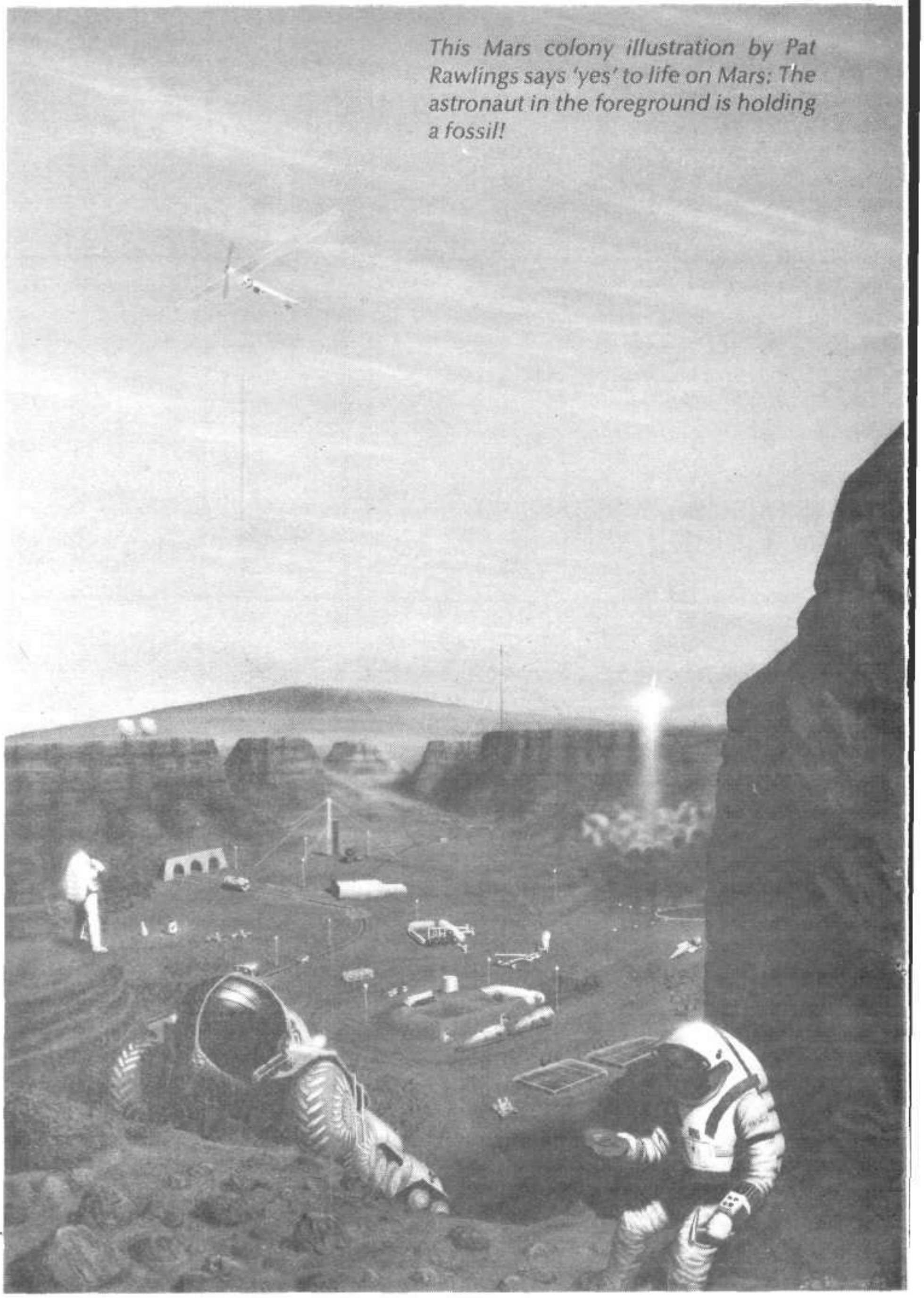
Mars is the only planet in our solar system that could possibly support life. The inner planets of Mercury and Venus are much too hot. The giant planets farther away from the Sun than Mars—Jupiter, Saturn, Neptune, and Pluto—are much too cold.

Our Moon is the right distance from the Sun, but it has no water or atmosphere; both of which are necessary for life. In fact, astronauts who explored the Moon during the Apollo program described it as a "dead body."

For generations, astronomers have pondered the possibility that Mars might have some form of life. In 1877, the observations by the astronomer Giovanni Schiaparelli of the deep channels on the red planet were immediately seized upon as evidence that intelligent beings on Mars had constructed sophisticated structures there.

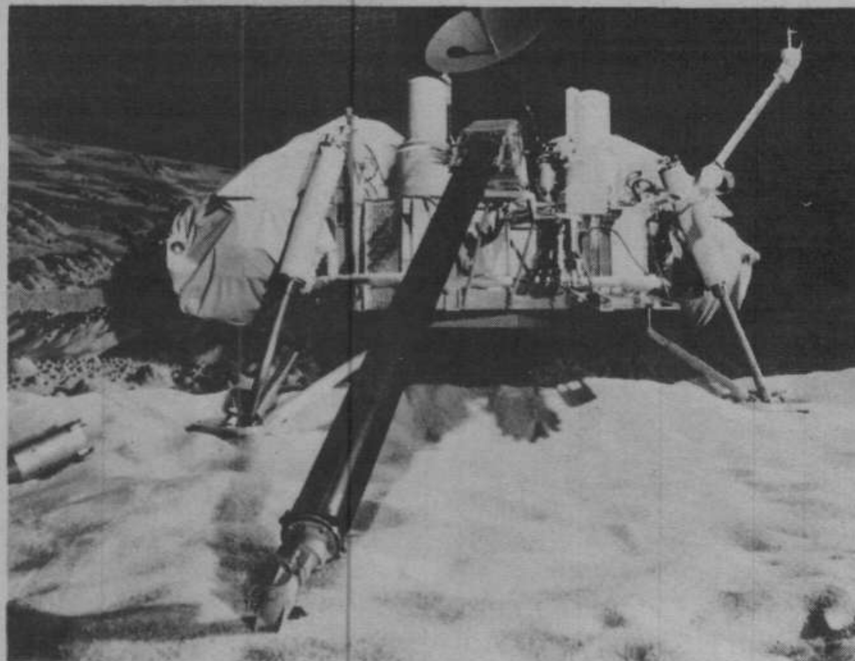
Almost 100 years later, observations from the Mariner 9 spacecraft, which orbited Mars for a year in 1971, revealed that at one time in its history, flowing water had carved the giant channels on Mars that Schiaparelli had seen through his telescope. It also revealed that like Earth, Mars has volcanos. When Viking 1 landed on Mars on the seventh anniversary of the first manned landing on the Moon, scientists got their first

NASA



This Mars colony illustration by Pat Rawlings says 'yes' to life on Mars: The astronaut in the foreground is holding a fossil!

Looking for life: The Viking Mars lander is a miniaturized laboratory packed into a hexagonal box only 59 inches across and 18 inches high, weighing about 1 ton. The soil sampler extends at the center. The two turret-like structures are cameras. This full-size working model is on display at the Jet Propulsion Laboratory in Pasadena, Calif.



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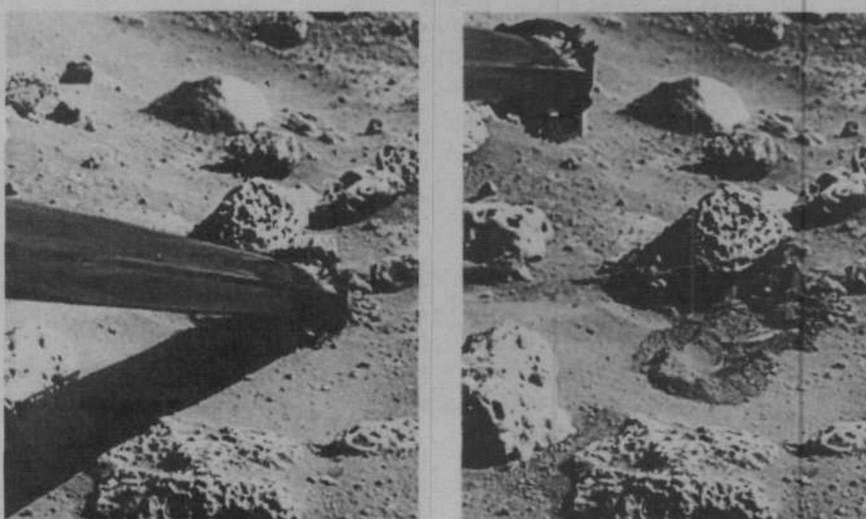
Viking's soil sampler at work, on Oct. 8, 1976. At left, the collector arm pushes a rock, displacing it and leaving a depression (photo at right). A soil sample was taken from beneath the rock, because scientists thought that if there were life forms on Mars, they would seek shelter under rocks from the Sun's intense radiation.



NASA

close look at the planet.

In 1984, two years after Viking stopped sending back information to Earth, the National Aeronautics and Space Administration (NASA) concluded in its publication on Viking's exploration of Mars that "the cameras found nothing that could be interpreted as living."

However, one of Viking's instruments had indicated, "maybe." In a conference on Mars July 21-23, 1986 in Washington, D.C., one scientist reopened the discussion on whether or not there is life on Mars.

What Living Systems Need

Even if there is no life on Mars now, it is clear that conditions were different ages ago, and that life may have existed there in the past. Perhaps if the first people on Mars do not find life, they will find fossils.

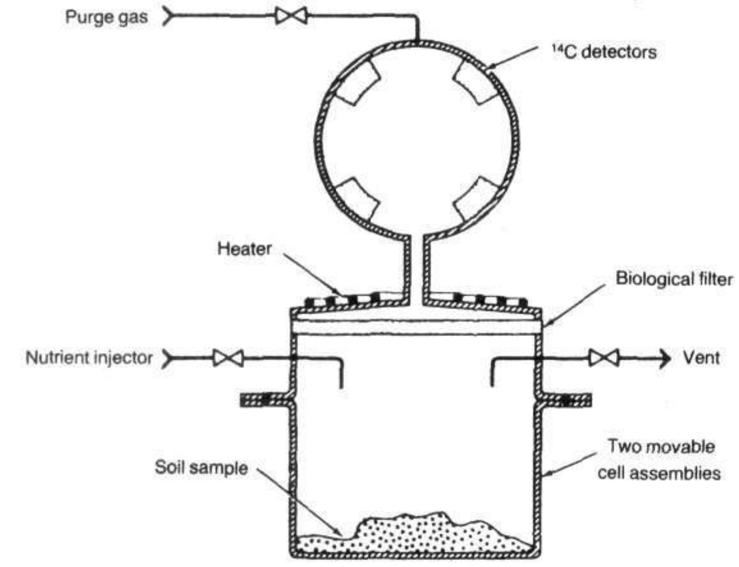
All known living things can only live within a narrow envelope of temperatures in their environment. The best estimates by scientists on the range of temperatures on Mars, which has seasons like the Earth, is that it is between minus 92 and minus 13 degrees Fahrenheit near the equator. While this is certainly too cold for many kinds of life, it is possible that primitive plants, such as lichens, could live in that climate.

At the poles of Mars, there is water ice frozen in polar caps, and the north pole has water ice there all year around. Scientists now speculate that there may also be water ice or even flowing water trapped in the Martian soil or underneath the surface, which could support life.

There is also water in the atmosphere of Mars. In October 1985 scientists revealed that there is more water than originally thought. The Mars Observer mission, planned by NASA for launch in 1990, will provide more information on this crucial ingredient for life.

The Martian atmosphere is very different from our atmosphere on Earth. It is mainly made up of carbon dioxide and is very thin; animals or people could not breathe it. However, it is possible that along with sunlight, it could provide adequate food for plants.

Over the past 10 years, two scientists, Drs. Gilbert Levin and Patricia Straat, have carefully examined the results of the one Viking instrument that showed there may be life on Mars. They concluded that there



THE LABELED RELEASE EXPERIMENT

In this experiment designed by Dr. Gilbert Levin, a sample of Mars soil was dampened with a solution of radioactive carbon (^{14}C). The soil then produced an increasing amount of radioactive gas, indicating that the trace carbon was being used as a nutrient by something in the soil. When the sample was heated to a temperature high enough to kill living matter, the emission effect dramatically decreased.

does not seem to be any other plausible explanation for these results but that there is life on Mars. But before looking at the evidence for life on Mars, let's review the evidence on the other side.

Searching for Life

One of the ways scientists thought they might find living things on Mars, was by seeing them. Each one of the two Viking landers, sent down to the Martian surface from the two orbiting spacecraft, had a pair of slow-scan cameras mounted about 3 feet apart.

For the cameras to see living things, these life forms would have had to be big enough to be seen by the human eye. The cameras eventually sent back hundreds of photographs of the surface of Mars, but none showed any sign of life.

Each lander also contained a package called the Biology Instrument, and a gas chromatograph/mass spectrometer (GCMS) to search for organic molecules in the soil. Their mission was to directly detect any evidence of smaller living things on Mars. Although there was always a chance that larger life would be found on Mars, biologists thought that the life forms most likely to be widespread on Mars (as they are on Earth) would be tiny microbes.

An analysis by Viking of the atmosphere and soil of Mars indicated that all of the elements essential to life on Earth—carbon, nitrogen, hydrogen, oxygen, and phosphorus—are present on Mars.

Samples for the biology experiments were provided by the soil collector arm on Viking which scooped up soil and delivered it to the chambers of the experiments.

The gas chromatograph/mass spectrometer instrument took each solid soil sample of about 100 milligrams and heated it in a small oven to see what gases would be released, or vaporized at about 200 degrees Celsius. These released or volatilized gases entered a chromatographic column that separated the various compounds. This works on the principle that different organic gases travel at different speeds through the materials packed in the column.

Next, the mass spectrometer ionized (electrically charged) the gases

NASA

Ice on the rocks and soil of Mars can be seen in this high-resolution photo taken by Viking Lander 2 in May 1979. The ice is extremely thin.

that emerged from the chromatograph and separated the molecules by their mass. The GCMS was searching for organic compounds—combinations of carbon, hydrogen, nitrogen, and oxygen—that are present in all living matter on Earth. Their presence would indicate the presence or former existence of life on Mars.

After these analyses were completed, NASA reported in 1984 that "to the surprise of almost every Viking scientist, the GCMS, which easily finds organic matter in the most barren Earth soils, found no trace of any in the Martian samples."

Testing for Life

Dr. Levin, however, wasn't satisfied that the GCMS test was adequate. To find out, he used a similar instrument to test soil samples from Antarctica, which has a climate similar to that at the poles of Mars. Levin's hunch was correct. The instrument showed that the Antarctic soil samples showed no signs of life, indicating not that the Earth has no life, but that the instrument is not as sensitive as some scientists believed!

Levin had doubted the accuracy of the GCMS results because of the one instrument that answered "maybe" regarding the question of life on Mars. The "maybe" came from a biological instrument called the Labeled Release Experiment, designed by Levin for NASA. This was a 1-cubic-foot box, "crammed with the most sophisticated scientific hardware ever built," according to NASA.

This Labeled Release Experiment is a very sensitive method for detecting microorganisms and monitoring their metabolism by feeding them chemical compounds containing radioactive carbon and then seeing what they excrete (see figure).

On Mars, a sample of soil was moistened with a solution of radioactive carbon chemicals. The soil produced an increasing amount of radioactive gas, indicating that the tracer nutrient was being used somehow by something in the soil.

According to Levin, in order to guard against the possibility that the radioactive gas had been released by a chemical or physical agent in the soil, the sample was heated to a temperature high enough to kill off any living things, but not stop chemical reactions.

This heating reduced the emission effect dramatically, "thereby satisfying the criteria for life." When these results were originally released in 1976, there was considerable confusion in the scientific community, because the other biology experiments had not detected any life on Mars.

Other Possible Hypotheses

In fact, scientists were so baffled by the results from the Labeled Release Experiment, that they tried to consider what nonbiological processes could have produced the effect the experiment found on Mars.

One theory put forward was that hydrogen peroxide in the Martian soil could chemically produce the release of the gases measured by the instrument. Levin pointed out, however, that William Maguire at NASA's Goddard Space Flight Center in Maryland had reexamined the 1971 Mariner 9 mission results and found no hydrogen peroxide on Mars.

Another point raised was that Viking 1 and 2 landed near to the equator of Mars, where there is no surface ice. Since Mars has no yet-discovered flowing water, where would microorganisms find water to live? Levin replied to this that there is enough moisture in the Martian atmosphere to supply primitive plants, such as lichens, with the water they need.

At the end of his July conference presentation, Levin showed two photographs that startled many scientists. (These are reproduced in color on the back cover of this issue.) The photographs are of a rock on Mars, named "Patch Rock," one taken on Mars day 28 and the other on Mars day 615. There is a greenish patch on the rock that is in a slightly different spot in the later photograph, and Levin attributed this to the possibility that there were lichens growing on Mars. To help make his point, he also showed a view of lichen-bearing rocks on Earth as seen through a Viking Lander camera. (This photo is also on the back cover.)

The spectral analysis (which measures the electromagnetic radiation emitted) of the Patch Rock was also similar to that of the Earth rock with lichens. Levin told the assembled scientists: "We have waited 10 years for all the theories and results from the many scientists investigating our experiment before voicing any conclusion. After examining these efforts in great detail, and after years of laboratory work on our part to duplicate our Mars data by nonbiological means, we find that the weight of scientific analysis makes it more probable than not that living organisms were detected on Mars."

Finally, Levin stated, "This is not presented as an opinion, but as a position dictated by an objective evaluation of all the relevant scientific data."

Does that mean there is life on Mars? Maybe. The unmanned missions to Mars now planned by the United States and the Soviet Union over the next decade, will help answer some of the many questions that the Viking experiments raised. These include how the climate of Mars evolved, the distribution and amount of water, the availability of various minerals, the geochemistry of the soil, the volcanism, and other dynamics of this Earth-like planet.

Whether these *unmanned* probes will satisfy any scientist, pro or con, regarding the question of life on Mars, is unlikely—no matter what they find.

Man is going to have to go to Mars, bringing with him the transportation systems to traverse the entirety of the planet, and the laboratory equipment to run experiments and tests to his satisfaction, before the book will be closed on the question of life on Mars.

However, in the second decade of the next millennium, the centuries-old arguments over whether or not there is life on Mars, will be somewhat superseded by the activities of the human life that will be arriving on Mars.

Then the definitive answer to, "is there life on Mars?" will be a resounding "yes"!

Glass Laser

continued from page 17

Finished cylinders of the glass are immersed in a hot bath of molten salts of sodium and potassium for more than 200 hours. Lithium ions migrate out of the glass surface, and sodium and potassium ions take their places. Because they are bulkier than lithium ions and must squeeze into the lithium holes, they create "compressive stress" within the network of the glass.

Cerqua said there was little compromise in laser gain as a result of the ion exchange.

The effort to strengthen phosphate glass has suffered from a fogging problem—the finished product absorbs moisture on its surface. Cerqua's team has solved the problem by adding aluminum ions to the bath to adjust pH (hydrogen-ion concentration), an idea based on suggestions from the Glass Science Department at Alfred University in Alfred, N.Y.

The new glass, called Q-89, is available in rod and slab form exclusively from Kigre, Inc. (rhymes with "tiger") of Toledo, Ohio, which participated in its development.

Cerqua is now engaged in posttreatment examination of samples for wavefront quality (flatness) and roughness.

The Laboratory of Laser Energetics is the home of the only major unclassified laser fusion facility in the United States. Scientists come from around the world to use the big (2.5 kilojoule), 24-beam Omega laser for plasma and fusion studies, and X-ray laser and microscopy research.

Books Received

Hydrogen Properties for Fusion Energy, by P. Clark Souers. University of California Press, 1986. Hardcover, 391 pp., $65.

Pioneering Space: Living on the Next Frontier, by Alcestis and James Oberg. McGraw-Hill, 1986. Hardcover, 298 pp., $16.95.

Spacefarers of the '80s and '90s, by Alcestis R. Oberg. Columbia University Press, 1985. Hardcover, 238 pp., $24.95.

Far Travelers—The Exploring Machines, by Oran W. Nicks. NASA SP-480, 1985. Hardcover, 255 pp.

Space Nuclear Power, by Joseph A. Angelo, Jr., and David Buden. Orbit Book Co., Malabar Fla., 1985. Hardcover, 286 pp., $48.95.

Space Nuclear Power Systems 1984, Proceedings of the First Symposium on Space Nuclear Power Systems held in Albuquerque, New Mexico, Jan. 11-13, 1984, *Mohamed S. El-Genk and Mark D. Hoover, eds.* 2 vols. Orbit Book Co., Malabar Fla., 1985. Hardcover, 584 pp., $110.

Lasers in Applied and Fundamental Research, Stig Stenholm, comp. Adam Hilger, Boston, 1985. Paperback, 273 pp., $19.50.

Medical Lasers—Science and Clinical Practice, by J.A.S. Carruth and A.L. McKenzie. Adam Hilger, Boston, 1986. Hardcover, 269 pp., $32.50.

George de Hevesy—Life and Work, by Hilde Levi. Adam Hilger, Boston, 1985. Hardcover, 147 pp., $25.

Diffractive Processes in Nuclear Physics, by W.E. Frahn. *Oxford University Press*, 1985. Hardcover, 179 pp., $32.50.

Foundations of Radiation Hydrodynamics, by Dimitri Mihalas and Barbara W. Mihalas. Oxford University Press, 1984. Hardcover, 718 pp., $75.

Quantum Theory of Finite Systems, by *Jean-Paul Blaizot and Georges Ripka*. MIT Press, 1986. Hardcover, 657 pp., $45.

Mathematical Physics, by Robert Geroch. University of Chicago Press, 1985. Paperback, 351 pp., $15.

Kurt Gödel Collected Works, Solomon Feferman et al, eds. Vol. I: Publications 1929-1936. *Oxford University Press*, New York, 1986. Hardcover, 474 pp., $35.

Crystal Structure Analysis—A Primer, by Jenny P. Glusker and Kenneth N. Trueblood. 2nd edn. Oxford University Press, 1985. Hardcover, 269 pp., $37.50.

Letters

Continued from page 3

exists) within our galaxy at this time—otherwise they would have revealed themselves to us by now.

Johannes Kepler hypothesized that the distances of the planets from the Sun were determined by golden mean ratios, according to a nested sequence of Platonic solids, with the Earth's orbit located between the dodecahedron and icosahedron.

The key constant in our universe is the speed of light. It is in relationship to this, that we determine the geometry of space-time.

To be sure, measurement of the circle according to degrees appears to be arbitrary; the question to be determined is whether or not it has a deeper geometrical explanation which connects it to the fine structure constant.

As Leonardo da Vinci and his collaborator Luca Pacioli showed, the golden mean is characteristic of living processes, and the structures determined by them—for example, the dimensions of the human body. I would contend that the universe itself is alive, in the sense that the creation is a continuing process: Therefore, the golden mean must characterize the geometry of physical space-time.

In Defense of Prince Charles

To the Editor:

Your snide quote from *Bildzeitung* [that Prince Charles's valet died of AIDS] does you scant credit. It makes me wonder what other items you print are highly suspect.

Please do not bother to send me further copies of *Fusion*.

G.A.R. Tomes
Poole, Dorset
England

The Editor Replies

We're sorry that you feel it necessary to defend Prince Charles by canceling your *Fusion* subscripton. Usually we are very direct in our attacks on Charles for his activities against science and technology, his proposals for population control, his belief in magic, and his work to destroy the Judeo-Christian tradition.

Happy 10th Anniversary Air and Space Museum

On the nation's bicentennial, July 4, 1976, President Ford dedicated the Air and Space Museum in Washington, D.C., saying that it was "America's birthday gift to itself." Since the museum opened its doors 10 years ago, it has become the most heavily visited museum in the world, hosting more than 100 million visitors.

In addition to exhibits on the history of air and space flight—from the Wright Brothers to the Space Shuttle—the museum sponsors free public lectures, films, concerts, and symposia.

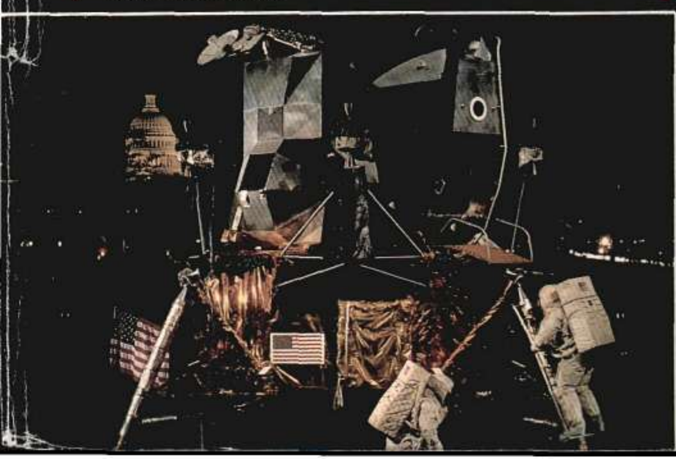
Through the exhibits, visitors can relive President Kennedy's announcement that mankind was going to the Moon, and can see the Mercury, Gemini, and Apollo command modules that returned to Earth with the astronauts who opened the space frontier.

One of the museum's most exciting exhibits, the Space Shuttle orbiter Enterprise, was flown to Dulles Airport in Virginia in 1985 on top of a NASA transporter. The Air and Space Museum plans to expand and build a wing at Dulles Airport.

Photographs are courtesy of Smithsonian Institution, Air and Space Museum

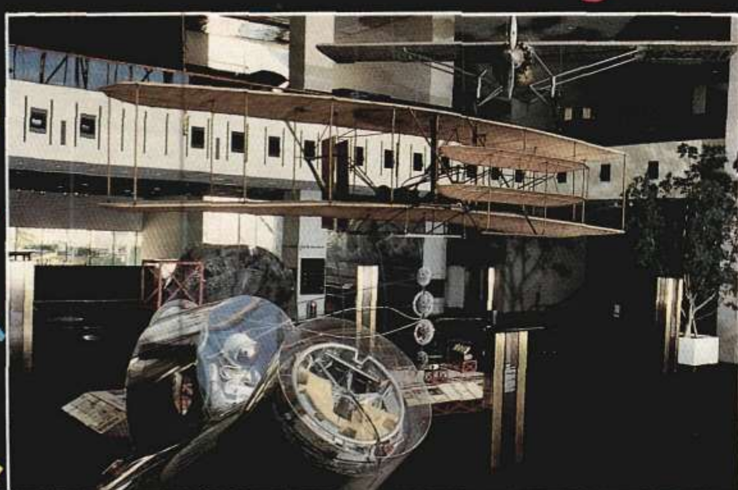
The Space Shuttle orbiter Enterprise (above) arrived at Dulles Airport in November 1985. Here, it has been removed from its transporter plane and is being placed on the ground.

The lunar modules of the Apollo program (below) brought the first human visitors to the Moon to the surface to explore and do scientific experiments. Later landers also included Rovers for lunar transport.



In 1984, the Air and Space Museum became the first museum to have an exhibit on another planet. The Viking I Lander (left), now on Mars, was donated by NASA to the museum, as the first historical artifact in their future "Mars wing."

The Milestones of Flight Gallery of the Air and Space Museum (below) contains the Wright Brothers Flyer, the Lindbergh Spirit of St. Louis, and other artifacts of the history of air transportation.

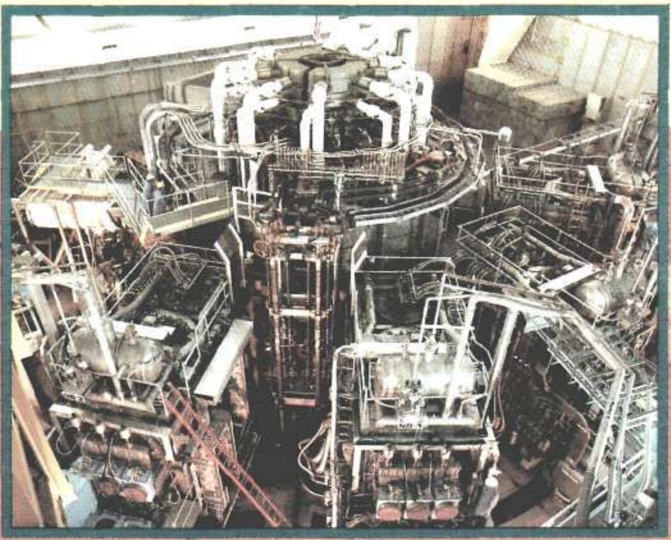


In This Issue

TFTR HITS HIGHEST TEMPERATURES EVER RECORDED IN A LABORATORY
Exceeding all expectations, the TFTR at the Princeton Plasma Physics Laboratory hit plasma temperatures of 200 million degrees Celsius while maintaining good plasma density and confinement time. The TFTR is expected to reach breakeven next year, but as Editor-in-chief Carol White explains, this milestone is meaningless unless the U.S. fusion budget is funded on a crash program basis to move to commercialization by the turn of the century. The nation already has the mandate and program to do this in the 1980 Magnetic Fusion Energy Engineering Act.

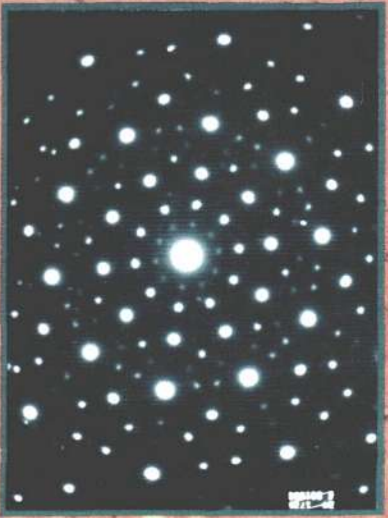
JOHANNES KEPLER'S QUANTUM THEORY
Although all might seem well in modern physics, German-language *Fusion* editor Ralf Schauerhammer shows how atoms and particles are involved in some blasphemous escapades, deviating from the Copenhagen School's interpretation of quantum physics. Specifically, new work with crystals indicates the astonishing fact that crystals can have pentagonal symmetry, not just the usual hexagonal configurations. The guidelines for understanding this can be found in Kepler's geometry.

LIFE ON MARS—NOW AND IN 2015
While the question of whether there is now life on Mars remains in scientific dispute, it is clear that by the year 2015, man must begin to colonize this neighboring planet. In the cover story, FEF board member Lyndon H. LaRouche, Jr., examines the "science driver" approach necessary not only to take man to Mars, but to revitalize our economy here on Earth. And in The Young Scientist section, Marsha Freeman explores the latest developments in the life-on-Mars dispute.



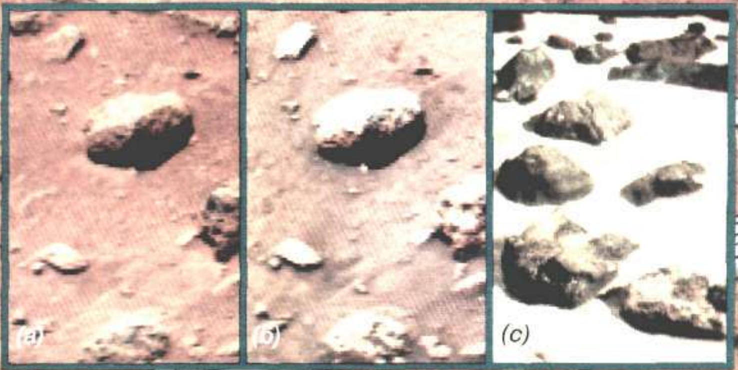
PPPL

The Tokamak Fusion Test Reactor, the nation's largest magnetic fusion device, is headed for breakeven in 1987.



Courtesy of D. Shechtman

A computer-enhanced image of pentagonal diffraction patterns formed by exposing aluminum-manganese crystals to Röntgen rays.



Courtesy of Dr. Gilbert V. Levin, Biospherics, Incorporated

Two Viking views of the same rocks on Mars are shown in (a) and (b), both at the same angle but at different times. The view in (a) was taken on Mars day 28; the one in (b) on Mars day 615. Note the change in the greenish patch, which shows through the dust deposited by wind or the Viking scoop. The patch is thought to be lichen.

For comparison, shown in (c) is some lichen on Earth rocks (greenish patches), as viewed through the same Viking imaging system at the Jet Propulsion Laboratory.