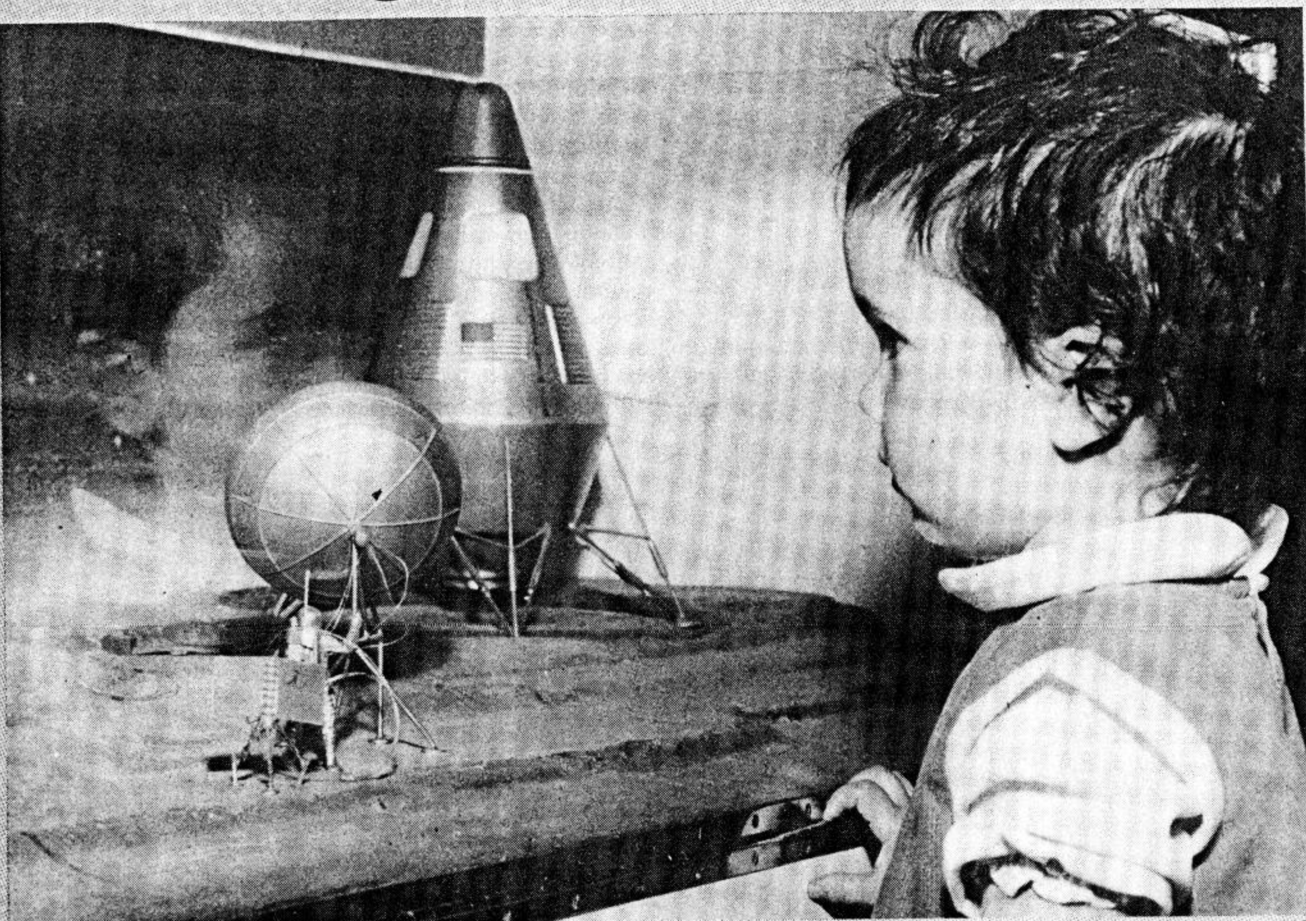
Sending Man into Space



NASA

A youngster looks at a model of a nuclear-propelled Mars lander in 1966 at NASA's Nuclear Rocket Development Station in Jackass Flats, Nevada. Had the United States pursued its ambitious space program, she might have been part of a Moon or Mars colony today.

Is the Key To Economic Growth

by Marsha Freeman

If man heads again for the Moon and Mars, there will be no limits to economic growth on Earth or to cultural optimism.

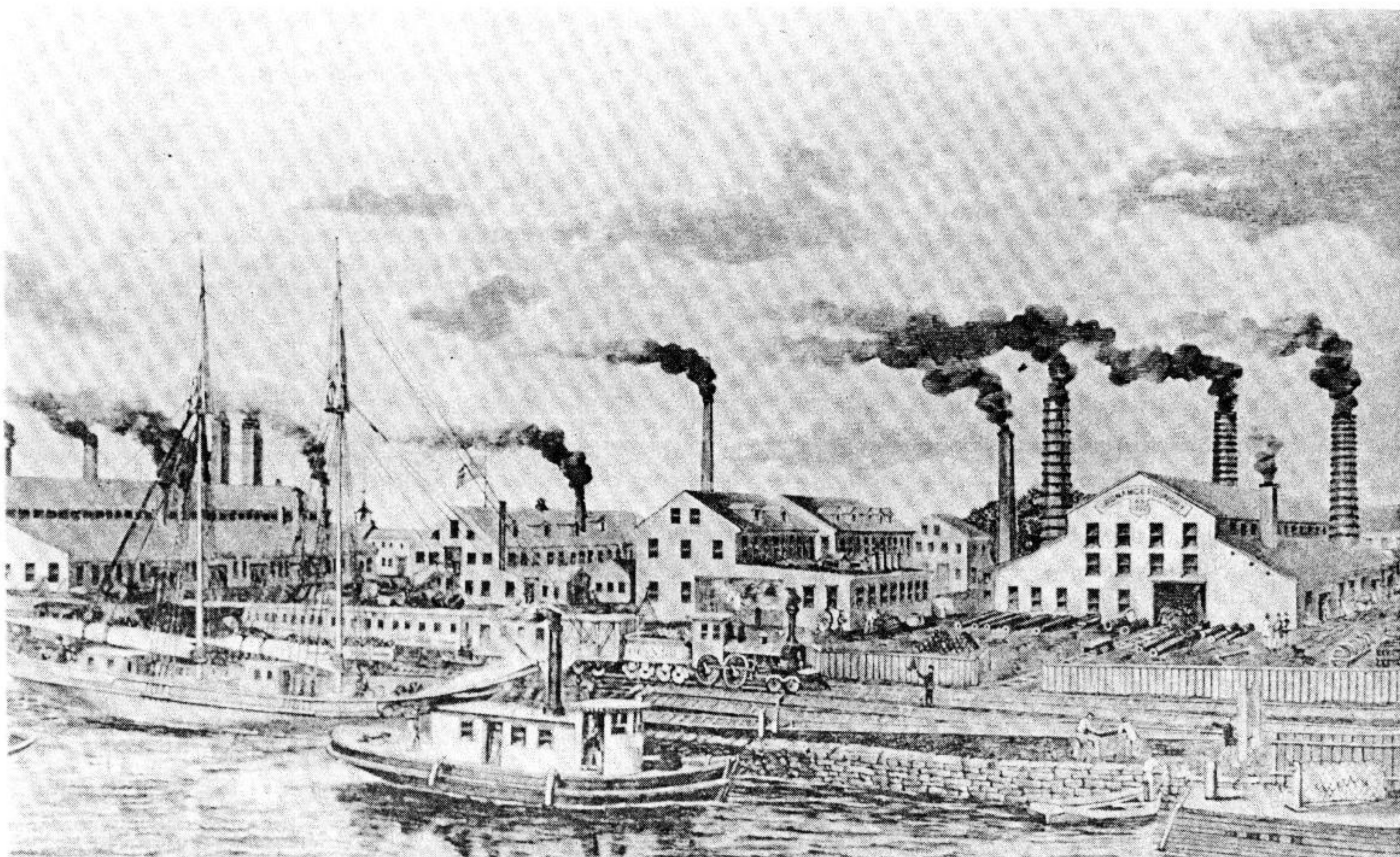
What would the world look like today had we made the energy technologies developed in the U.S. Apollo program the basis for the economy of the past 20 years?

- No nation would be concerned about pollution, or threatened with the cutoff of essentials (like refrigerators), because we would have significantly replaced the less-efficient—and, therefore, polluting—energy production and materials-processing technologies with nuclear sources and direct electricity conversion.
- No nation would suffer shortages or a catastrophic lack of energy resources. With an efficient, reliable, and economical supply of energy, every nation would have had the basis upon which to revolutionize agriculture, transportation, processing, and manufacturing industries, as well as consumer goods and services and health care.
- No nation would now have to see the life expectancies of its population fall, reversing the dramatic gains that were made throughout the 1960s.

The world has paid dearly for the fact that economic policies of the past two decades stopped the hands on the clock of technological progress. In the developing nations, the toll is in the tens of millions of lives. In the industrialized nations, the collapse in living standards of an increasing share of the population, combined with cultural pessimism, has helped produce the despair evidenced in the worsening drug epidemic.

Today, our home planet of Earth stands at the threshold of the greatest potential explosion of new knowledge and technological breakthrough—*if we set our sights on the Moon and Mars*. The clock can be restarted, by a recommitment of mankind to conquer the space frontiers that we so tentatively touched on 30 years ago. We can pick up where we left off and begin to use what our scientists and engineers created in the first decades of the space age: the basis for the permanent extension of mankind throughout the solar system.

In 1962, the editors of *Fortune* magazine authored a book



America's growth as an industrial nation depended on the investment in the 1800s in infrastructure—roads, bridges, canals, railroads—and in educating its people to create and develop new technologies. Here, the South Boston Iron Company in the 1830s, accessible by sea, rail, and road.

about the then-emerging aerospace industry, one chapter of which was titled "Hitching the Economy to the Infinite."* "There is no end to space, and so far as the U.S. economy is concerned, there will probably be no end to the space program," the chapter boldly stated. "Man has hitched his wagon to the infinite, and he is unlikely ever to unhitch it again. . . . The space venture, in short, is likely to be more durably stupendous than even its most passionate advocates think it will be. It is bound to affect the nation's economy powerfully and in many ways." Reflecting the overall optimism of the time, the dedication of the book reads: "To our grandchildren, who, no doubt, will think nothing at all of going to the Moon."

One of the most surprising observations to be made about the mobilization to land an American on the Moon is that it was *optimism* that drove the economic activity, not vice versa. In a study for the *Executive Intelligence Review* magazine published in 1986, Robert Gallagher examined the rate of investment in the aerospace industry, comparing the 1950s to the Kennedy years. He found that between 1950 and 1957, there was an 8 percent decline in new orders for capital goods in nondefense industries, which reached an 18 percent decline in 1958.

The Apollo decade of the 1960s dramatically reversed this trend, as orders for nondefense manufacturing capital goods more than doubled. Heavy industry basically "rebuilt" itself during this period, purchasing the stock of capital goods that carried the U.S. economy through the 1970s. In the year 1958, for example, there was a net *loss* of 211,000 metal-working machine tools; in 1963, there was a net *addition* of 124,000.

"Nothing is more fecund, industrially and socially, than large mobilizations of scientific knowledge and effort; and this is the greatest mobilization of them all."

—The editors of *Fortune* in *The Space Industry: America's Newest Giant*

Remarkably, companies began getting ready for the space program, by spending their own funds, not waiting for government contracts. They were motivated by the optimistic *expectation* that the nation would carry through the program the President had outlined in 1961 to go to the Moon, that Kennedy and the Congress would implement the financial and investment policies to make it possible. Gallagher showed in his study that by the end of the Johnson administration, the elimination of the long-range goals in the space program ended the optimism in industry as well as the progrowth Kennedy economic policies. Thus, the introduction of the Apollo-generated technologies into the civilian economy was aborted.

The contrast of this optimism to the state of the world today is striking. The majority of nations of the world are in an accelerating economic collapse. As the real fruits of the methods of "socialist planning" became painfully visible over the past year, the United States and its allies have promoted an equally bankrupt "free market" ideology, not only for domestic consumption but as the solution to decades of communist mismanagement. Lawfully, but ironically, the United States has nothing to *show* for 20 years of these Adam Smith economics but an economy that is now in a new race with the Soviet Union—not to colonize space but to physically destroy its economy.

Not this nation, nor any other, was built by any "free market." The economic freedom that was garnered for the inventor, the small manufacturer, the entrepreneur, was based on the nation's commitment to provide the infrastructure to make economic growth possible. The first hundred years' building of canals, bridges, roads, and schools enabled the establishment of this democracy. The American people's investment, carried out by their elected representatives, to complete the railroads, to connect the entire nation's waterways, to provide electric power to every farm, factory, and household, was what enabled the second hundred years' development of America into the greatest economic power and, rightfully, the envy of every nation in the world.

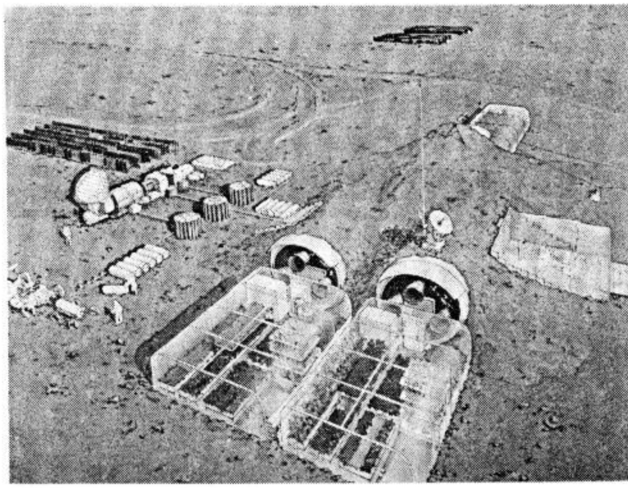


Illustration by Carter B. Emmart of a manned Mars mission as conceptualized by Jim French

Vast amounts of energy will be needed to power a colony on the Moon or Mars—to create an atmosphere for man to breathe and crops to grow, to build his infrastructure and industry, and to keep it going. Only nuclear or fusion energy is capable of providing the quantity and quality of power required.

In this artist's depiction of an early Mars settlement, two former cargo landers serve as living quarters. They are buried under the Martian soil to protect against radiation and connected to an inflatable greenhouse. The rectangular structures (top right) are two nuclear reactors.

The Role of the American System

In this century, the brief years of the mobilization of this nation to fight and win World War II, and the briefer still years of economic policies that enabled it to land men on the Moon, were not organized on the basis of "free enterprise." The organizing principle was one of dirigism—the

NASA

In the 1960s, NASA's scientists were working to develop the nuclear methods of propulsion capable of taking man speedily beyond the Moon—both fission and fusion. The Nuclear Engine Rocket Vehicle Application Program, known as NERVA, ended when the Mars mission was dumped in the early 1970s. This full scale mockup was constructed by Aerojet-General Corp.

mobilization of the nation's resources and its national will to accomplish a great task. The underlying precept guiding this American System school of economics, which traces back to Alexander Hamilton through the economic advisers of President Lincoln, is the importance of the *growth and development* of the population.

Of course, there were those in the 20th century who opposed this American System policy, the heirs of the 18th century Tories, whose world view was not republican but oligarchic and colonialist—the Teddy Roosevelts and the Averell Harrimans. But for two brief periods in World War II and the Apollo years, these oligarchs were forced to take a back seat.

In the 1960s, when the impulse was toward conquering new frontiers, rational citizens could not believe the Malthusian cry that the "world has too many people" or that "people pollute." There was an understanding during the Apollo years that without a critical density of population, and a higher standard of living due to advanced technologies and increased productivity, a highly cultured society was not even possible. As the American System economist Henry Carey spelled out in the 1800s, a thinly settled continent could not reach prosperity.

Economist Lyndon H. LaRouche has placed this fundamental concept of population density in its proper place—as the metric with which one measures the potential for economic growth of any society (Figure 1). The increase in potential relative population density requires the rate of introduction of new technology into the economy to accelerate over time. This is the only way to know if an economy is developing—or dying; there is no stasis in life or in an economy created by, and organized for, human beings.

It was veritably inconceivable to most observers at the beginning of the space age and through the Apollo lunar landing program that the people of the United States would ever willfully give up this infinite adventure, exploration, and promise of economic growth. It was obvious to most that the challenge of taking man into space, of allowing him to explore, of landing him on hostile worlds, would create the new technologies that could transform life on Earth, which is indeed what the space program did throughout the 1960s.

However, after the death of the president who had organized the policies of the nation to enable at least a brief return to the American System commitment to technologi-

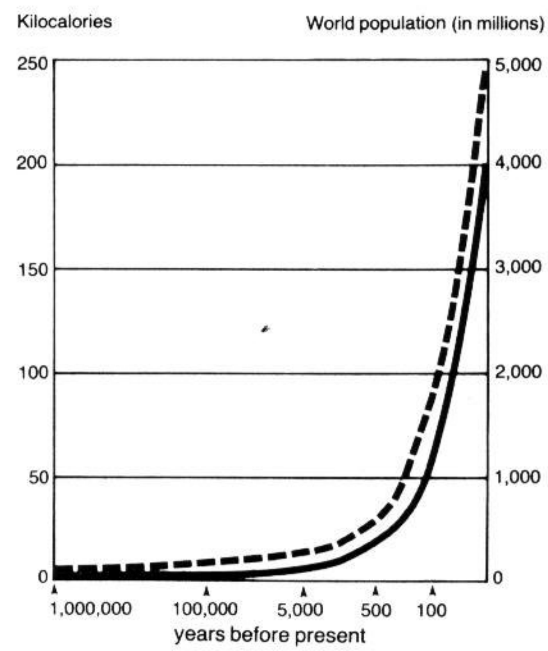


Figure 1
POPULATION GROWTH AND ENERGY CONSUMPTION PER PERSON

Energy consumption per person (solid line) is compared here with population growth over man's history. For about 900,000 years, the amount of available energy remains the same. Then, in less than 200 years, new technologies make the available energy jump up to its present level and provide for an accompanying jump in population. Energy consumption is measured in kilocalories.

cal progress, the promoters of the "free market" regained the upper hand. Government support for the basic infrastructure prerequisite for economic growth became "creeping socialism" to the conservatives and sops to "big business" to the liberals. Thus, from different directions, the right and the left came together around the same policies of Malthusianism. The nihilist examination of "inner space" replaced the commitment to explore outer space. Service workers replaced production workers. The antiscience counterculture replaced the American System.

Even as little as five years ago, it was reasonable to suppose that early in the next century we could still establish a colony on Mars. However, we are rapidly losing this potential, as we are losing the ability even to support our economy on Earth. Both crises have the same solution.

Energy Technologies for the 21st Century

To power the equipment men would need on the Moon, more efficient nuclear fission technologies, which would produce a higher *quality,* not just a greater quantity of energy, were being developed, along with new techniques to convert the nuclear energy into universally applicable electricity more efficiently than was being done anywhere on the Earth.

To take man farther than the Moon, to Mars, at least an order of magnitude improvement in the performance obtainable by chemical-fueled engines was needed. In the 1960s, the difficult job of converting nuclear energy to propulsive power was under way. To establish cities in space and move human civilization beyond Earth, next-generation thermonuclear fusion was seen on the horizon, even in 1962.

For space colonization, vast amounts of energy will be required not only to liberate man from physical toil, but to produce the very air he breathes and to replicate the earthly biosphere that is a prerequisite for life. Twenty years ago, space scientist Krafft Ehricke estimated that the approximately half million people living in Selenopolis, the lunar city he was designing, would need 8,760 billion kilowatt-hours per year of electric power. That is about four times the electricity consumed in the entire United States today!

Energy density
(megawatts per square meter)

Solar—biomass	.0000001
Solar—Earth surface	.0002
Solar—near-Earth orbit	.001
Fossil	10.0
Fission	50.0 to 200.0
Fusion	trillions

ENERGY DENSITY FOR VARIOUS SOURCES

The highly concentrated nature of nuclear and fossil energy is startling in comparison to the diffuse nature of solar energy on the Earth's surface. Even when solar collectors are placed in near-Earth orbit, the energy density is still 4 to 5 orders of magnitude below that of fossil fuel.

> **"We can justify the boldness of these aims by the reflection that, though it is true that 'Fools rush in where angels fear to tread,' man has now been foolish enough to rush in where angels used to fly."**
>
> —B. Mazlish in *The Railroad and the Space Program,* 1965

To take just one example, growing food will be one of the most energy-consuming lunar activities. On Earth, the Sun provides the energy and rain occurs naturally, as does much of the fertility of the soil. In space, these inputs will have to be provided using vast amounts of energy. Calculations performed by plant physiologists Frank Salisbury and Bruce Bugbee indicate that each person living in space will need an area between 12 and 30 square meters to grow the food he needs.†

If all the light and other energy inputs needed for the plants were to to be produced using electricity, Salisbury and Bugbee estimate it will take 600 watts per square meter. This translates to about 7.2 kilowatts per person, or 7.2 gigawatts (GW) per million population. Compare that to the approximate 1 GW per million population consumed in the United States today for all needs, not just food.

To provide the sheer amount of energy needed to support life in space, it was recognized that compact, high-energy cross-section nuclear reactor technology was required. Similar boundary conditions existed for the nuclear propulsion program at NASA, whose task it was to take men and materiel perhaps to the Moon and definitely to Mars.

Working with scientists at the Atomic Energy Commission, NASA developed composite, highly enriched uranium fuel elements coated with pyrolytic graphite and embedded in a graphite structure. These fuel elements could "burn" the nuclear fuel at a higher temperature than conventional fission plants. The space reactor would have to be virtually maintenance-free and safe, because people would be very close by, especially for propulsion. But when the Mars program was canceled in the early 1970s, the Nuclear Engine Rocket Vehicle Application Program (NERVA) was canceled too. Many of the 450 Westinghouse employees who had worked on NERVA transferred their skills and experience to the Westinghouse Clinch River Breeder Reactor effort (later canceled under the Reagan administration).

The high-temperature gas-cooled reactor built at Fort St. Vrain, Colorado in 1974 was based on the NASA design for a space-qualified second-generation nuclear reactor for trips to Mars. It offered higher temperature heat, in the range of 1,000°F, compared to 600° for light water reactors. These high temperatures could be directly applied to industrial materials and chemical processing, both on Earth and also on the Moon. Nuclear engineers at the Oak Ridge

"The premise of the case to be made for technological transfer is that even if we were not to use the Moon for *anything,* the trip itself would be more than worth the cost in terms of practical knowledge learned and applied. . . . It should and can contribute to maintaining or increasing our national rate of economic growth."

—Neil P. Ruzic in *The Case for Going to the Moon,* 1965

National Laboratory in Tennessee designed entire new cities for developing nations in the 1960s, based on the "nuplex," or nuclear-centered agroindustrial complex, clustered around a group of high-temperature reactors.

This technology has not yet been introduced into the commercial electric utility industry. It should, however, be the second-generation technology upon which the revival of the commercial nuclear industry is based in the United States, and designs for modular high-temperature gas-cooled reactors are under development.

Fusion: The Technology of Choice for a Growing World

For both propulsion and baseload energy, fusion has always been the future technology of choice in space, and the accompanying table (page 59) indicates why. The nuclear fusion process, the combining of light nuclei, releases orders of magnitude more energy per unit area of reactor surface than does nuclear fission.

Even more important than the efficient *quantity* of energy that can be obtained from fusion is the *quality.* Unlike fission, where the energetic neutrons produced in the nuclear splitting process are slowed down to release thermal energy, fusion can be "tuned" to produce energy along much of the electromagnetic spectrum. Microwaves, X-rays, gamma rays, and electrically charged particles can be extracted from the fusion process to be directly used in numerous applications—from fusion torching garbage and waste, reducing it to its constituent elements, to gamma-ray lasers.

In space, there will be no possibility of processing materials using water-based chemical techniques. The direct rearrangement and recombination of molecules will be required, which means using high concentrations of coherent energy. This will include processing lunar materials to extract usable ores, minerals, and elements like helium-3, which will be needed as fuel for the fusion process itself. The direct production of electricity—with no steam turbine cycle—will be necessary to meet all the myriad energy needs for space colonization.

The proper view of new, qualitatively superior energy sources was assumed during periods of this nation's growth. Today we have regressed to the wrong and dangerous Malthusian view. Nothing could more directly express the fallacious notion of the role of energy in human activity than the National Energy Strategy, completed by the Bush administration in early 1991. The fundamental premise of that document is that the growth of energy use must be curbed; that energy growth is "bad" because it uses up precious natural resources, producing pollution and waste—and because there will not be enough money available to build the capacity that would be needed for an unchecked growth in consumption.

This view leads to the report's recommendation, for example, that fusion energy need not be developed for commercial introduction until the middle of the next century, and that the next new nuclear fission power plant will not come on line for another 25 years. The argument is that a new energy technology is not "needed" until almost everything else currently available runs out or is used up. In fact, more efficient technology is "needed" as soon as it is available, as soon as man creates it, because it is both the quantity *and quality* of energy that enables man to improve his standard of living. Fusion will provide new *qualities* of energy.

The Electricity Yardstick

As the universal form of energy that can be transformed into mechanical, chemical, electromagnetic, and thermal energy, electricity can virtually free man from the toil of physical labor, enabling him to use his mind as his essential tool to transform nature. The standard of living, the distance from misery of every population in the world today, can be correlated, to a first-order approximation, to its per capita consumption of electricity.

To bring the entire world up to the level of electricity consumption still enjoyed in the United States today, more than 10,000 kilowatt hours per capita, requires more than a linear extension of today's technology. Using fossil fuels and standard nuclear technology would require the deployment of unacceptably large portions of the international labor force and worldwide supplies of raw materials, manufacturing capacity, and transportation, just to be able to adequately increase energy production. It would be like fueling the industry required for the 1969 lunar landing by burning logs from the world's forests.

The orders-of-magnitude increase in the density of energy that is required to live in space has created the potential technologies to produce energy in the quantities that the people on this Earth require. The time has come to restate the challenge to the human species to colonize the Moon and Mars, requiring the mobilization of a worldwide economy and marshaling the next leaps in energy technology, decades before the first manned spacecraft even takes off for Mars.

Plasma Technologies and 'Packaged Power'

As early as the 1960s, plasma physicists working in the fusion research effort recognized there could be many applications of low-temperature (this means thousands of degrees compared to the millions of degrees for fusion) plasma technologies, especially in materials processing. A number of plasma-type "furnaces" were brought to the prototype stage, making use of the energy of ionized gas, or plasma, to reduce, refine, and alloy metals and materials.

How the Investment Tax Credit Propelled Economic Growth

NASA

President Kennedy to Congress, May 25, 1961: "I believe this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth." A little more than eight years later, Astronaut Neil Armstrong became the first man to walk on the Moon.

Ninety days after taking office in 1961, President John F. Kennedy called for the most significant revision of the federal tax code since 1954. The central feature of the bill was a novel proposal for an investment tax credit to spur capital formation. The idea, according to Walter Heller, chairman of Kennedy's Council of Economic Advisers, was to shift the focus of government policy away from "corrective" action, geared to the swings of the business cycle, and toward a "propulsive orientation, geared to the dynamics and the promise of growth."

Today, to propel the economy out from even greater depths, economist Lyndon H. LaRouche has insisted that the Democratic Party must "develop a program of economic reconstruction, echoing to some degree, the Kennedy years—Kennedy's space program, his infrastructure-building program, and his investment tax credit program."

There was a firm conviction in the Kennedy administration that technological progress provided the indispensable basis for rising living standards and future growth. American success, Kennedy noted in his tax message to Congress, "has been one of rising productivity, based on improvement in skills, advances in technology, and a growing supply of more efficient tools and equipment."

The Investment Tax Credit was designed to create the maximum amount of new investment relative to the revenue loss to the Treasury and to spur capital purchases that would not have been made without such a credit. The idea was to allow a firm to take a proportion of its new investment as a credit, deducted directly from its taxes due. In fact, to encourage acceleration of investment, the original administration bill (later modified by Congress), would have created a sliding-scale system, giving enhanced rewards to firms with greater investment relative to past levels.

Specifically, a company that spent more on new plant and equipment than its depreciation allowance could deduct 15 percent of its investment above the allowed deduction; one that invested between 50 and 100 percent of its depreciation allowance could claim a credit of 6 percent on the amount above 50 percent. So, for example, a company with a depreciation allowance of $1 million that invested $2 million in one year in new factories, machinery, and vehicles, would be permitted to take 15 percent of the additional $1 million, or $150,000, off its taxes due. There was also a straight 10 percent credit for smaller firms and a universal 30 percent ceiling on the credit.

To allow businesses flexibility in their planning, the bill permitted a five-year carryover of unused credits. To assure investment in basic durable goods to refurbish U.S. industry, the credit applied only to domestic U.S. assets with a life of six years or longer. And to guard against abuses of the credit through artificial "swapping"—a kind of speculative secondary market, where a firm purchases new equipment primarily for the tax benefit and then sells off the asset to a firm not entitled to a further tax credit—the bill allowed for the recapture by the government of credits on any such assets.

The periodic survey of projected business investment by McGraw-Hill's Department of Economics in 1962, soon after the tax bill was passed, found that "businessmen have revised their capital spending plans sharply upward. The $40 billion they now plan to sink into new plant and equipment this year will set an all-time record." The survey further found that even preliminary long-term plans projected a steady acceleration through 1966. Conjoining the benefits of the Investment Tax Credit, and other measures of the 1962 and 1964 tax bills, to the technological gains associated with NASA provided a massive boost to the economy. Over the period 1961-1966, real per capita income rose by 20 percent, corporate profits doubled, and 7 million new jobs were created.

—Adapted from "Kennedy's Investment Tax Credit" by Andrew Rotstein in The New Federalist *newspaper, June 15, 1990.*

No Limits to Man's Spirit

Pope Pius XII:

"Some of you have advanced so far as to investigate the theoretical feasibility of interstellar flight, an aim which the name of astronautics itself indicates to be the ultimate purpose of your work. We will refrain from going into details, but it will not escape you, gentlemen, that an endeavor of such a scope includes intellectual and moral aspects that it is impossible to overlook. Such an endeavor demands a certain well-defined concept of the world, of its meaning, of its purpose. Our Lord, who placed an insatiable quest for knowledge into the hearts of human beings, did not intend to set limits to that quest when He said, 'Go out and subdue the Earth.' It is the whole creation that He entrusted to man and that He offered to the human mind, for the human mind to penetrate it, thus gaining deeper and deeper knowledge of the infinite greatness of his Creator."

—From his address to the 1956 Congress of the International Astronautical Federation in Rome

The Editors of *Fortune*:

"There have been some human protests—protests made by humanitarians, who feel that there are still too many things that need doing here on Earth before such energy is expended in space, protests made by other sensible people who are appalled at the extravagance, and felt by some religious people who are quite sure that 'God doesn't intend us to go to the Moon.' Objectors of all kinds must face the single devastating fact; they are all too late.

"It is not that certain formal decisions have already been made (a statement by the President, authorization by Congress); those are revocable. What is irrevocable is the vaulting ambition of man, which has brought him to the brink of this exploit.

"A religious argument actually can be made for going, or at least trying: all man is or has is God-given—his comprehension of physical law, his skill, his inquisitiveness, his soaring spirit, and, in fact, his vaulting ambition; since it is his God-given nature, therefore, that is taking him into space, the surmise cannot be made that the heights have already been divinely denied him. No; religion cannot logically argue against the endeavor from any assumption that man is predestined to failure. But religious and philosophic misgivings might loom over the possibility of man's triumph: triumph could produce a crisis of the human spirit."

—From The Space Industry: America's Newest Giant

Because there has been no serious program for rebuilding, much less improving, U.S. infrastructure or basic industry since the Kennedy period, there has been no "market" for steel, and, therefore, no perceived need to invest in these revolutionary new plasma technologies. Steel consumption per capita today in the United States is the same as it was in the Great Depression year of 1933.

To rebuild the basic steel and material processing industries in this country in order to revive the levels of overall economic growth experienced in the 1960s (and to go back to the Moon and on to Mars) by linearly extending our 50-year-old technologies would require more steel capacity than this country currently has, since most of what is in a steel mill is made of steel. Therefore, a serious economic program to return the nation to economic growth, with dramatic increases in productivity, would dust off these advanced plasma and directed-energy technologies and move their development into high gear.

Not all these advanced technologies are "heavy." To support assets in space, where weight is at a premium, energy technologies from the simplest to the most complex are required. The development of "packaged power" was described by the *Fortune* editors in 1962:

> Probably the broadest area of practical development will grow out of the new, compact, self-contained sources of power needed by satellites and spacecraft to operate their equipment and to maintain men and their equipment independently in space.
>
> Already being developed by private and government research for eventual commercial use, they include silicon solar cells, converting sunlight directly into electricity, which are being used to power such disparate things as portable radios, railway crossing lights, and community radio receivers in Indian towns.

These small solar-to-electric devices were placed atop bare houses in rural India, where they brought light, refrigeration, and the outside world over the radio, to people who before had little connection to the rest of civilization.

The Challenge of Direct Conversion

In the mid-1950s, one of the most challenging questions posed to scientists was how to understand the ionized portion of the upper atmosphere thoroughly enough to design and engineer an intercontinental ballistic missile (ICBM) vehicle carrying a nuclear warhead that could survive atmospheric reentry. After Sputnik in 1957, as the United States moved into the Mercury program for human spaceflight, the same question had to be answered in terms of a reentry vehicle that would not burn up an astronaut. Under the leadership of Dr. Arthur Kantrowitz, scientists at the Avco-Everett Research Laboratory in Massachusetts studied reentry problems and developed a theoretical understanding of the electrical conductivity characteristics of atmospheric gases at high temperatures.

Out of this research came the development of an experimental magnetohydrodynamic, or MHD, generator, which converts the movement of a very hot, ionized gas stream (a plasma) into electricity by passing it through a magnetic

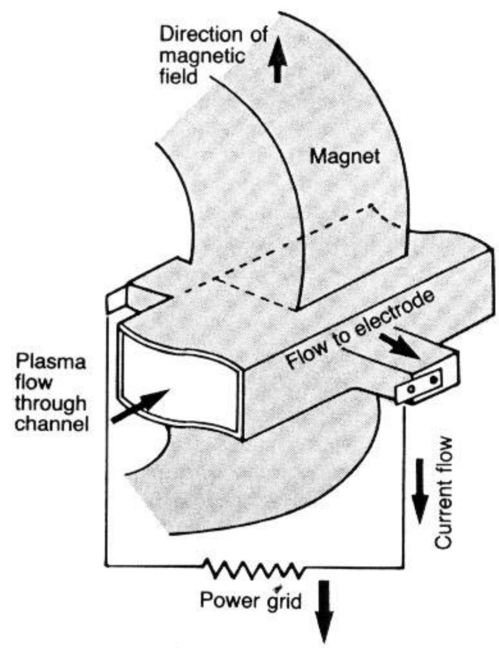


Figure 2
MAGNETOHYDRODYNAMICS (MHD) FOR DIRECT CONVERSION

It will not be practical to transport steam turbines into space, so MHD or other direct-conversion technologies will have to be developed. The basic MHD concept is shown here. When a conductor is moved through a magnetic field perpendicular to the lines of force, an electrical current is created in the conductor. Electrodes placed along the side wall of the MHD channel, perpendicular to the plasma flow and to the direction of the magnetic field, are connected to the load that will use the power.

The moving conductor in MHD is the supersonic flow of an electrically conducting gas or liquid. This can be made up of the combustion products of oil, coal, or gas; it can be a liquid metal heated by a nuclear fusion reactor; or it can be the plasma fuel in a fusion reactor. MHD would double the efficiency of electricity production, whatever fuel is used.

field (Figure 2). The plasma can be produced in many ways—by burning fossil fuels at high temperatures, by using the heat of fission reactions to create an ionized gas or liquid from an intermediate or moderating material, or, in the case of fusion, from the charged particles that are directly a product of the thermonuclear reaction.

The editors of *Fortune* magazine could report as early as 1962 that the Avco Corporation and a group of 11 electric utilities led by American Electric Power Service Corporation "are supporting a research program on MHD generators, which may turn out to be 40 percent more efficient than the most modern power generator."

For applications in space, there will be no alternative to MHD or other direct-conversion technologies. There is no possibility to transport or use steam turbines in Earth orbit, on the Moon, or even where there is already water-ice, on Mars. Electricity, as an electromagnetic form of energy, easily can be produced electromagnetically, with no moving parts or rotating machinery. The gains in efficiency will be substantial, as the physical limits of steam turbine generation in today's electric utility industry have already been reached. Nearly two-thirds of the thermal energy inherent in fossil fuels (coal, oil, or natural gas) is lost in today's conversion processes. MHD direct conversion can at least double the efficiency of electricity production, regardless of what fuel is used.

The practical result is that each unit of fuel used can produce twice as much electric power. In a world with dramatic deficits of electric-generating capacity, this potential represents an important way to *double* the capacity output of each generating plant. What's more, when used with fossil fuels, it eliminates any pollution. Anybody who really wants to "clean up" the environment should have been supporting MHD.

The Role of Optimism

When this nation no longer had the goal of living on the Moon and venturing out to Mars, the driver taking man's technology beyond what was already available came to a stop. Government-funded research and development was grossly cut back. The loss of funding, combined with the *loss of optimism,* stopped the commercial application of the space technologies, already in the demonstration stage, dead in its tracks. The slowdown in real economic growth, evidenced by the drop in capital spending on new plant and equipment in infrastructure and basic industry, put on hold the new generations of technology spun off from the space program.

In the 1960s, scientists had planned to land men on Mars by 1980. If that had happened, the economic policies of the early 1960s—the investment tax credit to encourage industry to invest in new capital equipment; the expenditures in education, health, and other social programs to prepare the population for the new generations of technology; the government-aided commercial introduction of nuclear power—would have had to continue (see box, page 61). The virulent opposition to those progrowth economic policies today makes President George Bush's Moon/Mars program an empty, unfulfillable promise, a cruel hoax.

Today the space frontiers are the same as they were when the future ground to a near-halt 20 years ago: back to the Moon for the purpose of moving human civilization beyond Earth and then on to the colonization of Mars. It might take a greater effort than it would have 20 years ago, but today we can still reach that frontier; it is a question of political will.

Marsha Freeman is an associate editor of 21st Century.

Notes

* The Editors of *Fortune, The Space Industry: America's Newest Giant* (Englewood Cliffs, N.J.: Prentice-Hall, 1962).

† Frank B. Salisbury and Bruce G. Bugbee, "Space Farming in the 21st Century," *21st Century* March-April 1988, p. 32.