1986

The Science and Technology Needed To Colonize Mars

by Lyndon H. LaRouche, Jr.

PART 2 OF 2 PARTS

April 26, 2019—It will be evident to the reader that Lyndon LaRouche's ideas expounded in this 1986 article have stood the test of time magnificently, and must light our way today. But certain circumstances would have changed Mr. LaRouche's way of expressing them were he writing this during the Twenty-First Century. Writing in 1986 when the United States was in a form of confrontation with the then-Soviet Union, LaRouche spoke of the Mars colonization mission as a U.S. mission. But later, after the breakup of the Soviet Union, he wrote of it as a cooperative international mission in which Russia, China, India, Japan and other applicable nations would be invited to join as sovereign equals. In the first section of this second installment, some formulations relating to the confrontation with the Soviets have been removed from the original. This article was first published in the November-December 1986 issue of Fusion *magazine.*

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.


NASA
International Space Station Commander, NASA Astronaut Peggy Whitson, looks back at Earth from the cupola control tower.

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.

EIRNS/Dennis Speed

"Americans lack those psychological potentials for space exploration which existed during the1960s and earlier." Shown here is the giant five-thruster array of the Saturn V rocket on display at the NASA Kennedy Space Center in Orlando, Florida.

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 un-militaristic 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.

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 Augustinian 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.

NASA/James McDivitt

"Over the recent 20 years, we have undergone a 'cultural-paradigm shift,' away from Augustinian tradition.... The psychological demands placed upon our society by bold ventures into space, are precisely the stimulant to bring us back to ourselves, our moral heritage." Shown here is Ed White, first American astronaut to perform a spacewalk during the Gemini 4 mission in 1965.

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 doom-saying "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.

NASA

Artist's depiction of an Earth Departure Stage of a proposed NASA Mars mission, docked to the Crew Exploration Vehicle.

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.

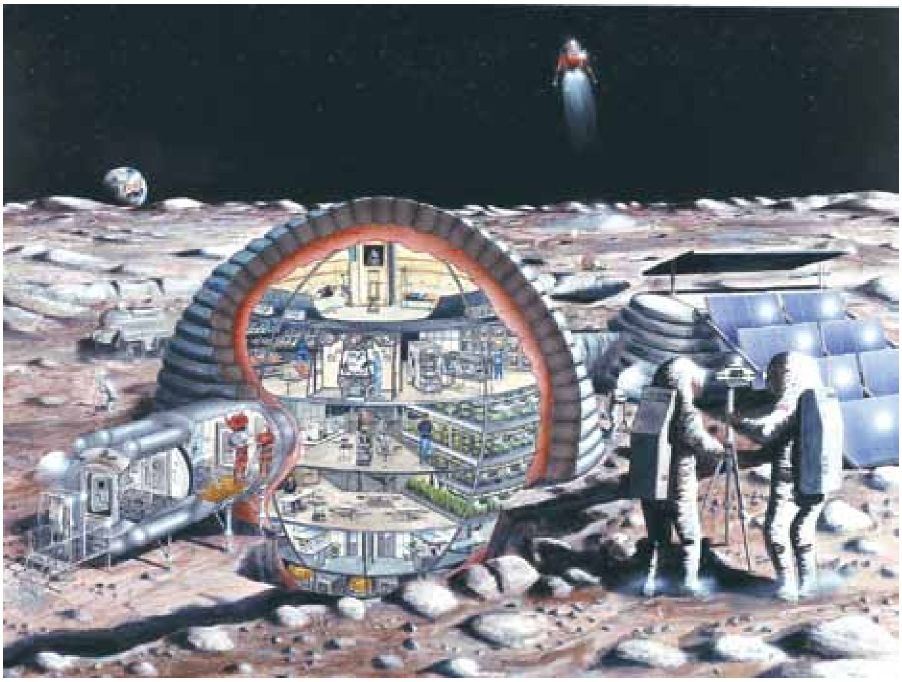
The only products sane people are likely to bring from space to Earth, are products which have a relatively immense value per pound of weight. The often-discussed growing of industrial crystals in the low gravity Earth-orbit, is typical of the limited classes of products we shall actually import from 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.



NASA

Not only must lunar structures house laboratories and food-growing capabilities, but they must be spacious enough for comfortable living. Shown here is an artist's cutaway depiction of an inflatable lunar habitat with an airlock (left) and a base operations center.

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;

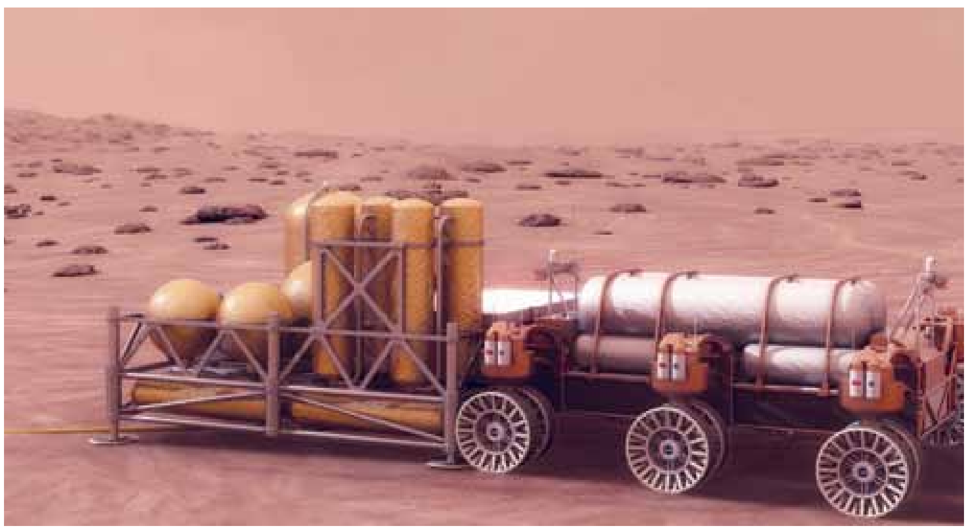
(3) to provide local supply for colonies in space.

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



NASA

Artist's depiction of autonomous robotic production and cryogenic storage of oxygen and methane rocket propellant, using carbon dioxide from the Mars atmosphere and water from Martian soil.

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 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 technological progress on Earth.

NASA/Pat Rawlings

"By between 50 and 60 years from now, the main source of scientific activity on Earth will be space exploration. We shall become a 'space civilization,' as distinct from an Earth-bound civilization." Depicted here is a Martian growth chamber, where fruits and vegetables could be grown hydroponically.

By between 50 and 60 years from now, the main source of scientific and 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 technological 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 managements 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.

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.


EIRNS/Stuart Lewis

Alexander Hamilton was the first to introduce, as official government policy, the economics of technology, the Leibnizian principals of physical economy.

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 the18th 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 agro-industrial power.

The principles of physical economy were discovered by Gottfried Leibniz. These principles were introduced to the United States through Leibniz's English ally, Jonathan 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 technological 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 re-emphasizing, 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.

CC/Jaimrsilva

"The term 'economic science' must be restricted in definition and usage, to signify 'physical economy' as founded by Gottfried Leibniz."

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 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 use 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 performances 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, 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 tool shop 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 especially 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.

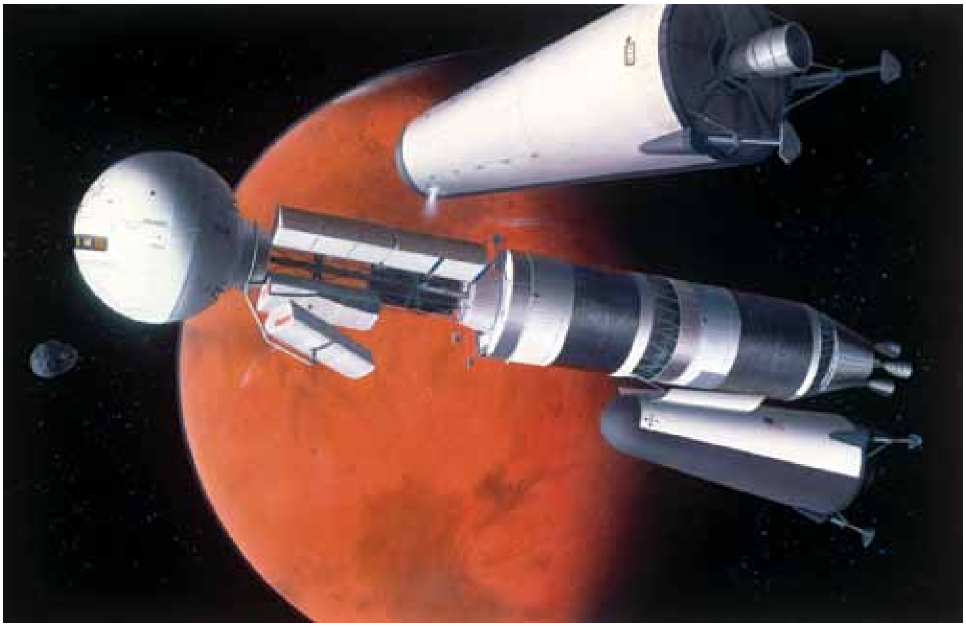
During the interval 1939-1943, the U.S. economy went through an accelerating recovery. This began by mobilizing every scrap of usable junk machinery, and recruits from the unemployment lines, often working in formerly abandoned or semi-abandoned buildings. After 1940, this "scrounging" phase of the mobilization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

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



NASA

In this artist's rendering, a nuclear thermal transfer vehicle, on its way to the Jovian system, refuels in a Mars orbit near the Martian moon Phobos.

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 agro-industrial 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 maintenance 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 of 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 sub-classifications:

(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 organizations' 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.

(40 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 veterans' 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

NASA/SAIC Pat Rawlings

During Exploration Mission-1, planned by the Trump administration, NASA's Orion spacecraft will venture over 60,000 km beyond the lunar orbit, farther than any crewed spacecraft has ever travelled.

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 Mange's École 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 transformation of the United States into the world's leading agro-industrial 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.

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 the 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 spacetime, 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.

Beginning1850, 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."

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, in 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.