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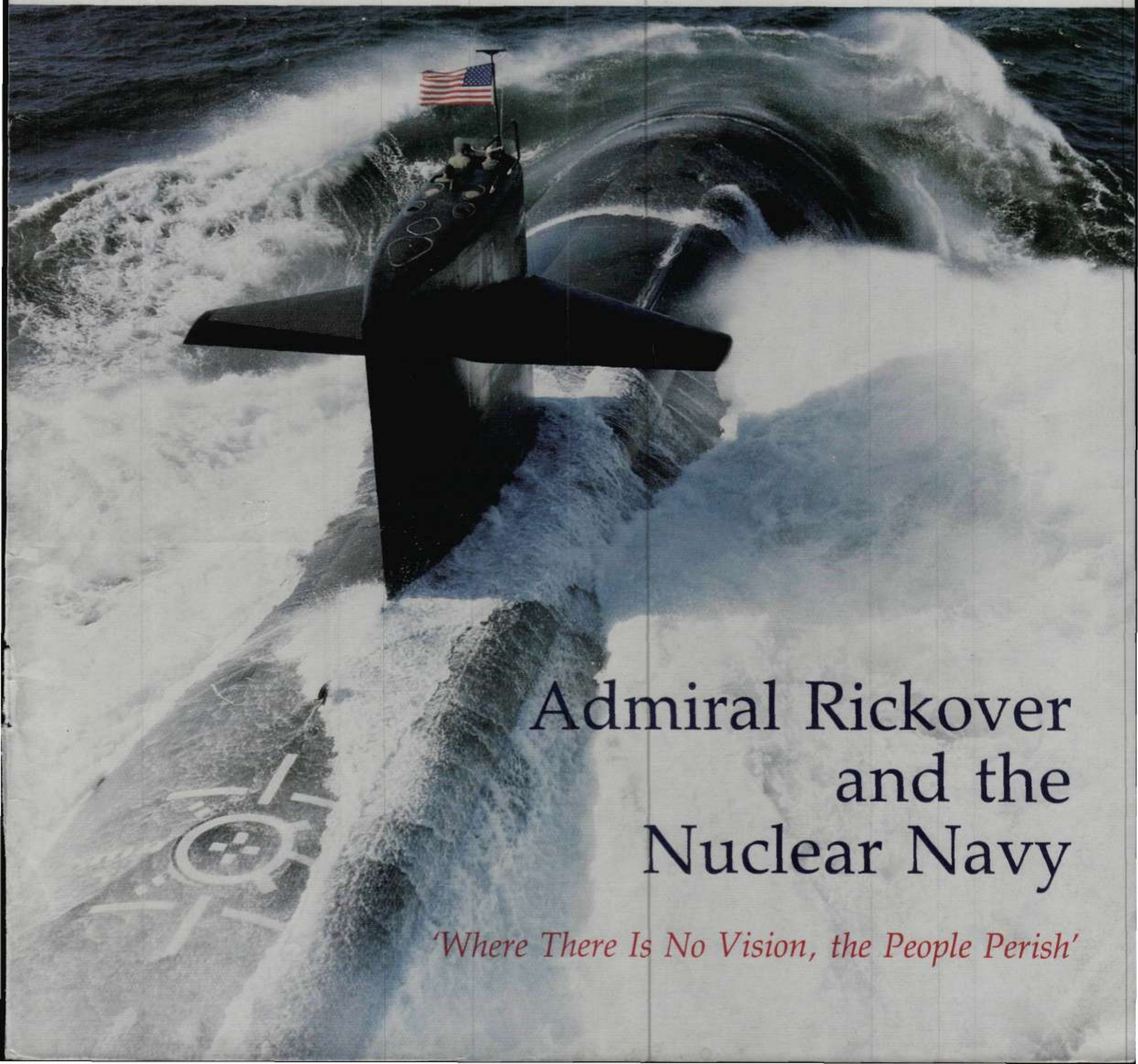
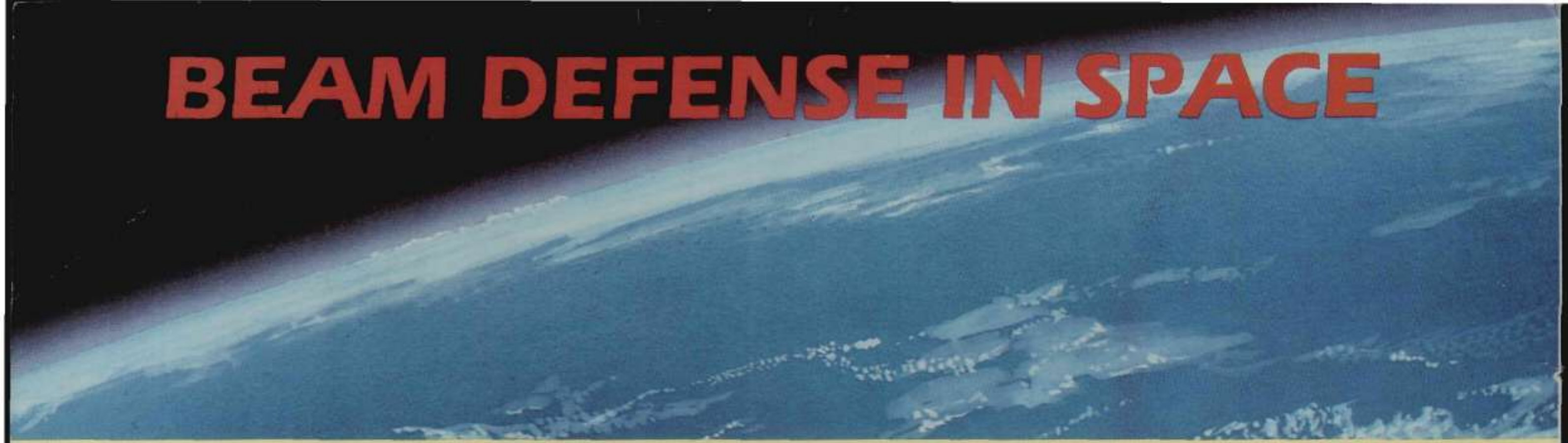


Admiral Rickover and the Nuclear Navy

'Where There Is No Vision, the People Perish'



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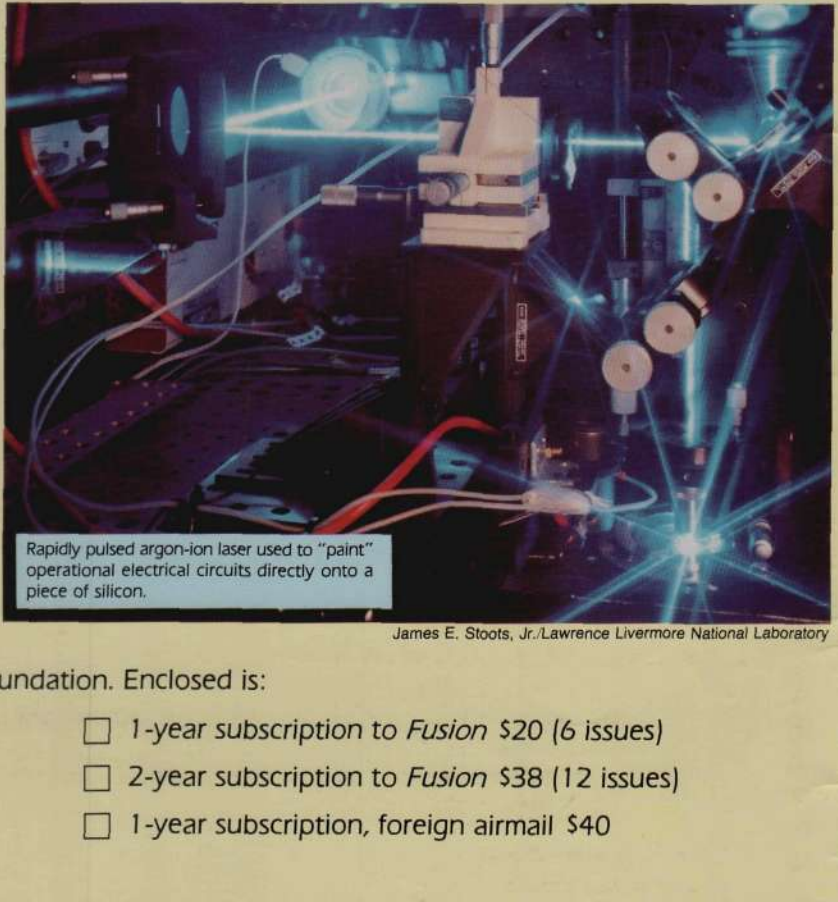
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FUSION

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Features

News

Departments

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On the cover: The *U.S.S. Phoenix*, courtesy of the U.S. Navy; cover design by Virginia Baier.

No More Appeasement

As we go to press, the President's Strategic Defense Initiative (SDI) is under full-scale attack by the Soviet Union and its U.S. allies. At Geneva, the Soviets are now demanding that the United States drop all *research* on beam weapons, or they will go on a massive arms buildup. Here at home, Soviet allies in Congress are using every pretext to reduce the President's military budget—and with it the Strategic Defense Initiative—to impotence.

The current fight to save the SDI takes place in the context of the reelection of Greek Prime Minister Andreas Papandreou. This self-avowed friend of the Soviet Union has been emboldened to give the United States an ultimatum: All NATO bases must be removed from Greece by the year 1988.

It should be clear to any thinking patriot, that our nation is in grave danger of being led down the path of Munich—*this time with the United States in the role of the British appeasers of Hitler.* However, there is no U.S. industrial giant in the wings to bail us out now, as we bailed out the British then. Thus the Soviets are treating us just as Hitler treated his appeasers, with contempt.

In the past, the Soviets had stressed that only the "testing and deployment" of SDI systems must be ruled out. But now that a bipartisan congressional decision has been made to *de facto* reduce next year's military budget below this year's, the Soviets have been emboldened to step up their threats.

On May 29, Soviet chief negotiator Viktor Karpov declared that "renunciation of the development, including research, testing, and deployment, of space arms would open the way to radical reduction in nuclear arms." Further, *he warned that continuing SDI research in the United States* would "sharply reduce chances of reaching an agreement on disarmament issues."

A KGB Congress

Here at home, Soviet demands are openly supported by liberal congressmen and senators, who admit that their purpose in whittling away the defense budget is to prevent the President from "challenging" the Soviets. Worse than

these openly pro-Soviet liberals, are the supposed conservative supporters of a strong defense (like House Armed Services Committee chairman Les Aspin) who are using their credibility with conservatives to undercut the President at every turn. Although a Democrat, Aspin has always come forward as a supporter of the MX missile and for a strong defense—with one slight proviso: he fully supports a freeze in the military budget.

Now he has announced a six-point Democratic Program for fiscal year 1986 that will bind the United States to the SALT II agreement, despite Soviet violations; replace the MX missile with the Minuteman; ban testing of U.S. antisatellite weapons; preserve the ABM treaty; and, last but not least, severely reduce the SDI budget.

At a time when every informed source agrees not only that the Soviets are outstripping the United States militarily, but also that they will have a working beam defense system (including the X-ray laser) within the next several years, Aspin wants to "check the feasibility of the SDI." While we are urgently in need of a crash program to develop beam weapons along the lines of—but far more massive than—the Manhattan Project, the Apollo Project, or Admiral Rickover's creation of the Nuclear Navy, Aspin proposes yet another feasibility study, with reduced funds to match the reduced goal. And he poses as a friend of the SDI!

This is the same game that Aspin played with the MX missile. At that time, he posed as the one man who could engineer a compromise between the out-and-out foes of the MX and the Reagan administration. As a result of his negotiating sessions, the administration found itself accepting deeper and deeper cuts in the program. Now the President has agreed to let Congress cut the overall program in half, and make a 75 percent reduction in production funds in 1986.

The best estimate we now have projects the year 1988, as the time when the Soviets will feel sufficiently secure to strike. By that time, the Soviets calculate, the U.S. economy will have disintegrated to the point that the United States no longer has an in-depth war mobilization potential. At the same time, the Soviets estimate that they will be able to use their assets within the U.S. government, from Henry Kissinger down to the Les Aspins, to sabotage any serious development of the SDI.

The Soviets Can Be Stopped

The Soviets can be stopped, but only if we begin now to put all of our resources into developing the SDI, as part of an overall military buildup. We must stop appeasing the Soviets.

Concessions, like that by Geneva arms negotiator Paul Nitze, must be immediately reversed. Nitze told an audience at the Johns Hopkins School of Advanced International Studies May 30, that the American SDI effort will be restricted to pure research, and that development, testing, and deployment are out of the question.

Appeasement means the defeat of the United States—and therefore Western civilization—by the Soviets. We cannot defend ourselves by mere bluff, however; we must begin a crash program to develop beam weapon and allied technologies now. This means a budget of about $5 billion for funding the SDI itself, and an equivalent amount of credits to industry directly involved in the program, to develop the industrial base without which the SDI cannot succeed as an actual defense system. In all, we need a military buildup, focused on the Strategic Defense Initiative, on the order of $400 to $500 billion a year.

Can we afford it? The answer is "no" only for those who have already determined to concede to the Soviets without a fight, or for those who are so stupid that they do not realize that we are giving the Soviets an overwhelming war-winning advantage by willfully destroying U.S. war-waging capabilities. And is any price too costly for the purpose of saving Western civilization?

Fortunately, we can "afford" it. A crash program for military buildup will put U.S. industry back on its feet, on the basis of an upgraded technology, just as the Manhattan Project and Admiral Rickover's development of the nuclear submarine gave the nation the potentiality for the civilian use of nuclear power. Such a crash program to develop beam defense will pay for itself many times over.

Viewpoint

Giving Away U.S. Technology and Markets

by Dr. Frederick B. Henderson, III

The U.S. government is poised on the verge of a bad decision on the commercial use of space that could lose this country a multi-billion-dollar global market and its position of technological leadership.

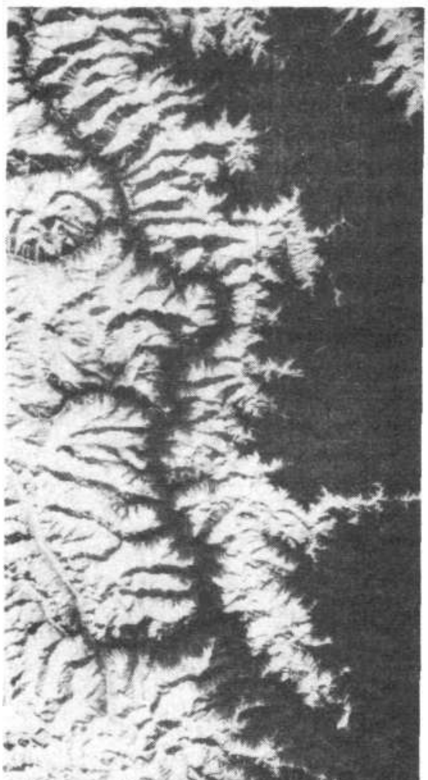
Such a decision could kill the U.S. land remote sensing program, the Landsat program, a series of satellites that for the past 13 years has provided invaluable information on worldwide crop harvests, oil and mineral deposits, forestry management, and various other land uses.

The technology will not die with the Landsat program, however; it has already been picked up and will be exploited by the Japanese and the French. Those nations will become the direct beneficiaries of our investment and will gladly assume the mantle of world leadership in the field. They see, apparently more clearly than we do, the importance of this information source in the global search for energy, minerals, foods, and fibers. They will extract the public good as well as the private value of our ingenious technology.

The tragedy is that the Landsat program initiated by this country has been a striking success, demonstrating to the whole world the power of this new civilian tool for sensing Earth's surface from space. Since the launch of the first U.S. land remote sensing satellite in 1972, Landsat has achieved every one of its original goals. It has "failed" only from the perspective of some in our government, because it has not generated sufficient revenue from direct data sales to support the cost of the program; but the program was not set up to be measured by that yardstick.

Information from the spacecraft was not copyrighted, so anyone could copy it. As much data were given away free as were sold. Landsat was run as an experimental program, with emphasis on broad dissemination of the data for research evaluation at the lowest possible price, that is, cost of reproduction, and not commercial use. As a government program, no attempt to market the program's products on a commercial basis was made.

And, finally, it was incorrectly evaluated, because no one in the federal budget office took the trouble to distinguish data sales revenue from the value of this information for solving the nation's resource problems.



Landsat view of the snow line along the south face of the Himalayas in India.

Addressing these defects, the Reagan administration took a reasonable step: It asked for competitive bids from private industry to sell the Landsat system. Seven bids were made, and after negotiation, one was accepted. Now, however, the Office of Management and Budget (OMB) wants to set aside the award, which would have the effect of scrapping the whole U.S. program, without transferring it to the private sector. OMB argues that there is no large proven demand for Landsat data, that U.S. data needs can be served by Japanese and French spacecraft supplementing existing data libraries, and that the government can save at least a quarter of a billion dolllars by terminating the Landsat program.

What the OMB Ignores

The OMB argument ignores a number of key points. U.S. investment in this field is now close to a billion dollars. An extensive industry infrastructure has developed to service Landsat products, including over 100 value-added service companies, 50 hardware manufacturers, 50 remote sensing centers, and an estimated 10,000 trained professional analysts of its data.

Furthermore, for each dollar spent on data, a minimum of $10 is spent on the manpower to interpret it and the hardware to process the data. At least $150 million is thus being invested annually by industry today to utilize these data, and every indication is that future growth will be very fast.

More than $100 million worth of data has been sold to users worldwide. U.S. companies have generated substantial revenues selling hardware and installing the facilities that let other nations record and use the information from the spacecraft; and our data users have finally reached a point of maturity where the data can be used as a regular component of business operations. The projected value of the products and services derived from these data over the next decade is conservatively estimated at $6 billion.

The arithmetic seems compelling. If sold to industry, the cost to the government to continue the program until 1995 will be, at most, $290 million—

Continued on page 64

Frederick B. Henderson, III, is president of Geosat Committee, Inc. in San Francisco.

The Lightning Rod

My dear Friends,

I am informed that an amazing predictive power has been demonstrated by the Nobel-Prize-winning physicist Hans Bethe, one of the most famous of those fellows who assert that beam weapon defense against nuclear missiles is "not feasible." Those working on the frontiers of science today, as I was more than 200 years ago, tell me that no one who cares for the future of science, that is, for the future of mankind on this and other planets, can afford to ignore the consequences of "Bethe's Law."

"Bethe's Law" was developed, so I am told, during the course of a half-century in the most advanced laboratories, by a greatly respected figure whose opinion is often cited as authoritative on scientific matters; I mean the good Dr. Bethe himself. In its original form, "Bethe's Law" states simply, "Results of a crucial scientific experiment bearing on a fundamental invention show a marked tendency to exhibit inverse proportionality to the certitude of the forecast opinion advanced."

Or, to put the matter in terms perhaps somewhat more accessible to the layman, "If I say it won't work, it will."

"Bethe's Law" was reportedly first demonstrated back in the late 1930s, after Ernest Lawrence and his collaborators had built the cyclotron, a circular device for accelerating charged atomic particles. Beams of accelerated ions from the cyclotron were to unlock the atom and provide a means to study nuclear fission. But Bethe quickly identified the "impossibility" of accelerating ions past a theoretical limit in Lawrence's cyclotron. Bethe argued that the harmonic laws upon which the cyclotron was based were valid only at low energy, and that the harmony of the universe—demonstrated successively by Plato, Nicholas of Cusa, Kepler, Leibniz, and Carnot—broke down as the beam approached the speed of light.

Bethe conclusively demonstrated his point with a brilliant series of mathematical equations published in articles in the *Physical Review*. Whereupon new accelerators were built, and the "relativistic limits" were shattered, along with the theoretical construct, as it was conclusively demonstrated that the beam exhibited a new set of "self-organizing" harmonic properties at the moment Bethe had portrayed as an entropic "breakdown." "Bethe's Law" was in effect.

In the 1950s and 1960s, "Bethe's Law" was repeatedly demonstrated in various controversies involving nuclear weapons testing. There was, it is reported, a notorious case where Bethe's prediction of the strength of an electromagnetic pulse was "off" by a couple of orders of magnitude. As a result of this miscalculation, the entire power system of Hawaii was temporarily blacked out! (This incident established "Bethe's Corollary": "Linear extrapolations based on the nonexistence of singularities are not necessarily efficacious in forecasting of actual physical events." Or, "If I say it will work, watch out!")

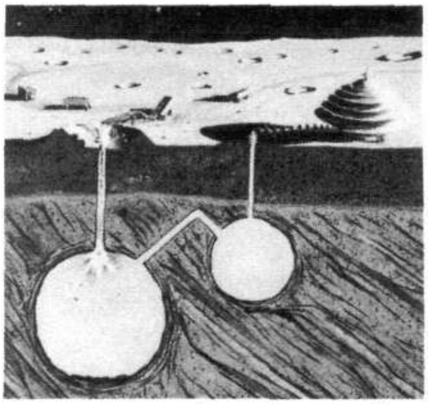
Then there was the debate over the meaning of the huge Soviet blasts of the late 1950s and early 1960s, before nuclear testing in the atmosphere was subjected to the Test-Ban Treaty. Dr. Edward Teller argued that the Soviet tests were part of a program aimed at devising a defense against ICBMs. Bethe pooh-poohed this suggestion. This particular controversy was resolved in early 1967, when a Soviet scientist, apparently imagining that the United States was already in possession of this knowledge, described Soviet experience with the "X-ray effect" it had deployed against nuclear missiles. Whereupon it was ascertained that the Soviets had identified the existence of the "X-ray effect" as early as 1958, and, just as Teller had indicated, had used it to disable nuclear warheads in the atomic tests of 1961.

Obviously, this mass of evidence shows that it would be folly to ignore the predictive power of "Bethe's Law" in today's debate over the Strategic Defense Initiative. In fact, it appears to me, that the very existence of "Bethe's Law" and its progenitor's forthright stand against the SDI ought to cause the Congress to quickly vote up the full appropriation requested by the President for beam weapons defense "with a whoop and a holler."

I remain yr. obt. svt.

Benj. Franklin

Benjamin Franklin



"The only limit to the application of the new technologies is that of our creative capacity." Here, Krafft Ehricke's atomic oven system for lunar gas extraction, mining, and smelting.

News Briefs

ABRAHAMSON SAYS SDI WILL LAUNCH '20TH CENTURY RENAISSANCE'

In a lengthy interview with the Italian daily *Il Tempo* May 22, Lt. General James Abrahamson affirmed that the Strategic Defense Initiative program, which he heads, will launch a "20th century renaissance" in space. "The SDI could become the nucleus of a new renaissance of space, the renaissance of the 20th century, and would contribute to the generation of very many new technologies. Around such a program there is being created an alliance with scientific investigators, who form part of both the industrial and academic worlds, and this interdisciplinary quality will remain one of the most notable tendencies we will inherit from the SDI," Abrahamson said. "Far from functioning as an obstacle to civilian use of space, I believe the SDI will strengthen and increase such activity."

Commenting on the various technological spinoffs from the program, Abrahamson noted that many of the ideas of space scientist Krafft A. Ehricke would now be realized: "The only limit to the application of the new technologies, as Krafft Ehricke would say, is that of our creative capacity. In fact, the larger portion of great innovations in the field of production—those innovations which create new markets and form the basis of new industries—is the fruit of technological victories, more than of any specific market demand. And in the future, technological progress will be the cause of even more powerful changes. . . . Our activities in space have created new opportunities for us to expand our knowledge of the universe and improve the quality of human life. . . ."

BRAZIL APPROVES FOOD IRRADIATION FOR MAJOR FOOD PRODUCTS

"I was tired of seeing food being thrown out in a hungry country like Brazil, said Dr. José Xavier, director of the Brazilian National Division of Food, who recently approved the marketing of 21 irradiated food products, including onions, rice, beans, wheat, corn, peppers, potatoes, cinnamon, cumin, and mango. According to the weekly *Revista do Jornal do Brasil* March 24, Brazil had been studying food irradiation since at least 1973, but had not approved its use because of "lack of guts."

EXCESS CLASSIFICATION INHIBITS SDI, SAYS DR. EDWARD TELLER

Charging that the present system of classification does nothing to protect U.S. scientific and military secrets, but actually obstructs U.S. scientific progress, Dr. Edward Teller called for a radical loosening-up of the government's "secrets" policy. "The Soviets know all our secrets, including those we will discover over the next three years," Teller told a Capitol Hill forum June 5. "We are keeping secrets from our own people, which they need to know. . . . The H-bomb is still classified as secret," nearly 40 years after the Soviets developed their own, he said. "This just doesn't make sense."

Teller laid out two directions for the United States to move in. "First, a strict time limit, two to three years at most, on technical secrets. What the Soviets want to find out, they can find out. Second, differentiate between ideas and their execution. We don't want to open the possibility of channeling detailed information, like blueprints, to our enemies."

Stuart K. Lewis

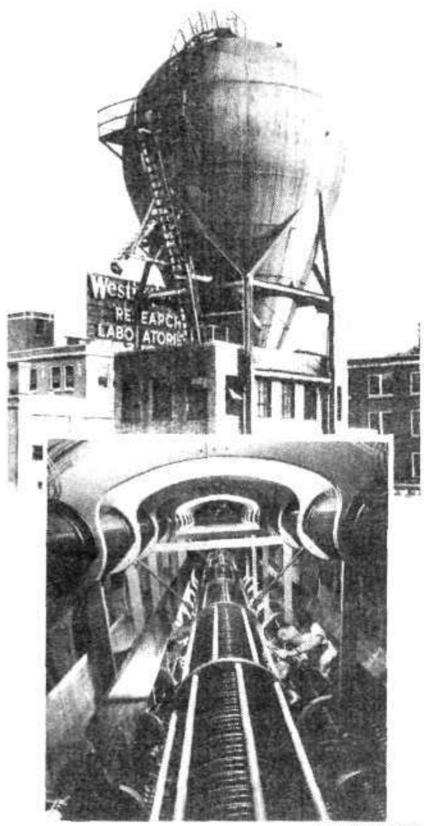
Union of Concerned Scientists expert Richard Garwin, here at the podium in a 1984 debate with the FEF on beam weapons.

'I DIDN'T DO IT,' RICHARD GARWIN TELLS PRESS CONFERENCE

The occasion was a May 29 press conference in Washington, D.C. called by the Union of Concerned Scientists to launch its national media drive against the Strategic Defense Initiative. The group's expert against beam defense, Dr. Richard Garwin, was on hand to take questions.

One astute reporter commented on a newly released TV spot by the group that shows a child singing "star light, star bright" who is then consumed as the star he watches explodes like a nuclear bomb. This "clearly misrepresents the SDI as an offensive system directed against the civilian population," the reporter said.

"I have nothing to do with that TV spot," a frazzled Garwin replied.



Westinghouse

The huge pear-shaped tank of the accelerator, shortly after its construction in 1937. Inset: The interior of the atom smasher during the final construction phase. Workers are making adjustments to the central accelerating tube tower supports.

IEEE HONORS 1937 WESTINGHOUSE NUCLEAR PHYSICS SITE

The Institute of Electrical and Electronics Engineers honored the Westinghouse 5-million volt Van de Graaff generator site in Forest Hills, Pa., as the first large-scale program in nuclear physics established by industry. Westinghouse's atom smasher was built in 1937 to conduct basic research that eventually led to the development of nuclear reactors for submarine propulsion and nuclear power plants. The generator was designed to create nuclear reactions by bombarding target atoms with a beam of high-energy particles. The steady voltage of the generator allowed the reactions to be measured precisely.

FEF SCORES A TACTICAL VICTORY AGAINST SOVIETS AT PARIS AIR SHOW

Fusion Energy Foundation representatives at the prestigious biennial Le Bourget Air Show in Paris scored a tactical victory over the Soviet delegation at the show that tried repeatedly to have air show officials shut down the FEF booth. The FEF displayed signs calling for "reinforcement of the Western alliance," "for the conquest of space," and, to make the beam defense message unmistakable, the slogan "better a beam in the air, than an Antonov in the derrière." The Soviets were displaying their giant Antonov-124 aircraft, the largest in the show.

Under Soviet pressure, air show officials at first told the FEF to remove the posters or leave the show, otherwise the Soviets would have pulled out. But this decision was revoked after the FEF representatives successfully argued the necessity of educating air show attendees on the purpose of the beam defense programs.

FEF HOLDS CONFERENCE IN BANGKOK ON ECONOMIC DEVELOPMENT

Thai Vice Premier, Admiral Sontee, opened a two-day conference in Bangkok May 14-15, sponsored by the Fusion Energy Foundation, on the subject, "Southeast Asia: Economic Development and Security 1985-1995." Sontee invoked the tradition of Thailand-American friendship, going back to the reign of King Rama IV and President Abraham Lincoln. Uwe Parpart-Henke, FEF research director, called for the United States to return to the postwar policy of MacArthur and Roosevelt in carrying out cooperative initiatives to industrialize the area.

In the spirit of this conference, the Thai Parliament recently approved the appointment of a 25-man commission to study the feasibility of the Kra Canal industrial complex and the role the waterway will play.

LOUSEWORT LAURELS TO THE CITY OF SAN FRANCISCO

This month's Lousewort Laurels award goes to the city of San Francisco—the first time any city has received the honor—for its ballyhooing of a $5 million deal to build a herbal medicine factory there. Reportedly, San Francisco's sister city of Shanghai will supply half the funds, while a group of investors, led by San Francisco acupuncturist Andy Soo Hoo, will supply the rest. The group expects to export its herbal medicines all over the world, especially to the Chinese living outside of China, who consume $7 billion of herbs annually, according to Soo Hoo.

Admiral Rickover

'Where There Is No Vision, the

It is ironic that the Reagan administration, which came into office with a commitment to revive America's nuclear industry and restore its military strength, should have forced the retirement of Admiral H.G. Rickover in 1982. After creating the Nuclear Navy after World War II, Rickover then launched the civilian nuclear power industry. He and his Navy team at Shippingport, Pa. completed the nation's first nuclear power electric station within three years in 1957. Even more impressive, today an estimated 60 percent of all civilian nuclear plant operators were trained in Rickover's Nuclear Navy.

Rickover accomplished these feats over the cries and obstruction of an antitechnology faction typified by Carroll L. Wilson, former general manager of the Atomic Energy Commission, who recently coauthored the low-growth *World Coal Study*. In the middle of Rickover's career he had to battle former secretary of defense Robert S. McNamara and the Harvard Business School cost-benefit methods that he imported into the U.S. military, which consistently nixed advanced technology projects as not cost effective. By contrast, Rickover's method was in the tradition of the French military scientist Lazare Carnot, whose Ecole Polytechnique not only provided Napoleon with his engineers, artillery, and victories, but also gave Western civilization the science and technology that laid the basis for 100 years of industrial development.

The Necessity of the Nuclear Submarine

The history of Rickover's project to build the Nuclear Navy begins at the end of World War II, when the necessity of the nuclear submarine first asserted itself. At the close of the war, the United States found itself with vast global military and economic commitments that could be supported only by maintaining control over the seas. Yet, the advent of the atomic bomb had made large fleets of aircraft carriers, battleships, cruisers, and other surface combatants vulnerable and obsolete. Moreover, during World War II, the submarine had already proved itself to be an almost decisive naval weapon, as illustrated by the near destruction of Britain by German U-boats and the less well-known but much more devastating campaign by U.S. submarines against Japanese shipping.

The submarines of World War II were not true submarines, however. They had to spend the majority of their time at sea running on the surface, powered by air-breathing diesel engines, and could endure submerged only for 12 to 48 hours, powered at low speed by their electric storage batteries. Most of the submarines that were lost in the war were destroyed on the surface, either caught there by a patrolling aircraft before they could dive, or sunk by naval vessels when they surfaced because their submerged endurance had expired.

The Navy sought a power source that could operate indefinitely below the water, with an effectiveness comparable to that which diesel engines provided surface vessels. Certain exotic chemical fuel combinations were tried out experimentally but were found to be unsatisfactory. The best hope seemed to be nuclear power itself. Thus, in 1946, the U.S. Navy's Bureau of Ships sent a team of engineers down to the Atomic Energy Commission's laboratories at Oak Ridge, Tennessee to study nuclear technology and its possible naval applications. The leader of the Navy team was the top electrical engineering officer from the Bureau of Ships, Captain H.G. Rickover.

Born in Russian Poland in 1900 of Jewish parents, Hyman G. Rickover had come to the United States at the age of six and attended public schools in New York and Chicago. Showing promise, he secured a congressional appointment to the naval academy at Annapolis, from which he graduated in 1922. Despite the antisemitism rampant in the anglophile Navy, Rickover's keen abilities allowed him to advance. He received a master's degree in electrical engineering from Columbia University in 1929, became qualified to command submarines, and spent the 1930s on several tours of sea duty as chief engineer on various ships, including the battleship *New Mexico*. The beginning of World War II found Rickover as commanding officer of the mine sweeper *U.S.S. Finch* in the Asiatic station. He

The nuclear powered ballistic missile submarine U.S.S. James Madison *at sea. Today Rickover's Nuclear Navy is the most reliable component of America's strategic deterrent.* U.S. Navy

and the Nuclear Navy

People Perish'

by Robert Zubrin

was subsequently recalled to Washington where he was placed in charge of the electrical section of the Bureau of Ships.

It was in this post that Rickover really distinguished himself. Unlike other section heads who limited themselves to administering contracts, Rickover assembled a group of the best officers and engineers he could find, and he personally sifted through battle reports and inspected battle-damaged ships to see how electrical equipment performed under combat conditions. Then, working with his staff, he would decide what changes in equipment were required and would supervise contractors to ensure that the new equipment was produced on time and to the desired specifications. Besides correcting deficiencies that would have cost thousands of lives in battle, Rickover's group developed fundamental engineering data on such subjects as shock resistance and took the lead in designing new and improved equipment, including motors, generators, lighting systems, power distribution systems, circuit breakers, relays, and infrared detection gear.

The Development of Nuclear Power

During the war, the Manhattan Project to develop the atomic bomb had been coordinated by the Army with no Navy involvement, and now the new Atomic Energy Commission (AEC) was making much of its civilian status in order to keep the Navy out. But in 1947, the AEC finally invited a small Navy team to go to Oak Ridge to study the possible uses of nuclear technology. Rickover had a reputation as a workhorse who would not take no for an answer and who would freely violate bureaucratic domains of responsibility in order to get what he wanted. These traits had antagonized many in the Navy against him, but given the Navy's adversary relationship with the AEC, Bureau of Ships chief Earle Mills felt that if the Navy was going to force its way into nuclear power, Rickover and no one else was the right man to head the team.

Rickover deployed the Navy team at Oak Ridge like a search and seize task force. Not a single lecture was given, not a single paper was delivered, without a member of Rickover's group being present to receive and study it. Rickover himself took the responsibility of assimilating all the knowledge that the team was gathering, and in less than a year at Oak Ridge, he knew all that anyone in the country knew about nuclear technology. On the basis of that knowledge, he was able to decide conclusively that the question of developing a nuclear power reactor was no longer a theoretical question but simply an engineering problem. Rickover reported back to the Navy that the development and construction of a nuclear reactor for submarine propulsion should be made a number one priority.

Rickover was able to quickly win over Bureau of Ships chief Mills and afterwards Admiral Chester Nimitz, the chief of Naval Operations, to his viewpoint. But the AEC opposed the project. AEC General Manager Carroll L. Wilson and J. Robert Oppenheimer, chairman of the AEC's general advisory commission, both of whom had helped draw up the State Department's Baruch Plan for containing world nuclear development, stonewalled Rickover. Wilson and Oppenheimer argued—in a manner similar to the opponents of fusion energy engineering development today—that any move into engineering nuclear reactors was premature, and that another decade or so should be spent on research.

Wilson, who is today a member of the Club of Rome and the Trilateral Commission, opposed Rickover's project to build a naval nuclear reactor because it would inevitably mean that civilian nuclear energy plants would follow as a spinoff. At the same time that he was maneuvering to block Rickover, Wilson, also a member of the Order of the British Empire, was passing U.S. atomic secrets to British-national Donald MacLean, an assistant to the British delegate to the joint U.S.-Canadian-British agency on atomic power. MacLean was later exposed as a top-ranking KGB agent when he defected to Moscow in 1951. As Wilson well knew, even disclosing atomic secrets to an agent of British intelligence was a violation of the MacMahon Act.[1]

The buildup of a large Soviet submarine force by 1948, followed by the detonation by the Soviets in 1949 of an atomic bomb, greatly strengthened the urgency of Rickover's case. In conceding, however, Wilson demanded that the development of the naval nuclear reactor be done totally under AEC control. This Rickover would not allow, as it would have guaranteed failure. The Navy also opposed the AEC plan, for "proprietary reasons." By a series of deft bureaucratic maneuvers, Rickover managed to set up the project under the joint auspices of the AEC and the Navy, with himself as project manager for both agencies, thus giving himself enormous maneuvering power.

Drawing on both the AEC and the Navy for engineering skills and funds, Rickover's Naval Reactors Branch (now the Nuclear Power Directorate) directed a huge research and development effort. Westinghouse Electric Corporation had drawn up a design for a water-cooled reactor, which Rickover regarded as the most practical design for submarines (rather than the liquid metal or gas cooled reactors being looked at by General Electric and Allis Chalmers). The water-cooled Westinghouse design that


U.S. Navy

Vice Admiral Rickover visits the U.S.S. Nautilus. *The completion of the world's first nuclear submarine in 1954 was the result of Rickover's determined political fight.*

Rickover selected was the basis for most light water nuclear reactors in civilian use today. On July 15, 1949, the contract was signed, and the project that was to lead to the *Nautilus*, the world's first nuclear submarine, was underway.

Mark I and Mark II

Rickover insisted on a number of decisions in order to maximize the rate of development of the project: Rather than building many scaled-down prototype reactors, only one test reactor would be built, the Mark I, which would be identical to the Mark II reactor that would be eventually installed in the *Nautilus,* whose hull was already under construction at the Electric Boat Company shipyards in Groton, Connecticut. The easy path of building Mark I spread out over a large floor for easy access was rejected; instead it was installed in a submarine hull built into the Mark I test site in Idaho, surrounded by a huge tank of water so that all the radiation reflection problems experienced by a submerged submarine could be simulated. And rather than cool the reactor with air, air conditioning was built into the Mark I since that was the way the *Nautilus* would have to be cooled.

The Mark I components were placed in an old submarine and depth charged in Chesapeake Bay; those that could not take the shock were redesigned. In all respects, the operative design slogan was, "Mark I equals Mark II." If Mark I functioned adequately, so would the *Nautilus.*

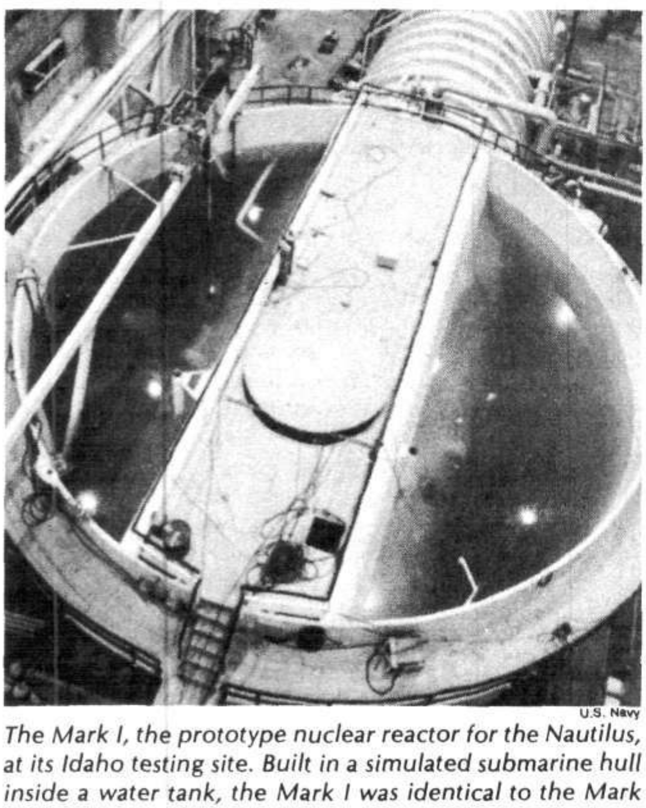
By the end of May 1953, the Mark I reactor was finished. Rickover, who had followed developments at the site on an hourly basis, flew out to Idaho with Thomas E. Murray, his close ally on the AEC. And on May 31, Murray turned the throttle that allowed steam generated by the reactor into the turbine. There was great uncertainty as to what would happen. Even Rickover is reported to have said, "If the *Nautilus* makes two knots on nuclear propulsion, she will be a success." Others thought the power life of the reactor might turn out to be only a few hours, thus giving no advantage over battery propulsion. The first run, however, was an amazing success. The reactor ran for two hours, generating several thousand horsepower, and then was shut off.

During the next month, the tests were repeated, with power levels increased daily. By June 25, full power was reached. It was then decided to let the reactor run at full power for 48 hours. But after 24 hours of smooth running, the officers on the site decided to end the test, as an engine that can steam for four hours at full power is generally considered suitable for naval use. When Rickover heard about the plan to abort the test, he immediately overruled it. Instead he issued orders for the charts to be brought into the control room to plot a simulated great circle course to Ireland. No submarine had ever traveled more than 20 miles submerged at full speed, and Rickover reasoned that if such a dramatic test were successful, it would end all doubts in the Navy and elsewhere about nuclear power, giving his project the momentum it needed to carry through until the *Nautilus* was launched.

Edwin Kintner, the prominent fusion scientist, was at that time the Navy commander of the Mark I test facility in Idaho. In a 1959 article in the *Atlantic Monthly,* he related the suspenseful, simulated voyage of the Mark I to Ireland.[2] As senior naval officer at the site, he felt that the extension of the run was unwise and told Rickover that he could not accept responsibility for the safety of the $30 million prototype reactor beyond 48 hours. Rickover, however, instructed him to proceed. At the 60th hour, the nuclear instrumentation became erratic. Then problems developed with one of the pumps that kept the reactor cool by circulating water through it. At the 65th hour, a tube in the main condenser into which exhausted steam was being discharged failed, and steam pressure fell off rapidly. At that point, Kintner recounted,

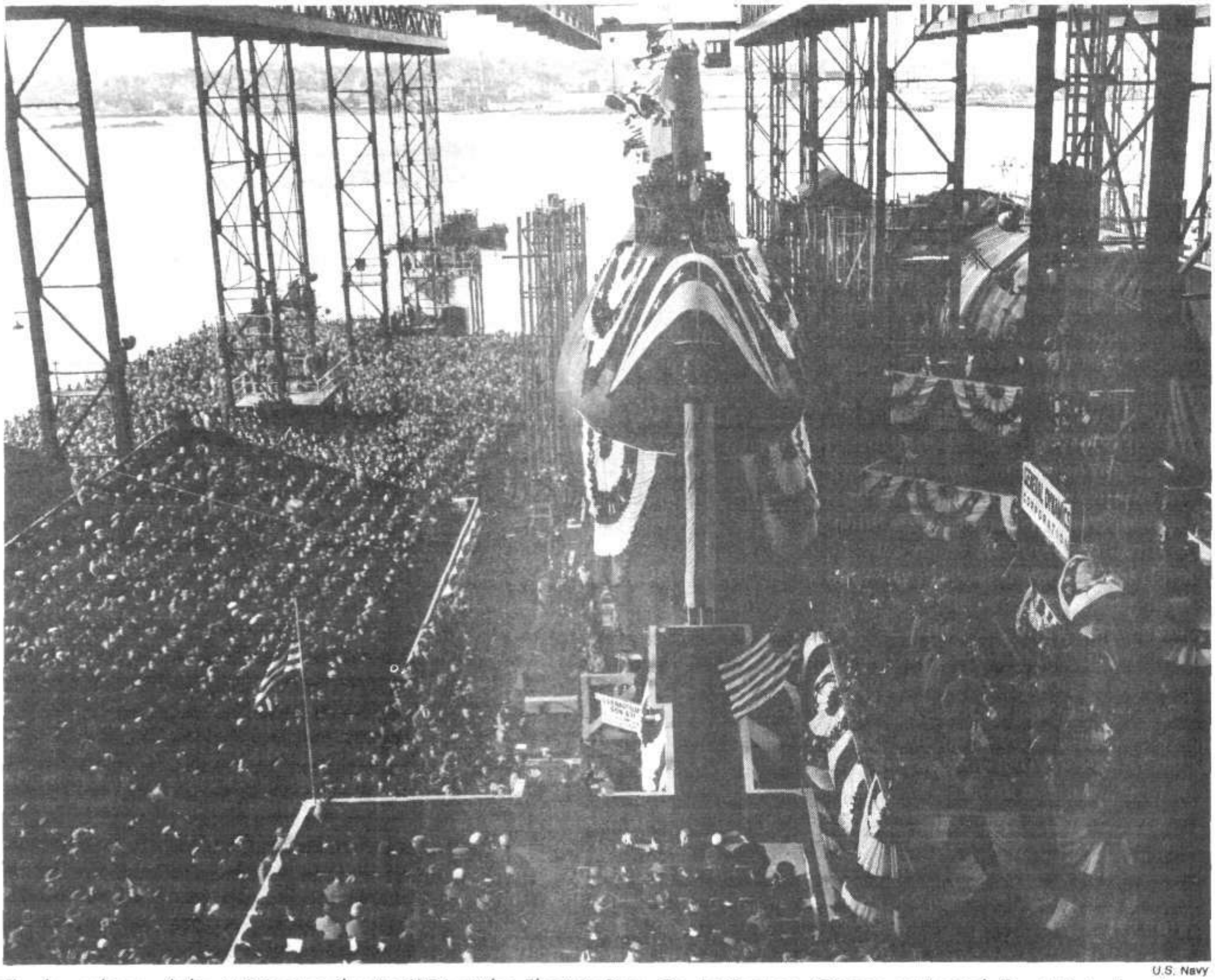
> The Westinghouse manager responsible for the operation of the plant strongly recommended discontinuing the run. In Washington, the technical director of the Naval Reactors Branch was so concerned that he called a meeting of all its senior personnel, who urged Rickover to terminate the test at once. But the Captain was adamant. . . .
>
> "If the plant has a limitation so serious," he said, "now is the time to find out. I accept full responsibility for any casualty." Rickover had twice been passed over by Naval selection boards for promotion to Rear Admiral. As a result of congressional action, he was to appear within two weeks for an unprecedented third time. If the Mark I had been seriously damaged, Rickover's prospects for promotion and his Naval career were ended.
>
> The tensions surrounding the test increased the challenge to the crews, and as each watch came on duty it resolved that it would not be responsible for ending the run prematurely. Crew members worked hard to repair those items which could be repaired while the plant was in operation.
>
> Finally, the position indicator on the chart reached Fastnet. A nuclear powered submarine had, in effect, steamed at full power nonstop across the Atlantic without surfacing. When an inspection was made of the core and the main coolant pump, no "crud" or other defects which could not be corrected by minor improvements were found. It was assured that the *Nautilus* could cross the ocean at full speed submerged.

Six months later the *Nautilus* was launched, and within a year it was breaking all records. In April 1955, the *Nautilus* traveled submerged from New York to Puerto Rico, 10 times the distance any submarine had ever traveled under water. In war games held in August of that year, the *Nautilus* demolished (in simulation) an antisubmarine task force consisting of an aircraft carrier and several destroyers; its high speed and unlimited submerged endurance made it almost invulnerable.



U.S. Navy

The Mark I, the prototype nuclear reactor for the Nautilus, at its Idaho testing site. Built in a simulated submarine hull inside a water tank, the Mark I was identical to the Mark II that would eventually power the Nautilus.


U.S. Navy

The launching of the U.S.S. Nautilus *in 1954 at the Electric Boat Co. in Groton, Conn.: a triumph for U.S. technology.*

Congress immediately ordered six more nuclear submarines.

The Ecole Polytechnique Tradition

Rickover quickly realized that a nuclear development program of the dimensions that he envisioned could not succeed by raiding manpower from the precious few nuclear engineers and other skilled personnel available to other agencies. He decided, therefore, that he would take responsibility for developing such an engineering cadre. As a first step, in 1949 Rickover sent several aides to the Massachusetts Institute of Technology where they persuaded the institution to set up graduate courses in nuclear physics and engineering. Simultaneously, working with nuclear scientist Alvin Weinberg at Oak Ridge, Rickover established the Oak Ridge School of Reactor Technology, which opened its doors to its first class of 20 students in March 1950. Within a few years, enrollment reached 120, and included not only Rickover's people, but many of the leading engineers of Westinghouse, General Electric, and other private contractors that were soon playing a leading role in the construction of the Nuclear Navy and the civilian nuclear power industry as well. Meanwhile, Rickover initiated a series of courses for his Washington staff in reactor theory, physics, mathematics, nuclear engineering, and naval architecture. Special classes were set up even for the clerks and secretaries.

This was only the beginning. Starting in 1951, selected groups of the most talented officers and enlisted men in the Navy were put through a grueling one-year course that included the study of mathematics, general physics, heat transfer and fluid flow, electrical engineering, reactor dynamics, chemistry, aspects of reactor plant operations, materials, radiology fundamentals, core characteristics, and reactor plant systems. In addition to 700 hours of classroom instruction, trainees were given six months of experience in hands-on running of the Mark I and later other landlocked training test reactors. The net result was *the creation not of trained personnel in the ordinary sense* of the term but of top-notch engineering cadre, who could not only operate a nuclear reactor but design and build one. By 1979, 7,000 officers and 40,000 enlisted men had graduated from Rickover's curriculum. Today these men represent the core of the engineering and technical cadre of the American nuclear industry.

The Attempted Purge

Building a nuclear submarine was one thing, but by 1952, Rickover's activities made clear to many in the antiprogress Eastern Establishment what Carroll Wilson had sensed in 1947: Rickover was interested not merely in building a nuclear navy but an entire nuclear power industry. For those individuals who hoped to maintain world political control through controlling fixed energy and mineral resources, this goal was intolerable. Alarm bells went off, and the attempt to purge Rickover began, making use of the Eastern Establishment's long-time hold over the Navy brass and its personnel selection and promotion system.

Thus, despite the fact that in July 1952 Secretary of the navy Dan Kimball admitted that "Rickover has accomplished the most important piece of development in the history of the Navy," during that same month Captain Rickover was once again refused promotion to the rank of rear admiral. Rickover had been a captain since 1942 and was now 53 years old. Under the Navy system, this second refusal meant automatic forced dismissal by no later than June 30, 1953.

Knowing what was at stake, Rickover fought back furiously, first mobilizing friendly journalists, then supporters in Congress. He prepared material that was read into the *Congressional Record* in February 1953 by Rep. Sidney Yates, an important figure on the Armed Services Committee who represented the Illinois district that had sent Rickover to Annapolis. This material included high praise for Rickover from President Truman, AEC Chairman Gordon Dean, and others. Yates went on to attack the Navy's selection process and added teeth to his criticism by introducing a bill to restructure the process by putting civilians on the board.

The decisive intervention on Rickover's behalf came from Sen. Henry Jackson, a Washington Democrat. Jackson knew Rickover from his days on the Joint Committee on Atomic Energy, and he saw through the Navy's claim that "we now have on hand a number of Engineering Duty Captains who are well qualified to assume this post"—the one Rickover was seeking. Acting through the Senate Armed Services Committee, Jackson had the committee pass a resolution refusing to pass on any promotions "pending an investigation of the selection system." Secretary of the Navy Robert B. Anderson and Navy personnel director James Holloway were forced to capitulate, and in July 1953, Rickover was promoted to rear admiral. But the harassment of Rickover persisted; for example, when the submarine *Nautilus* completed its historic mission under the North Pole in 1958, Rickover was not even invited to the White House reception!

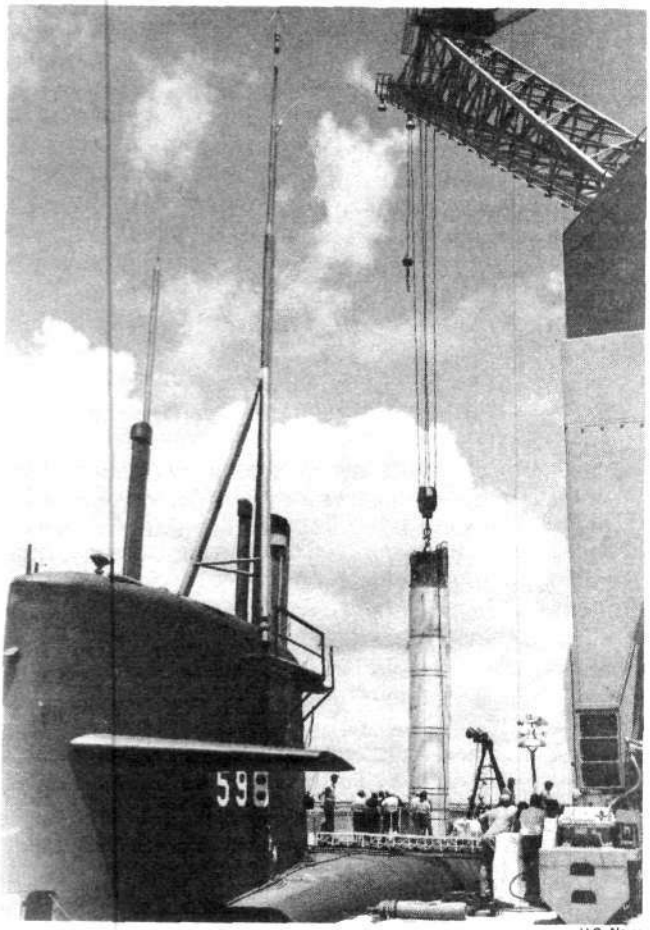
Atoms for Peace

Rickover's promotion and his new alliance with Congress gave him enormous stature and political clout. Thus, when budget cutters in the Eisenhower administration, working with anti-Rickover elements in the Navy, managed to kill his program for a nuclear powered aircraft carrier reactor, Rickover fought back by proposing that the carrier reactor program, already under preliminary development by Westinghouse, be continued under AEC sponsorship as a program to develop a civilian atomic energy plant. This idea found support within the industry and the AEC, but was adamantly opposed by Navy secretary Anderson. Anderson, who had just rejected Rickover's plan for a naval nuclear carrier, now said that the Navy could have nothing to do with the scheme since it was strictly a civilian enterprise.

Nuclear historians Hewlett and Duncan report that Anderson said, however, that he "was ready to cooperate with the commission in any way, including the transfer of Rickover to another assignment if his continued presence in the naval reactors branch caused difficulties."[3] Others attempted to sabotage the project by saying that it was a fine idea, but since it was to be a civilian reactor, industry should pay for the entire cost including R&D.

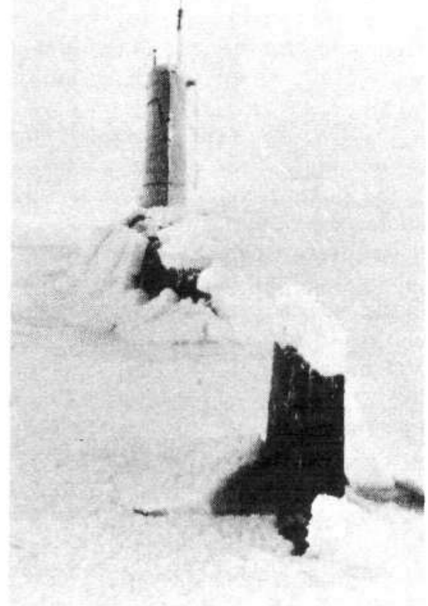
News from the Soviet Union once again strengthened

Missiles are loaded into the U.S.S. George Washington, *the first Polaris submarine.*



U.S. Navy

Frank J. Fahey/Wilmington Morning News



U.S. Navy

Left: The N.S. Savannah, *the world's first nuclear cargo-passenger ship, as it passes under the Delaware River Memorial Bridge, between Pennsylvania and New Jersey, on its first journey under its own power, Jan. 31, 1962. Right: The first photograph of the* U.S.S. Skate *in the Arctic, March 17, 1959, 50 years after Cdr. Perry first reached the Pole. The* Skate *established the ability of submarines to operate at any time in the polar regions.*

Rickover's hand. In August 1953, the Soviets exploded the world's first hydrogen bomb. Rickover's ally on the AEC, Thomas Murray, took advantage of the occasion to write President Eisenhower, urging that the United States could carry out a major coup by answering the Soviet development with an announcement of a full-scale U.S. civilian nuclear energy program; atoms for peace would be the American answer to Soviet atoms for war.

While the administration was mulling over this proposal, Murray acted, delivering a historic speech in Chicago on Oct. 22, 1953. The United States must take steps to develop nuclear energy for the electric-power-hungry countries of the world, Murray said, or else the nation would not be able to count on them for the uranium ore upon which U.S. nuclear weapons and national security depended.

Finally, on Dec. 8, President Eisenhower delivered his famous "Atoms for Peace" speech to the United Nations, committing the United States to lead the way in the peaceful exploitation of nuclear power for all mankind. The development of a civilian nuclear reactor was now made a national priority, and the responsibility for getting the job done could only be given to Rickover and his team at the Naval Reactors Branch.

A group was soon assembled that consisted of Rickover's Navy team, Westinghouse, Stone and Webster, Burns and Roe, and the Duquesne Power and Light Company of Pittsburgh. Contracts were signed; and on Sept. 6, 1954, President Eisenhower used a radioactive wand to activate the bulldozer that broke the ground for construction of the nation's first nuclear power plant at Shippingport, Pa. Rickover's team worked closely with Westinghouse R&D people at the company's Bettis Labs, laying down requirements, objectives, and specifications, and continually inspecting the work at the site, ordering any equipment that did not meet specifications to be torn out and replaced at once. No compromises or excuses from contractors or vendors were tolerated, as Rickover and his staff drove the pace of construction like furies. Despite strikes and steel shortages, the plant was completed by October 1957, and by Dec. 23, it was generating power at full capacity. Thus, Rickover and his team performed the remarkable feat of constructing the world's first civilian nuclear electric power station in just over 3 years, a job that today takes a much more experienced nuclear power industry some 6 to 12 years to complete.

Although small by current standards (60 megawatts), the Shippingport plant had an enormous impact on the development of civilian nuclear technology. Because it had no military applications (unlike the slightly earlier British reactor at Calder Hall), its design was unclassified. Hundreds of engineers from around the world attended seminars on it given by the Naval Reactors Branch, Westinghouse, and Duquesne during 1954-55, and Westinghouse made available thousands of technical reports on every aspect of the project. Shippingport thus functioned as a school in reactor technology for hundreds of engineers until well into the early 1960s, and the the reactor's design has been the model for more than three fourths of all civilian nuclear reactors produced in the United States and many in foreign countries since that time.

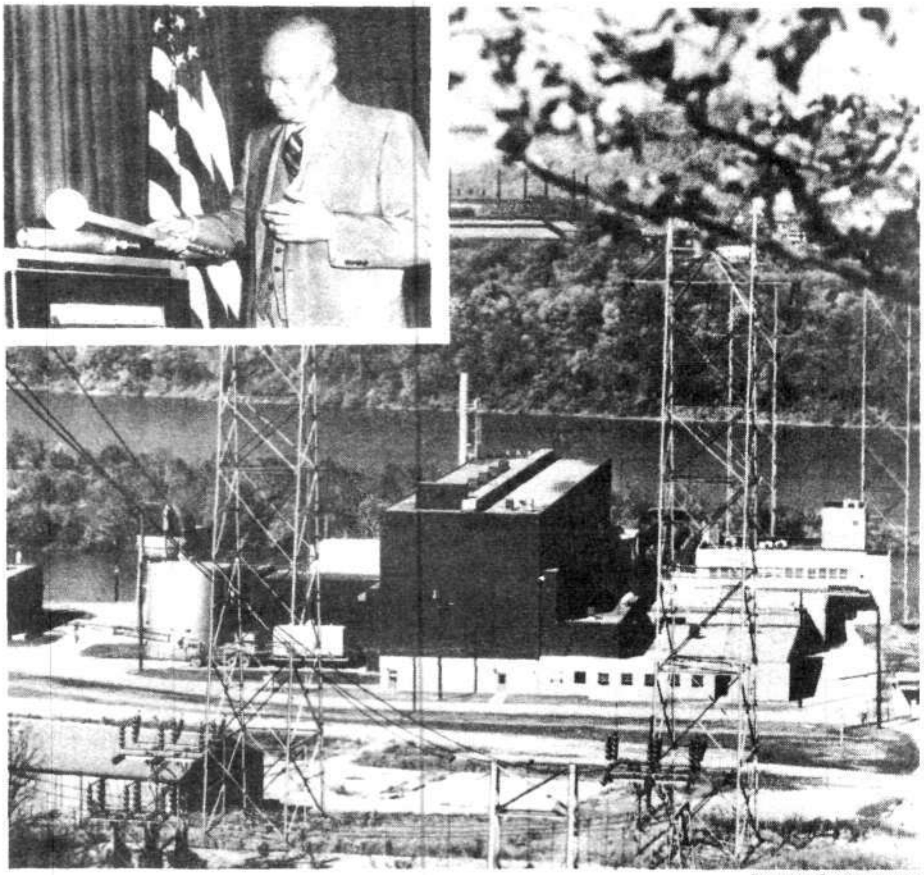
What Carroll Wilson had feared most back in the 1940s had come true: The nuclear genie was out of the bottle.

Rickover Versus McNamara

In the 1960s, the United States military came under full-scale assault by a wrecking operation directed by then secretary of defense Robert S. McNamara. Instead of pushing technological progress through the development of new and advanced types of weapons systems, McNamara advocated a "small is beautiful" policy for the military of reliance on simple and backward weapons. To justify this policy, McNamara imported into the military

The world's first civilian nuclear plant at Shippingport, Pa. was completed within three years. At its dedication, Rickover stated: "Now that we have unlocked the energy of the atom, man holds it in his power to change his environment. . . . This power to modify his environment on a scale which can affect all humanity imposes on man a great moral and political responsibility in attempting to do God's work."

The inset shows President Eisenhower waving the neutron wand to activate the bulldozer that broke ground on the plant on Sept. 6, 1954.



Duquesne Power and Light

swarms of systems analysts who knew nothing about military science but instead conducted endless, methodologically fraudulent cost-benefit studies. On the basis of these studies, which always showed that the older technologies were more cost efficient, McNamara canceled numerous advanced projects such as the X-20 orbiting bomber (a 1966 precursor of the Space Shuttle), the Pluto nuclear jet engine, nuclear aircraft carriers, and nuclear submarines.

These policies enraged many in the military, most of all Admiral Rickover, who launched a series of public broadsides against the defense secretary. In articles and congressional testimony, Rickover repeatedly ridiculed every aspect of McNamara's approach, and called instead for an all-nuclear Navy.

On systems analysis, Rickover had this to say:

> At one time Pagan gods ruled the world. . . . Now it is the cost accountants. The cost effectiveness studies have become a religion. . . . They are fog bombs. . . . Frankly, I have no more faith in the ability of social scientists to quantify military effectiveness than I do in numerologists to calculate the future. . . . On a cost effectiveness basis the colonists would not have revolted against King George III, nor would John Paul Jones have engaged the Serapis with the Bonhomme Richard, an inferior ship. The Greeks at Thermopylae and Salamis would not have stood up to the Persians had they had cost effectiveness people to advise them. . . . Computer logic would have advised the British to make terms with Hitler in 1940, a course that would have been disastrous.

On the social psychiatrists that McNamara imported into the military, Rickover was even more pithy:

"Perhaps a study of 'Witchcraft in the Pentagon' might be more germane."

In 1967, McNamara and then deputy secretary of defense Paul Nitze retaliated by attempting to force Rickover's retirement. However, with support of powerful congressional allies like Senators Henry Jackson and Clinton Anderson, a New Mexico Democrat, the admiral held on to his post. Rickover also won the fight to keep all new submarines nuclear powered, but many of his planned nuclear surface vessels were either scrapped or turned into diesel-powered projects.

Toward Educational Reform

Perhaps nothing gives a better idea of the quality and scope of Rickover's thinking on military and scientific questions than his profound commitment to transforming American education into a rigorous advanced curriculum capable of producing the scientists and engineers who could take America into the 21st and 22nd centuries. Rickover wrote a stream of books attacking the Deweyite deficiencies in American education, demanding the reinstitution of rigorous training in mathematics, science, history, the classics, and foreign languages.[4]

"It isn't difficult," Rickover wrote in *American Education: A National Failure*,

> for a layman to perceive who has been better prepared to handle family, job, and civic responsibilities: The young man or woman whose mind has been disciplined by a challenging education, who has been taught at school to respect facts, reason, and logic, who feels at home in the world of ideas and abstract concepts? Or the young adult whose schooling has impressed upon him the notion that adjustment to the group, personal popularity, and skill in projecting a pleasing image of himself will spell success in adult life?
>
> One consequence of technological progress is that man must use his mind more and his body less. . . . Schools must return to the traditional task of formal education in Western civilization—transmission of the nation's cultural heritage and preparation for life through rigorous training of young minds to think clearly, logically, and independently.

To those who criticized his views on American education, saying that he was only attacking it because it did not produce enough graduates suitable for participation in his nuclear power development program, Rickover replied that this was precisely the point—the measure of the adequacy of a nation's educational system must be determined by the degree of fitness of its graduates to participate in pushing forward the frontiers of technology of that society.

"Whenever man makes a major advance in his age old effort to utilize the forces of nature," Rickover wrote in his book *Education and Freedom* in 1959, "he must simultaneously raise his education, his techniques, and his institutions to a higher plateau":

> [F]rom the splitting of the atom in the 1930s to the bomb of the 1940s, to the practical nuclear power plant of 1953, a vast amount of intellectual effort of a high order had to be expended. Highly trained nuclear engineers are needed to design, build, and run nuclear power plants. Still greater demands on the human mind will be made if and when we obtain energy from hydrogen fusion.
>
> It is obvious that the kind of American who thoroughly mastered his environment on the frontier in the muscle, wind, and water state of technology would be totally ineffective in the atomic age which is just around the corner, and the fusion age which is still a way off.

Coming at the time they did, shortly after the launching of Sputnik by the Soviet Union, Rickover's books were bombshells and played a significant role in the attempt that was made to upgrade U.S. scientific education during that period. However, the Deweyites were quick in counterattacking, denouncing Rickover's call for curriculum reform and national standards as "totalitarian" and "exceedingly destructive to our tradition of respect for the individual," to quote Lawrence Derthick, U.S. commissioner of education in 1960.

Unfortunately the Deweyites won, and almost all of Rickover's attempted reforms were stopped dead or sidetracked. It is significant though that the only section of the U.S. military today that is not plagued by drug infestation is the Nuclear Navy, where the respect for the value of the human mind has allowed for the enforcement of a policy of instant dismissal for any drug use.

Rickover's Mottos

Today Rickover's Nuclear Navy, now comprised of 130 ships, represents the mainstay of America's strategic deterrent. Yet, Rickover was dismissed from his post in 1982 by Secretary of the Navy John Lehman, who is not simply opposed to Rickover the man but to everything that Rickover fought for over the last four decades. Where Rickover's understanding of military science was rooted in his comprehension of the critical role of advanced technology and cadre development, Lehman's approach has been to take 40-year-old battleships out of mothballs and call this a reconstituted American naval fleet. Lehman is part of an administration that is currently cutting back on all those areas of research and development—in space exploration, nuclear fission, fusion, and military technology—that are vital to the future of the nation.

Rickover's contrasting outlook is well summed up in the two mottos that hung in his Washington office. The first is from Shakespeare's *Measure for Measure*—

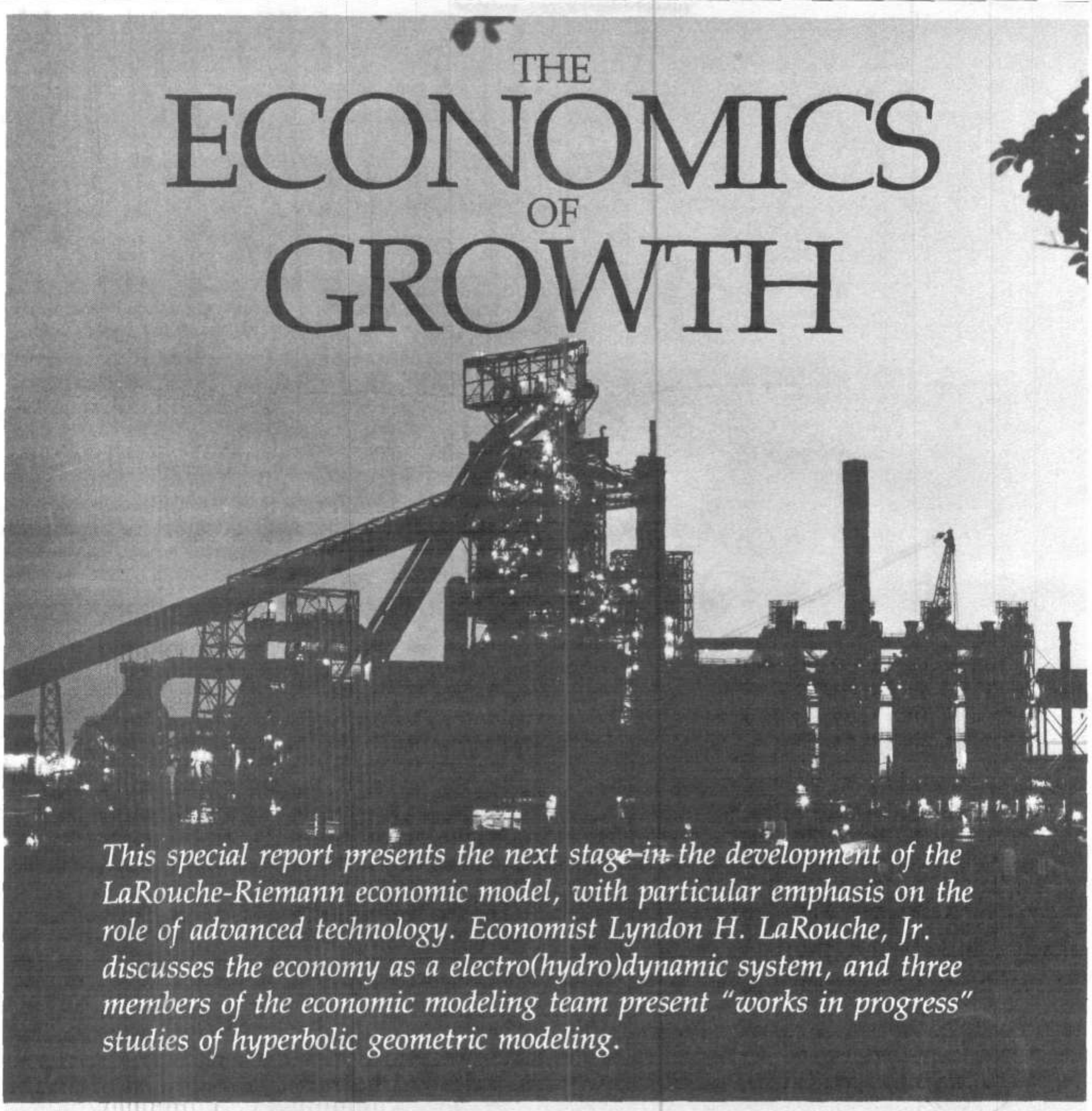
> Our doubts are traitors,
> And make us lose the good we oft might win,
> By fearing to attempt.

The other is from the Bible—"Where there is no vision, the people perish."

Robert Zubrin is a former member of the Fusion Energy Foundation staff.

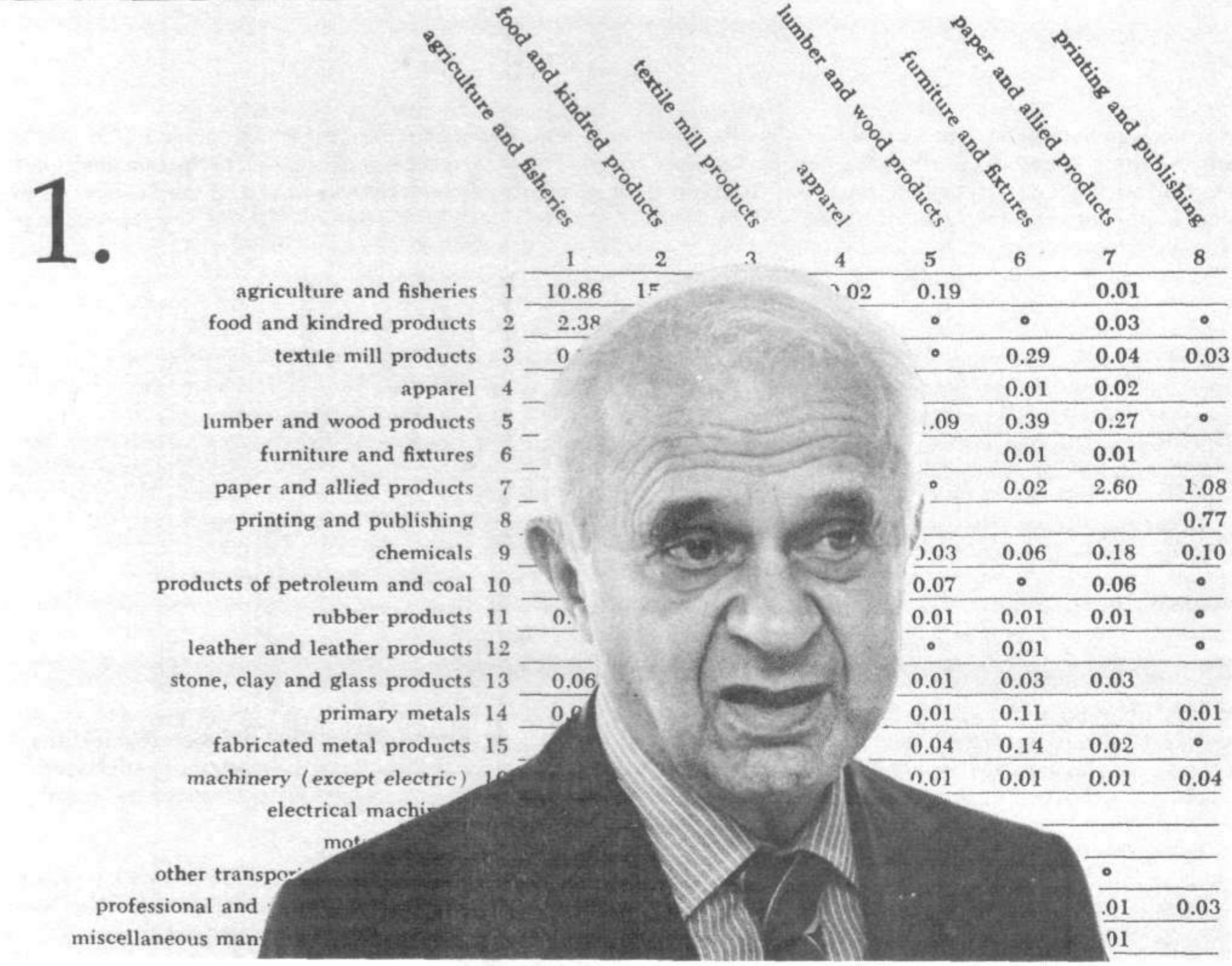
Notes

1. See Bruce Page et al., *The Philby Conspiracy* (New York: Doubleday, 1968), p. 190. In an interview with the author in Dec. 1981, Wilson justified his conduct in passing U.S. atomic secrets to MacLean as follows: "Sure I expect that most of the papers were labeled 'secret' at the time, but this was one of the carryovers from the wartime era."
2. E. Kintner, "Admiral Rickover's Gamble: The Land-Locked Submarine," *Atlantic Monthly*, Jan. 1959, p. 31.
3. An excellent general source book for the history of the Nuclear Navy is *Nuclear Navy* by Richard Hewlett and Francis Duncan (Chicago: University of Chicago Press, 1974). In addition to that work, the author relied for his material on Admiral Rickover's extensive testimony before Congress, other public speeches, and the news-clippings collection of the Navy Department Library in Washington, as well as on the recollections of a number of officers and enlisted men who participated in the Nuclear Navy.
4. Admiral Rickover's views on education are set forth in five books and many articles including, *Education and Freedom* (New York: E.P. Dutton, 1959); *Swiss Schools and Ours: Why Theirs Are Better* (Boston: Little Brown, 1962); and *American Education—A National Failure* (New York: E.P. Dutton, 1963).



THE ECONOMICS OF GROWTH

This special report presents the next stage in the development of the LaRouche-Riemann economic model, with particular emphasis on the role of advanced technology. Economist Lyndon H. LaRouche, Jr. discusses the economy as a electro(hydro)dynamic system, and three members of the economic modeling team present "works in progress" studies of hyperbolic geometric modeling.



Stuart K. Lewis

"No comprehension of technology": Wassily Leontief, shown here with an example of his input-output model from his 1966 book Input-Output Economics.

Wassily Leontief Acts to Block Effective Implementation Of the SDI

by Lyndon H. LaRouche, Jr.

Wassily Leontief may be saner than Milton Friedman and Karl Marx, but he doesn't understand the nonlinear role of technological progress in making an economy grow. Lyndon LaRouche discusses the shortcomings of so-called economists today and presents some details of the next stage of the LaRouche-Riemann economic model.

Among all my more prominent adversaries in the so-called economics profession, Bolshevik-educated Professor Wassily Leontief is the only one who exhibits a streak of sanity. He is not entirely sane, of course; his connections to the theosophical mysticism of Bolshevik Professor Kondratieff's "long-wave" ["Great Wheel"] cycles dogma, are a case in point. Whenever Leontief shifts his attention from the industrial engineer's standpoint in production cost-accounting practices, to the subject of money, his economic theories take on the fascist hues of the notorious Lausanne school of Walras and Say.

However, he is not completely insane, like the "ivory tower" positivists of the Operations Research Society. He is not a mere hoaxster, like that ex-communist professor who runs Wharton econometrics. Nor, is he by any means a silly babbler, like the choleric Professor Milton Friedman, or the Fabian Society's Friedrich Hayek. He is one of the rare few living economists worth criticizing; even when he is terribly wrong, one is obliged to recognize that there is some important work involved, of practical merit, in the construction of his fallacies.

Harvard's Leontief is famous as the leading figure associated with the design of the United States' present system of National Income Accounting, and thus also more or less the father of the "Gross Domestic Product" method of accounting used by foreign nations generally. At his best, he is a knowledgeable and skillful industrial cost-accountant; his input-output charts of accounts have served the useful purpose of prompting governments and supranational agencies to collect statistics in a sensible form. Until it comes to the subject of price theory, Professor Leontief is a down-to-earth, sensible fellow. As a cost accountant, he earns his fees; it is when he pretends also to be an economist, that he falls off the deep end.

Leontief presents himself at his best, and his worst, in a recent report, "The Choice of Technology," as the featured item of the June 1985 issue of *Scientific American*. Although Leontief appears, on the surface of his argument there, to be recommending increased rates of investment in new technologies, his argument is aimed specifically against the "economic spillovers" feature of the Strategic Defense Initiative (SDI).

The subject of "economic spillover" benefits of the SDI was introduced by this writer and his associates during 1982, many months before the President's famous announcement of March 23, 1983.[1] The writer's proposals on "spillovers" were publicly adopted by administration spokesmen during the spring of 1983, and were briefly echoed by Britain's Prime Minister Margaret Thatcher, during her 1983 election campaign. Not only does Leontief date his present attack against "economic spillovers" to approximately two years ago, but there are other special features of his piece which more than strongly suggest that it is my own thesis which he has been working to refute during the recent two years. In any case, it is certain, that if his arguments were influential in Defense Department policy, SDI would be as effectively sabotaged as if it were never adopted at all.

I reply to this now, not to waste the precious pages of *Fusion* with a mere rebuttal of Professor Leontief's blunders. There are very far-reaching issues of U.S. economic and defense policies posed, and *Scientific American*, unfortunately, is regarded by the credulous as a most respectable publication, with significant circulation.

Did Leontief Attempt to Refute LaRouche?

Leontief's piece was referred to my attention by a friend whose judgment was that this was an attempted counter to my own theses on "economic spillovers." On the basis of the item's content, the most probable inference is that it is exactly that. Leontief explains:

> Two years ago Faye Duchin and I, together with seven of our colleagues at the Institute for Economic Analysis of New York University, assembled the data needed in order to apply input-output analysis to the current prospects for technological change.

The dating itself is indicative. Not only were the studies of this matter by the economics staff of the *Executive Intelligence Review* weekly magazine and the Fusion Energy Foundation publicized during 1982, but it was the common knowledge around government and among private forecasting services, that the LaRouche-Riemann Method of forecasting had provided the only competent forecasts since the October 1979 introduction of what Paul Volcker himself had identified as "controlled disintegration of the economy." During 1982, there was a scramble among economists, to attempt to head off the growing authority of the LaRouche-Riemann model in government and industry. New York University is among the locations which closely follow this work, and has been the nesting-place of my avowed adversary, McGeorge Bundy, since Bundy left the Ford Foundation.

Leontief's next point pins the matter down:

> They [the data] are based on the input needs of technology that can be expected to replace the present methods of production in the next 15 years. Our method did not require us to make any projections about *unknown, future technology*. On the contrary, the technology we considered is already well understood, but it has not yet been widely introduced. [emphasis added]

Later, he qualifies this. His study limited itself to projection of effects of automation: "technological changes related to the introduction of computerized automation."

> We made no effort to assess the economic effects of the technological changes than can be expected in agriculture from the genetic engineering of crops, in mining . . . or in various industries from substitution of materials. . . .

Thus, he excludes most of the primary categories in which technological progress is occurring, or might occur, and limits himself to the "technetronic."

Even had the Professor taken a broader spectrum of technologies into account, his approach would still have the same terrible defect central to the article in question. If his method were employed in devising either the federal defense budget for SDI, or employed as policy for SDI implementation within the Department of Defense itself, it would be next to impossible to get the SDI off the ground. The unfortunate fact is, that Professor Leontief's flaws are deeply embedded in Mr. Stockman's computerized Office of Management and Budget (OMB), and have been embedded in the civilian, "systems analysis" staff of the Pentagon for nigh on 25 years.

At this point in our introductory remarks, the purpose of publishing this criticism of the *Scientific American* piece can now be fairly stated. The practical importance of this piece, from an economist of such legendary respectability as the Professor, is that it helps to tilt the balance of U.S. SDI-implementation policy, in favor of "systems analysis," and against revival of those "crash program" methods which served us so well in the Manhattan Project and the pre-1967 phases of the postwar aerospace program. The point is to save this republic, this civilization of ours: And we cannot expect our nation to survive much beyond 1988, unless the SDI is effectively implemented.

On this account, there are only two "econometricians" whose work itself requires any depth of criticism. Professor Leontief's, and the sly Ilya Prigogine. Everything else in present-day economics was thoroughly refuted by leading scientists during the 18th and 19th centuries. By contrast with Leontief, John von Neumann, the putative founder of "Operations Research" varieties of "econometrics," is an ignorant simpleton in economics, and the von Neumann-Morgenstern *Theory of Games & Economic Behavior* a hoax. Prof. Milton Friedman is merely a carnival pitchman, the Wharton Institute merely fakers, and the rest generally a cast of characters from the play "Marat-Sade." Prigogine is important, only because he has duped many credulous people into the delusion that he has provided a method for dealing with "nonlinear" network-problems; refuting Prigogine belongs more to the domain of mathematical-physics formalities as such, than to economics. Flawed as his work is, Leontief is the best among the outstanding figures of the academic economists as a lot.

I have been familiar with Leontief's work for three decades. I have missed more than one or two of his pieces over this period, but have followed a large enough sampling to warrant firm general conclusions. There are, without doubt, three major incompetencies permeating his work as a whole:

(1) He has no comprehension of "technology," not in the sense the term was defined by Gottfried Leibniz.

Leontief's relative merit, is the degree of emphasis he places upon examining the physical magnitudes of inputs and outputs of production. What lies between these inputs and outputs, the process of production itself, eludes him entirely. He appears never to recognize the existence of the question: "What is it that occurs in the productive process, between the inputting of inputs and the outputting of outputs, which accounts for economic growth?" This flaw is the central feature of the piece in the *Scientific American*.

(2) His work ignores the question: "How is it possible to show that the relative prices prevailing in an economy are wrong prices?"

Let us suppose the extreme case, that relatively favorable cost-price ratios in financial usury, prostitution, drug-trafficking, and operation of gambling casinos, compared to very poor cost-price ratios in agriculture and basic industry, cause capital to flow out of the latter into the former, collapsing agriculture and industry, and thus collapsing the society. Obviously, the cost-price ratios are wickedly wrong. Since such anomalies are commonplace, it is clear that price mechanisms are not to be relied upon as determinants of relative economic value. It should also be obvious, that the only remedy for the unreliability of price mechanisms is the adoption of some other yardstick; the only yardstick available for such purposes is the physical relations of production, physical relations defined without yet introducing the measure of price.

This problem Leontief sidesteps. Like Karl Marx, he assigns a price to "average labor," and makes the "market basket" of wage commodities the means for turning price into the common denominator of economic relations. There is no indication that he, any more than Marx, recognizes what is terribly, terribly wrong, in such tricks.

(3) Like Karl Marx, and like all modern academic economists, Leontief fails to recognize the fact that economic processes are intrinsically "nonlinear."

Since John von Neumann laid down his dogma on the subject, modern econometricians and Operations Researchers, have assumed that economic processes can be reduced to a mathematical system of "linear inequalities"; and that solutions to such systems are more or less adequate analysis of real economic processes. Worse, von Neumann assumed that these systems could be reduced to relative utilities, as measured in relative price. Since von Neumann was a very famous mathematician, who had been a child prodigy in arithmetic, who could dare to challenge the oracular utterances of the "Great von Neumann"?

It happens, that von Neumann's dogma was absurd. All economic processes are intrinsically "nonlinear."

Let us review, as briefly as possible, the matters of which Professor Leontief is ignorant.

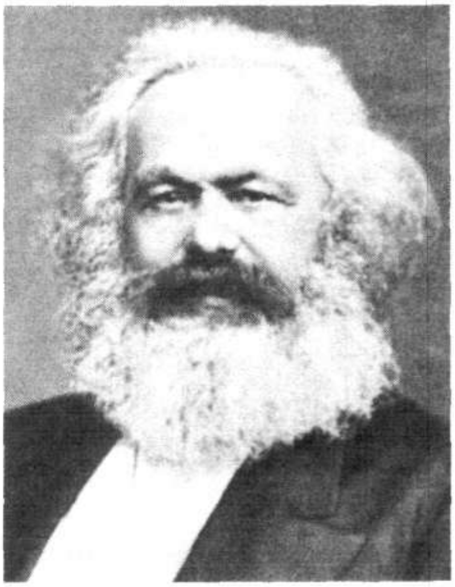
'Technology'

"Economic science," in the strict sense of the term, was established by Gottfried Leibniz, beginning with his short paper on "Society and Economy," of 1672. The central feature of Leibniz's work on economy, the key to the founding of economic science strictly defined, is his concentration on the subject of the heat-powered machine. Leibniz created the notion of "technology," as a leading included feature of his principles of heat-powered machines.

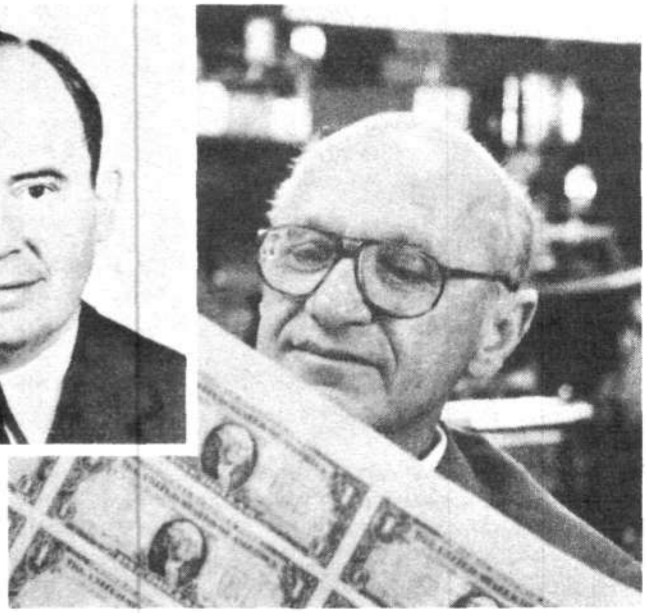
The principles of machine design were essentially completed by Leonardo da Vinci. After Leibniz, the principles of machine design were brought to near perfection by the 1794-1814 Ecole Polytechnique of France, under the leadership of Lazare Carnot and Gaspard Monge. Beginning the work of the 1794-1814 Ecole, the center of work was shifted, from machine design, toward development of a general theory of electro(hydro)dynamics, an effort centered around the work of Gauss, Weber, and Riemann, at Göttingen University in Germany.

Although Leonardo had already mastered the principles of animal-powered machines, and perfected the hydrodynamics of wind-powered and water-powered machines to a high degree, Leonardo merely began exploration of steam-powered machinery. After Leonardo, circles around Gilbert in Tudor England, pressed for development of coal as a replacement for charcoal. Until after the Peace of Westphalia, and the 1653 defeat of the Hapsburgs, technological progress was generally suspended by the catastrophic conditions of the early 17th century. Work toward a doctrine of heat-powered machinery waited until Leonardo's approach was resumed by Huygens and Leibniz, later in the 17th century. It was Leibniz who established the foundations of a general solution.

Given a coal-fired source of power for a machine, and given a standard quality of unit-output of an operative, what is the relationship between increasing the heat supplied to drive the machine and the number of units of output of the



"By contrast with Leontief, von Neumann is an ignorant simpleton in economics. . . Milton Friedman is merely a carnival pitchman, the Wharton Institute merely fakers, and the rest a cast of characters from the play Marat-Sade." From left, Karl Marx, von Neumann, and Friedman.



operative?

Immediately, several variables must be considered:

(1) the amount of coal-equivalent consumed per day;

(2) the temperature at which the coal is burned;

(3) the average cost of each unit of output, after adding the cost of producing and processing the coal and producing the machine, to the cost of the operative: capital-intensity costs;

(4) technology.

Note the special case: Given two machines, each consuming the same coal-equivalent, but different in the respect that the same operative employing one produces greater unit-output than when employing the other. The difference in performance lies in some internal features of the machine's organization. The ordering-principle, which defines increasing "efficiency" of machine-designs in such terms of reference, is the barebones definition of "technology."

Actually, "technology" is an ordering-principle which subsumes all four of the conditions listed above:

(1) quantity of usable energy per operative;

(2) energy-intensity (energy-flux density) of the usable energy supplied;

(3) capital-intensity;

(4) internal organization of the machine (or process). All of these, combined coherently under a single ordering-principle, determine the relative physical productivity of operatives.

What is that ordering-principle? Start with bare beginnings, and proceed until a single principle is sufficiently elaborated to subsume all of that for which we must account.

Leibniz began to define the solution, by adopting a principle discovered by Cardinal Nicholas of Cusa: that in Euclidean physical space-time, only circular action has self-evident existence. Cusa named this "The Maximum Minimum Principle" (*De Docta Ignorantia*, 1440); it is familiar to modern mathematicians as the isoperimetric principle of topology.

Leibniz divided the action of machines into two aspects, simple action and work. Action is measured as displacement of a closed cycle of action, as the displacement of action along the perimeter of a closed line of motion. Work is measured, in first approximation, as the area subtended by that perimetric action. Thus, action is expressed as equal to mv, where m is mass and v is perimetric displacement; while work is expressed as proportional to mv^2.

The isoperimetric principle shows, that the least action required to generate an area of closed action is circular action. Therefore, the amount of action required to generate a defined amount of work (least action) is the amount of circular action needed to do so. No action in physical space-time is greater in magnitude than the least action: the Principle of Least Action.

Therefore, the constant increase of the energy flux density of action, and work, is represented by a self-similar conical spiral. If the amount of action associated with increase of energy flux density is constant, the action is converging self-similarly upon the apex of the cone. If the radian-measure of perimetric action is constant, and the energy flux density is increasing per unit of radian-measure, the result is described by an expanding cone.

So:

(1) The relative energy is the rate of helical action with respect to time.

(2) The relative energy-flux density is the area of work subtended by each interval of helical perimetric displacement.

(3) The relative capital-intensity is expressed by work supplied per operative.

(4) The internal organization of the process is expressed by a conic function. This is the case in first approximation. A function subsuming increases of these relative values,



Economic science was established by Gottfried Leibniz (center), beginning with his short paper "Society and Economy" in 1672. Leibniz drew on the 15th century work of Cardinal Nicholas of Cusa (right). The American System economists, including Friedrich List (right) continued this tradition in economics, focusing on the productive powers of labor.

coherently, to the effect of increasing the productive powers of the average operative, is the definition of "technology."

These first-approximation relations are readily shown by comparative statistics for capital-intensity, energy-throughput per capita unit of potential relative population-density, and per capita output rates, for assorted economies in the world today. Such data, compiled in the manner Leontief's input-output designs variously specify or imply, show these to be the proper first-approximation criteria.

Economies As Processes

The gross characteristics of economic processes, are indicated simply, by comparing the potential population levels of mankind for "primitive hunting-and-gathering society," about 10 million maximum, with nearly 5 billion today. It is also possible to construct estimates for population levels since Roman times, with increasing accuracy as we approach the present. By such means, we are able to construct arbitrary mathematical functions which incorporate the most visible characteristics of successful population growth, and of economic growth.

The first modern effort to construct such a function, is the work of Leonardo of Pisa, the so-called Fibonacci series. Toward the close of the 15th century, a more accurate function was discovered, by the collaborators Luca Pacioli and Leonardo da Vinci.

The latter, working on the basis of Nicholas of Cusa's specifications for scientific method, showed that all living processes exhibited distinctive harmonic patterns, both as patterns of growth, and determined morphologies of bodily functioning. These harmonic patterns were congruent with the Golden Section of geometry. Today, we know that this distinction of living processes applies to all ranges of phenomena between the extremes of astrophysical and microphysical scale. From Pacioli and Leonardo, through Louis Pasteur, there is a continuity running into modern optical biophysics. Within the ranges indicated, all processes which are harmonically congruent with the Golden Section, are either living processes, or are artifacts produced by living processes.

Economic growth is harmonically congruent with the Golden Section.

Since the work of Gauss, Dirichlet, Weierstrass, and Riemann, we know that the images which appear to us because of the organization of our brains, as primarily Euclidean images, are a kind of distorted-mirror image of the real universe. We know that the real universe is of the form of a Riemannian hyperspherical function, generated by three degrees of self-reflexive conical self-similar spiral action in physical space-time. Through study of stereographic projection, we also know that we must not assume that our brain-images are literal pictures of the real universe, but we have the comforting certainty that certain features of those images, called "projective invariances" or "topological invariances," are in agreement with the physical space-time experienced.

In this context, we also know, that the existence of Golden Section harmonics among the brain's images of Euclidean space-time, conforms to conic self-similar spiral action in the Gaussian manifold of real physical space-time. Looking at Kepler's astrophysics retrospectively, from the vantage point of Gauss, et al., we know that the universe as a whole is ruled by laws which are invariant with respect to the Golden Section.

Inasmuch as the notion of "negentropy" is associated with the phenomena of living processes, we are obliged to discard the definitions of "negentropy" and "entropy" supplied by statistical thermodynamics. We define "negentropy," properly, as the characteristic of processes which are either living processes, or are like living processes.

A healthy economy, like a healthy living organism, is "negentropic." Once the living process ceases generating "negentropy" at a sufficient rate, it is sick, possibly dying. Similarly, an economy.

Therefore, what we must measure, to determine the performance of economies, is the relative rate of negentropy generated per capita. "Economic value" is properly measured only as per capita negentropy. Therefore, to measure "economic value," we must define a mathematical function in which the content of "work" measured is measured in "units of negentropy."

In other words, if you do not assist in some necessary way, in transmitting negentropy to the economic process as a whole, you are economically useless. Any product produced and consumed, which does not satisfy this requirement, is economically valueless.

The paradigm for the transmission of negentropy to an economic process, is technological progress.

To the degree, an economic process is doing the same thing over and over again, it is, to that degree, entropic, and is dying. In that sense, its output is worthless. It is only as output contributes to the production of negentropy, technological progress, that output has economic value. It is technological progress which has enabled mankind to rise from the status of primitive man desperately gorging himself on the raw fish left as jetsam on the beach.

Simple Thermodynamics of Economy

In the simplest thermodynamics, we subdivide the total usable form of energy throughput in a closed cycle, into two general categories. The first category is the amount of such throughput which must be consumed or wasted, merely to maintain the process at a constant level of potential. This portion, we call the "energy of the system." If there is any remaining energy throughput, after deducting the "energy of the system" requirement, we call this the "free energy."

Thereafter, all interesting questions are posed in terms of the ratio of the "free energy" to the "energy of the system," and the correlation of changes in this ratio, to the total energy throughput. For the condition in which the ratio rises in correlation with an increase of the energy-throughput, we describe the process, roughly but fairly, as "negentropic." If this condition is not satisfied, we estimate the process to be "entropic."

In analysis of economic processes, we must reduce all physical economy (inputs, outputs, and so on) to common thermodynamical units of measurement. We approximate this, by measuring the usable energy throughput in per-square-kilometer and per capita terms, and by correlating these two measurements in terms of rates of increase of the productivity of labor. We measure increase of the productivity of labor, as increase of potential relative population-density.

This enables us to analyze economic processes independently of price mechanisms. Although the studies require guidance by rigorous mathematical procedures, the results of such studies are readily accessible to intelligent "common sense."

The interesting aspect of thermodynamic negentropy, as we confront it in economic processes, centers around the variable effects of converting the "free energy" of the economic process-cycle into augmented "energy of the system." Typically, this signifies increasing the energy-intensity and capital-intensity of the economy, per capita. In other words, the energy cost of maintaining the average person and operative is increased—by increasing the energy-intensity and capital-intensity per capita.

Karl Marx foolishly imagined, that such "reinvestment" of profit in production, caused a "falling rate of profit." In thermodynamics language, this means, that if the "free energy" produced is generated only by labor of operatives, and the capital-intensity of production is increasing, then the ratio of "free energy" to "energy of the system" must tend to fall. Leontief's system is implicitly Marxist, on this and other counts.

It should be noted and stressed, that once we convert physical inputs and outputs into prices, and then attempt to explore economic processes in terms of price mechanisms, Marx's folly of "the tendency of the rate of profit to fall," appears a certainty. It should be obvious, on such and analogous grounds, that once we price out physical relations of production, as a precondition for economic analysis, we have excluded from consideration the essential principle of economic processes, the function of technology, just as Leontief does, in his "The Choice of Technology."

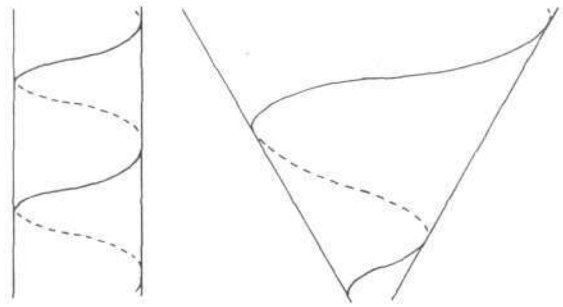
So, Leontief hunts for technology everywhere, unsuspecting that that for which he searches, he has just banished from his priced-out data: "Data, data, everywhere, but not a drop to drink."

Marx's error, like Leontief's quasi-Marxist constructions, is that in plagiarizing the notion of "labor-power" from Friedrich List and Henry C. Carey, Marx was like a baboon who stole a watch: he didn't know the use of what he had stolen. "Socially necessary average labor," is not Alexander Hamilton's meaning of "productive powers of labor." True, only the labor of goods-producing operatives actually produces wealth. The increase of the productive power of labor is the advancement in technology brought to the point of production: the increase in energy-intensity, the increase in capital-intensity, and the advancement in the internal organization of the productive process under such conditions. This depends upon the power of the operative's mind, to assimilate advances in technology for efficient use. The relations of production are defined in per capita operative terms, but the relations are essentially the technology of production per capita.

It is that relationship, which exists only in the physical economy, not the prices of commodities, which vanishes with the introduction of the price mechanism.

The Geometrical Approach

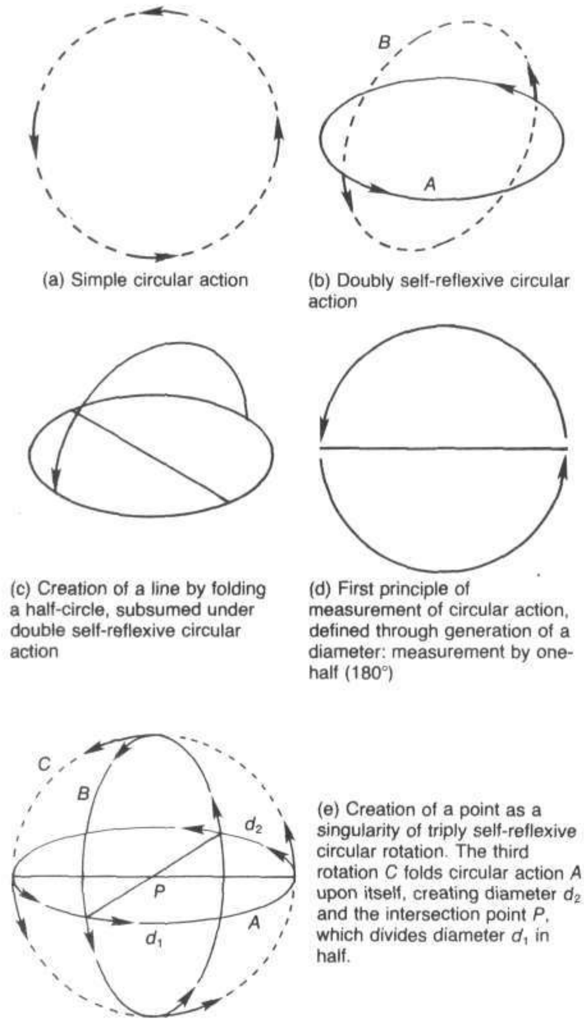
In the mathematics which I employ for economic science, algebraic expressions appear only as descriptions of geometrical constructions. None of the axiomatic assumptions, or deductive methods of the Ptolemaic "Euclid's" geometry are allowed, and no axiomatic arithmetic. The only self-evident form existing in mathematics, is circular action; from circular action alone, all constructions must be derived and constructed. In other words, a "synthetic



(a) Simplest form of circular action, the cylindrical helix

(b) Self-similar spiral action on the surface of a growing cone

Figure 1
THE PRINCIPLE OF LEAST ACTION
The least action required to generate a defined amount of work is the amount of circular action needed to do so. The constant increase of the energy flux density of action and work is represented by a self-similar conical spiral. If the amount of action is constant, the action is converging self-similarly on the apex of the cone (a). If the amount of action is increasing, the cone is expanding (b).



(a) Simple circular action

(b) Doubly self-reflexive circular action

(c) Creation of a line by folding a half-circle, subsumed under double self-reflexive circular action

(d) First principle of measurement of circular action, defined through generation of a diameter: measurement by one-half (180°)

(e) Creation of a point as a singularity of triply self-reflexive circular rotation. The third rotation C folds circular action A upon itself, creating diameter d_2 and the intersection point P, which divides diameter d_1 in half.

Figure 2
CIRCULAR ACTION AND CONSTRUCTIVE GEOMETRY
The only self-evident form existing in mathematics is circular action, and from this all constructions must be derived and constructed. Simple circular action is shown in (a); doubly self-reflexive circular action in (b); the creation of a line in (c); the generation of a diameter to create measurement by one-half in (d); and the creation of a point in (e).

geometry," or what some might wish to describe as a "radically constructive" geometry.

I have described my methods in other published locations, so I shall merely summarize the most relevant points here.[1]

(1) To construct all forms which are commensurable in Euclidean physical space-time, construction must begin with circular action, straight lines, and points. Therefore, straight lines and points must first be created by circular action upon circular action.

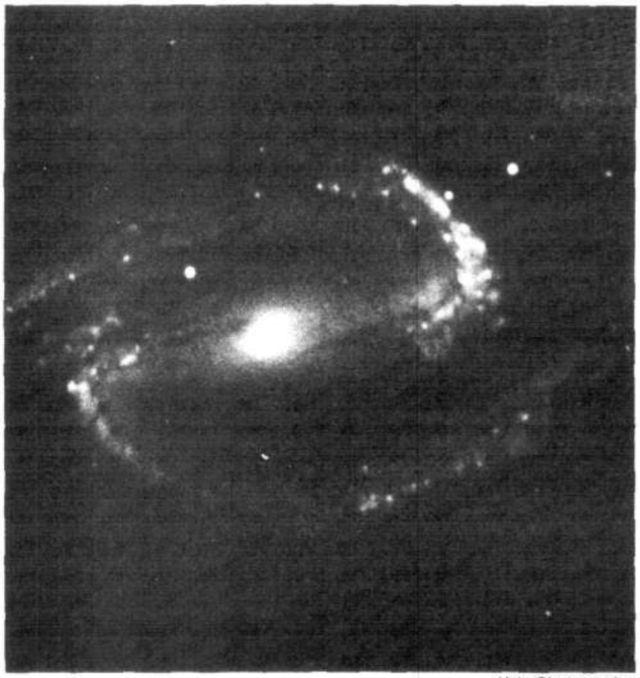
(2) This requires triply-self-reflexive circular action: For every small interval of Circular Action A, Circular Action B must be acting, as if perpendicular to Circular Action A; for every small interval of Circular Action B, Circular Action C must be acting, as if perpendicular to both Circular Action A and B. This is sufficient to generate a straight line, a point, a sphere and a hypersphere, and measure by a factor and powers of 2. These are the minimal preconditions for Euclidean physical space-time.

(3) However, since perception occurs in never less than a finite interval of physical space-time, circular action appears as helical action. Triply-self-reflexive helical action is the minimal precondition for generalized physical space-time. The required form is triply-self-reflexive, conical, self-similar spiral action.

The minimal ideal model for technological progress in an energy-intensive, capital-intensive mode, is doubly-self-reflexive self-similar spiral action. This generates an hyperboloid, whose central axis is the time axis. This is to be constructed on the surface of a Riemannian sphere, rather than in Cartesian coordinates.

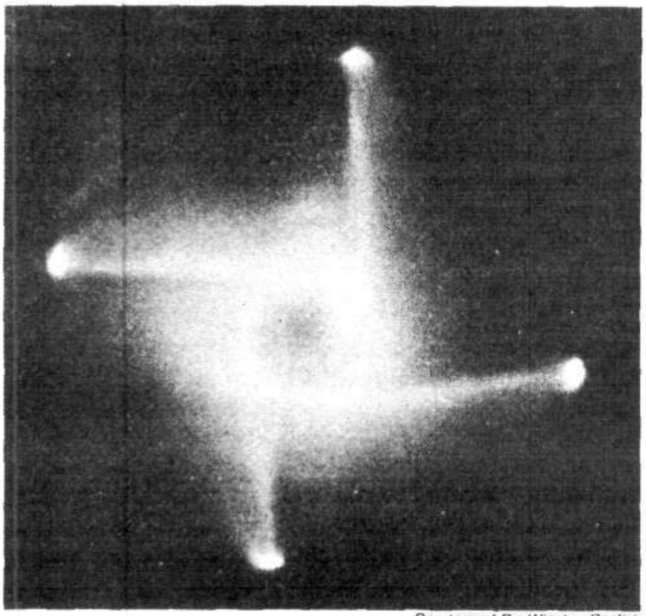
The flaring of the hyperboloid, through the vanishing point, apparently defines a mathematical discontinuity. Yet, the economic process is not halted; there is no discontinuity in the physical process, but therefore some inadequacy in the mathematics.

Let perimetric action be defined as the area swept on the surface of the sphere, and work, therefore, as the subtended volume of the sphere. So, the topological singularity (the apparent discontinuity) defines a "jump" of the continuing action to the larger, concentric sphere, whose image we can project downward onto the first sphere's surface. The action continues, thus. The rate at which the next hyperbolic flaring is generated is more rapid. And, so on and so forth, in the idealized case. The relative density of singularities is increased, harmonically: the nested spheres



Hale Observatories

All ranges of phenomena between the extremes of astrophysical and microphysical scale exhibit distinctive harmonic patterns congruent with the Golden Section of geometry. Here, a "galaxy" (left) created by colliding electron beams in the laboratory of fusion scientist Winston Bostick in 1957, and a photograph of the barred spiral galaxy in the constellation Eridanus, as seen through the 200-inch telescope at Hale Observatories.



Courtesy of Dr. Winston Bostick

form a harmonic series. This hyperspherical function corresponds to triply-self-reflexive self-similar spiral action.

The significance of the increased volume of action, as a jump to a larger concentric sphere occurs, is an increase of the "energy of the system." In this schema, increase of the energy of the system is measured as increasing density of singularities.

This increasing density of singularities correlates with the increasing complexity of the production of the unit marketbaskets of households' and producers' goods, per capita, the increasing complexity of the division of productive labor.

This process proceeds, both mathematically and in real economic experience, as periodic "jumps." That is, the gradual technological progress of the economy does not alter the economy simply, but in periodic jumps, like shockfronts.

These "jumps" correlate with the process of dispersion of technological advances, from points of initial impact, radiating effects into the economy more broadly. Think of this dispersion as "technology waves." As the division of labor in the economy is upshifted by these waves, the energy of the system for every local action in the economy is upshifted accordingly. This corresponds to the flaring of the hyperboloid. Thinking of this radiation of "technology waves" in hydrodynamic imageries, think of resonance of the economy with respect to this radiation of technology waves: that is what the historical data show us. As "structural changes" in the economy are so induced, the entire economic process upshifts to a new phase state, new resonant characteristics: the jump occurs.

A similar pattern appears in economic devolution, technological downshifts. The U.S. economy has been downshifting since 1967-1971. In physical, technological parameters, the productivity of labor has been falling since approximately 1971. The rate of fall was accelerated by the 1973-1975 impact of the induced energy crisis and the Rambouillet monetary resolutions' implementation. Since Federal Reserve chairman Volcker's introduction of the "controlled disintegration of the economy," beginning October 1979, the economy has been passing through accelerating, successive downshifts.

The post-1979 downshifting of the U.S. economy, has proceeded like the down-side of a roller-coaster ride. Down, then up, then down, then up, with the up never reaching the height of the point before the preceding down. Beginning February 1980, down. A slight up, later that year. A deep down-plunge, from early 1981, into October 1982. A slowing of the rate of collapse during 1983 and most of 1984, followed by a new down, starting September-October 1984, and a plunge into a deep down-slope by March 1985.

Each downward-shift is a devolutionary shock-front. The economy reaches a lower plateau, and briefly stabilizes at the new, lower level: the slight up-tick. Then, the erosive process sets off a new down-tick, a collapse to a lower plateau, then a slowing of the rate of decline, prior to a new down-tick. Each speeding-up of the rate of collapse, is a devolutionary shock-front. Instead of "jumping" to the larger concentric sphere, as in technological progress, the economy collapses, in jumps, to smaller spheres.

These "jumps" are what appear to the befuddled "econometricians" as "nonlinear anomalies." Whenever one of the jumps appears, their econometric forecasts break down, and they have no means, within the scope of von Neumann's systems of linear inequalities, to forecast these occurrences.

The Folly of the Automation Myth

The computer, except as potential means for collapsing the percentage of the labor force employed in clerical occupations, is not truly, in itself, a means for increasing the productive powers of labor. Digital-computer technology may be an indispensable auxiliary to implementation of new technologies, but is not the basis for technological leaps purely in and of itself.

The new technologies are essentially three:

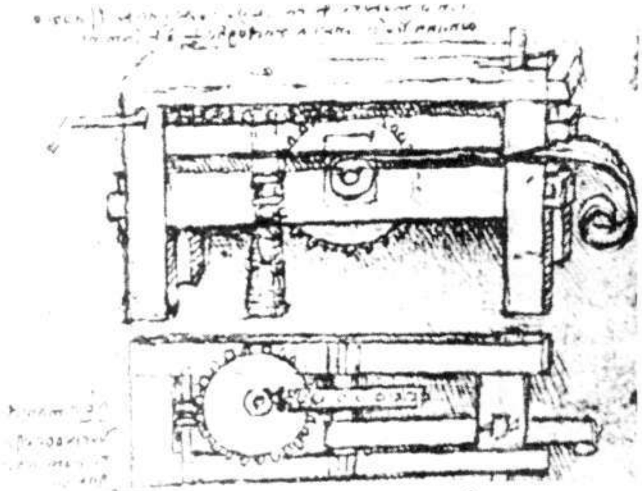
(1) controlled thermonuclear fusion, and related applications;

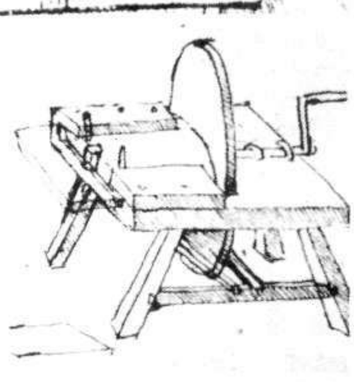
(2) coherently directed energy;

(3) optical biophysics.

Respecting the first two of these three, the impending upward jump centers around the possibility of a fourfold or greater rise in the average effective temperature of heat-driven productive process. A fourfold leap in "average temperature" of productive processes, requires and makes possible new kinds of materials in general use, and redefines radically both the absolute and relative-cost meaning of the term "natural resources." The confinement of hot plasmas as sources of commercial energy, combined with the means to transform such plasma energy directly into industrial forms of directed-energy applications, suffices to signify the greatest and most rapid leap upward in productivity, in the history of mankind. An increase of the productivity of labor in the United States by a factor of between two and three, by the year 2000, is not a wild estimate—on condition we get to business quickly, before the present collapse of the U.S. economy goes much further.

Leontief does make passing reference to biotechnology, sometimes called "genetic engineering." This work is important, but it's small-time stuff compared with another dimension opening up in biology today: optical biophysics.





Ladislao Reti, *The Two Unpublished Manuscripts of Leonardo da Vinci in Madrid* (Norwalk, Conn.: Burndy Library, 1969).

So far, excepting lines of inquiry opened by the work of Louis Pasteur, biochemistry has not treated living processes as living, but as organic-chemicals factories which happen also to be living. That aspect of living processes which distinguishes living from nonliving organic-chemical reactions, has not been isolated in itself. Now, that is beginning to change.

The problem has been, that as long as we assume that atoms are composed of elementary, irreducible particles, it is axiomatically impossible to define the conditions in which a chemical process must necessarily "come alive." Yet, Kepler already implicitly demonstrated that the general laws of astrophysics are invariantly negentropic. In the geometry of the Gauss-Riemann manifold, it is necessary that the most elementary of the apparent particles also reflect an invariant negentropy. So, it would appear, that if we combine the approach of Gauss-Weber-Riemann electro(hydro)dynamics, with the approach taken by Leonardo and Pasteur, that scrutiny of the electromagnetic, optical, characteristics of living processes will discover those "anomalous" distinctions of living processes which distinguish living from nonliving organic chemistry.

Otherwise, the mere fact that the electrodynamics of living processes are characteristic, overall, of negentropic processes, as inorganic processes on the ordinary macroscale are not, has a very special significance. In optical biophysics, we are not only examining living processes through means made possible by modern instruments; we are examining the most fundamental laws of the universe in a way not otherwise accessible to us in the laboratory.

Let us be cruelly frank with ourselves. Optical biophysics, like controlled thermonuclear fusion and directed-energy systems, are weapons of warfare, as well as tools of the works of peace. After all, a weapon is, by definition, nothing but a tool, a machine, or a scientific instrument, applied to the actions of warfare. Every tool, even a simple pencil or ashtray, is a weapon which can be used very efficiently to kill, with proper practice. The field and forest abound with weapons of biological and chemical warfare, in knowing hands. The greater the productive power of a tool, the greater the firepower and mobility it represents, potentially, as a weapon.

Microwaves are excellent killers. Optical biophysics is also a source of weapons in warfare against insects and pathogens, which are vulnerable in various respects, if we tune our beams rightly. We do need greater firepower and mobility in our warfare against parasites and pathogens. We need the full range of biological armament, including that of optical biophysics, to defend our populations against insidious weapons, and epidemic disease not otherwise

In his elaboration of technology and the heat-powered machine, Leibniz drew upon the work of Leonardo da Vinci, who had mastered the principles of animal-powered machines and perfected the hydrodynamics of wind-powered and water-powered machines to a high degree and began exploration of steam-powered machinery. Top: Leonardo's design for a machine to stretch copper wire; inset, an apparatus for grinding optical glass.


LLNL

The greater the productive power of a tool, the greater the firepower and mobility it represents. Here, the electron beam injector for the Advanced Test Accelerator at Lawrence Livermore National Laboratory, which is researching laser fusion for the civilian economy and beam defense.

mastered efficiently. It would be insane not to include optical biophysics, too, in the spectrum of SDI technologies.

Of course, we need better computers. We need them to assist equipment dedicated to acquiring targets, for aiming beams, and so forth. We need them to control the "new physical principles" of SDI, as those weapons also appear as new tools of production. We need true parallel processing urgently; we need analog-digital hybrids of a new type, more urgently. These needs are defined, either directly, or implicitly, by the auxiliary requirements of systems incorporating the three classes of technology we have identified here.

More than we require computers, we require:

(1) A forced-draft increase in energy supplies, otherwise our economy will break down before any significant degree of economic recovery could be effected: we are surviving with present levels of energy capacity, only because of the extensive collapse of our agro-industrial sectors.

(2) A forced-draft increase in capital-goods production, especially in machine tools and related categories; otherwise new technologies cannot be translated into production.

(3) A revival of basic economic infrastructure, in transportation, water-management, and urban-industrial infrastructure.

(4) A rapid and extensive shift of capital flows, away from recently burgeoning "service industries," into employment in energy-intensive, capital-intensive, goods-producing industry and agricultural improvements.

There are two reasons, it might appear to some, that the United States has a surplus of foods. Principally, most citizens are eating poorly, for financial reasons, as reflected in diseases whose spread shows a lowering of immunological potentials. Second, a temporarily, artificially overpriced dollar, enables the U.S. to import foodstuffs even from foreign nations where near-famine conditions exist in parts of the population, while adding to the permanent and growing U.S. trade-deficit; once the dollar drops to competitive levels, the food shortages will become apparent.

Similarly, we appear not to have an energy shortage, because the collapsing economy's consumption of energy is shrinking. "Demand" is dropping only more slowly than import-fed consumption, because the economy is collapsing.

If we continue the "price-mechanism" policy-trends building up since 1967, the mechanisms which Leontief proposes to "inform," not change, we as a nation are doomed. The undertaker, the Soviet empire, is anticipating our earlier need of his services.

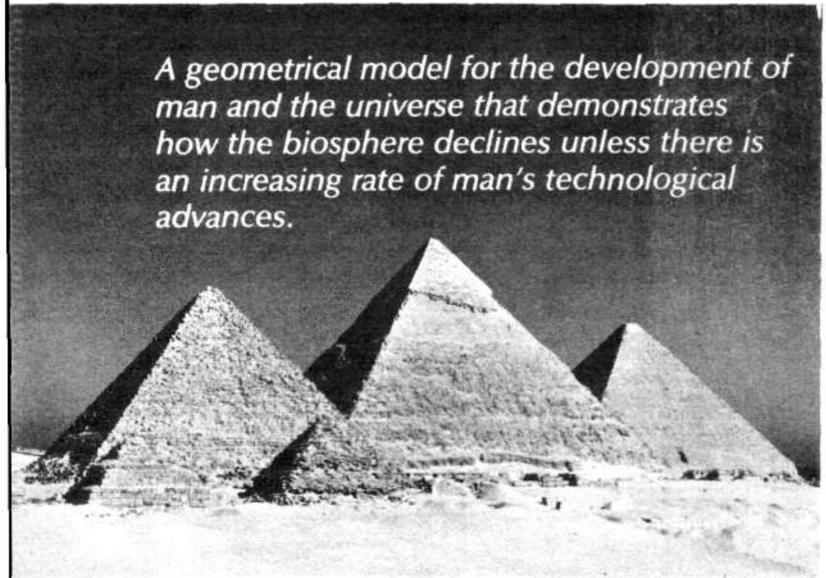
Lyndon H. LaRouche, Jr., an economist, is a member of the board of directors of the Fusion Energy Foundation.

Notes

1. The author discussed the beam defense policy in a March 1982 pamphlet titled "Only Beam-Weapons Could Bring to an End the Kissingerian Age of Mutual Thermonuclear Terror." The FEF published a preliminary study of the spinoff effects in January 1983, and a full study, "The Potential Economic Impact of Relativistic Beam Technology," was issued by the *Executive Intelligence Review* in June 1983. See also LaRouche, Lyndon H., Jr. *So, You Wish to Learn All About Economics? A Text on Elementary Mathematical Economics*, (New York: New Benjamin Franklin House, 1984) and "The Recovery That Never Was" in *EIR Quarterly Economic Report* (April 15, 1985), pp. 1-12.

2. A Primer on Hyperbolic Functions

by Jonathan Tennenbaum



George Holton/Photo Researchers, Inc.

How many man-hours of labor would be required, at the scientific-technological level prevailing during construction of the Egyptian pyramids, to put a man on the Moon? The question contains an absurdity: at that technological level, it is *impossible* to put a man on the Moon. The number of man-hours required is "infinite"—beyond any determinable limit as measured from the standpoint of the Egyptian pyramid-builder. Yet, in 1969, after a definite number of man-hours of work by the human race (counting back from the completion of the pyramids), a man was successfully placed on the Moon.

This paradoxical result should induce us to consider the *difference in quality* between today's man-hour and the man-hour of the pyramid-builders. The relationship between these quanta cannot be expressed by a scalar measure; they are incommensurable. Nevertheless, today's man-hour is strictly larger in the topological sense, than the Egyptian one, in such a fashion that the former subsumes powers which, from the standpoint of the latter, appear "infinite."

How do we accomplish such so-called impossible tasks? If we apply only our present powers, we shall never achieve the goal. Therefore, we must apply our powers toward the *expansion* of those powers, through a series of intermediate tasks whose mastery mediates such expansion. This process generates a series of singularities, in which the quality—the metric—of labor power changes nonlinearly. Each such stage subsumes an apparent divergence to "infinity," whenever a scalar measure appropriate to a given stage is extended to the boundary of the next stage. The rate of generation of such "infinities" is, to a first approximation, the rate of scientific-technological progress. We call such functions *hyperbolic*, because the hyperbolic cone is the least-action surface corresponding to generation of an "infinity" in finite time.

The Simplest Hydroelectrodynamic Singularity

It is our hypothesis that there must be an upper limit on the frequency of simple electromagnetic action (that is, laser beam radiation) that can be propagated in the "vacuum" medium continuously, without generation of a singularity. This limit must be defined by the maximum rate of virtual work performable by the medium in its normal state of organization, to absorb and reemit—to propagate—the action. At the limit, the medium and the mode of propagation (which is the same thing) reorganize themselves, a change manifested by the appearance of a space-time singularity.It is useful to consider two hypothetical experiments. In the first experiment, a tunable laser—a free electron laser for example—is driven to ever-higher beam frequencies. In the second experiment, a constant frequency is maintained, but the intensity or amplitude of the beam is continually increased and it is focused through a fixed, bounded surface in space. In both cases, a phase change occurs at some critical parameter in the experiment. Let us enumerate some possibilities:

Experiment 1

(1) As the singular limit is approached, the efficiency of the laser and focusing system decreases to zero. The effort expended in creating the beam diverges to "infinity," as ever-larger proportions of input energy dissipate in undesirable forms of output, for example, heat. We never reach the singular limit.

(2) A particle-like singularity (a shock wave) forms at the critical frequency.

(3) The hyperbolic relationship $f = c/d$, between frequency f and wavelength d, breaks down by formation of a hydroelectrodynamic singularity that subsumes an apparent change in the local velocity of light c.

Experiment 2

(4) The beam "refuses" to focus down beyond a certain energy-flux-density. The harmonic value of the beam frequency does not correspond to a possible value for a singularity. The beam spreads out to lower energy-flux-densities.

(5) A singularity is formed, in which the original frequency of the beam is "upshifted" by the medium to higher values, allowing more dense propagation of electrodynamic action.

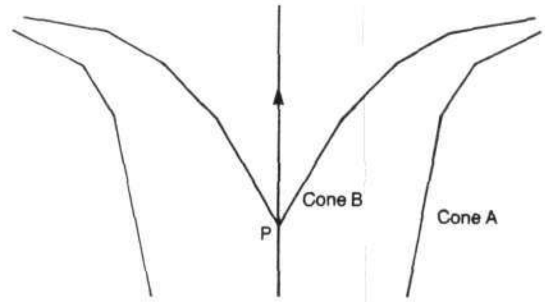


Figure 1
HYPERBOLIC HORN MODEL OF MAN AND NATURE TIME LINE
The relation between man and nature can be represented by an ordered succession of hyperbolic horns. Cone A represents the biosphere; cone B, the changing rate of consumption of biosphere resources by the human race. P *is the singularity on the time line representing the emergence of man.*

(6) A particle-like singularity is formed, as in the first experiment.

The relationship between amplitude, frequency and density rates of generated singularities, for increasing values of total applied action and for different harmonic modes of organization of the action, form the primary subject-matter of hydroelectrodynamics. The amplitude-frequency relationship is merely the most obvious of many hyperbolic functions in elementary physics.

The Necessity of Hyperbolic Singularities

It is easy to see that the hyperbolic horn or, more precisely, an ordered succession of such horns subsuming ordered nonlinear changes in the metric, is the minimal necessary form for the relationship between man and nature. The double-conical construction in Figure 1 provides a rough heurism for this relationship. Cone A represents the changing rate of singularity-generation of the biosphere as a whole, measured with respect to creation and maintenance of "resources" for human existence.[1] Cone B represents the changing rate of consumption of biosphere resources by the human race. Singularity *P* marks the emergence of man. The following conditions exist for a "world-line" of man's history:

First, man is characterized (among other things) by the condition that his consumption grows faster than the negentropy rate of the biosphere within which man emerges. Hence, except insofar as man's activities effect an acceleration of global biosphere negentropy, the two cones will collide (Figure 2). At that point, the biosphere is no longer able to maintain human existence, and the human race ceases to exist.

Man cannot avoid this singularity by adopting a "zero-growth" mode (Figure 3); for, in this case, the biosphere is robbed of the characteristic mode of activity supplied by man. Since the emergence of this mode of activity within

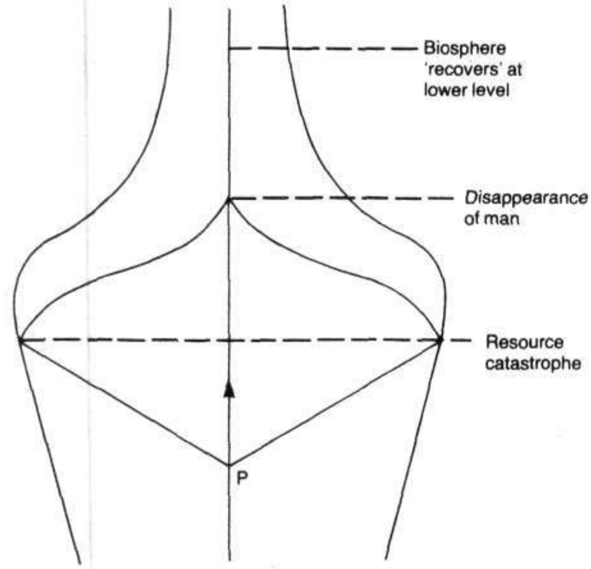


Figure 2
MODEL OF BIOSPHERE NO LONGER ABLE TO MAINTAIN HUMAN EXISTENCE
Because man's consumption grows faster than the negentropy rate of the biosphere within which he emerges, the two cones will collide and the biosphere will no longer be able to maintain human existence—unless man's activities effect an acceleration of global negentropy.

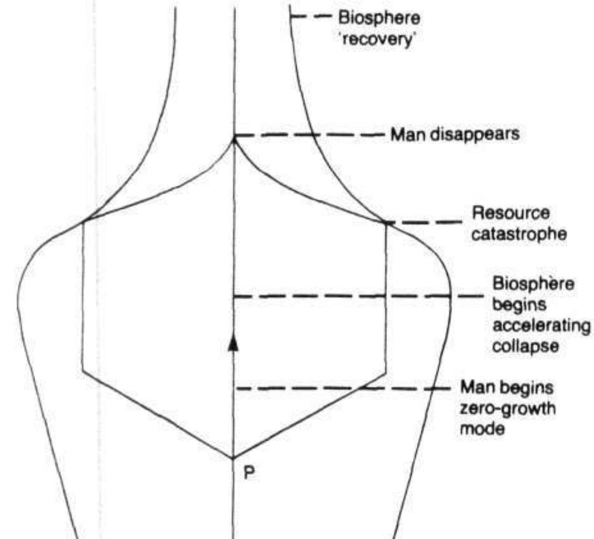


Figure 3
ZERO-GROWTH MODE CAUSES BIOSPHERE TO COLLAPSE
Adopting a zero-growth mode will not avoid the singularity in Figure 2, for this robs the biosphere of the characteristic negentropy man provides. In this case, the biosphere itself will collapse to a lower negentropy rate than that at singularity P.

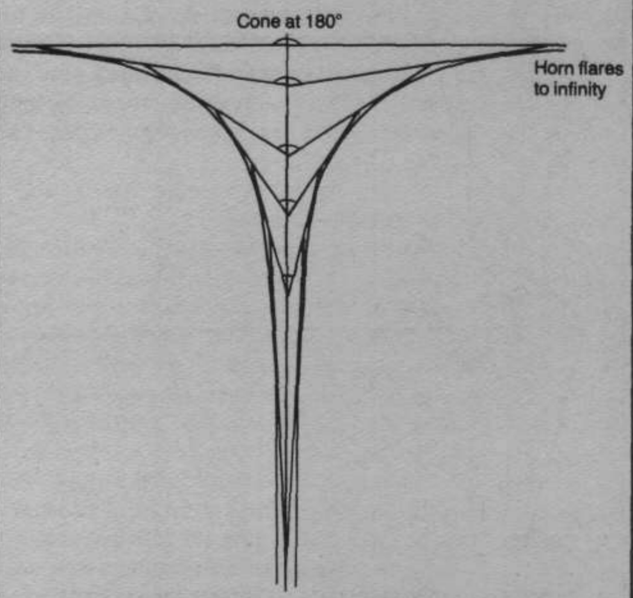


Figure 4
HYPERBOLIC HORN MODEL WITH A CONTINUOUS SERIES OF CONES
The hyperbolic horn can be viewed as the locus for a continuous series of simple cones whose apex-angles increase continuously up to 180 degrees, at which point the cone is completely flat and the horn flares to infinity.

the biosphere was *necessary to the biosphere* at the point *P* when it occurred, adoption of a "zero-growth" mode by man will cause the biosphere itself to collapse to a lower negentropy rate than that prevailing at *P*. At that lower rate the preconditions for man's biological existence no longer obtain, and man disappears.

Second, the continued existence of man requires an acceleration of biosphere negentropy, accomplished through man's productive activities. However, to maintain the biosphere in this accelerated mode requires an acceleration of man's consumption over and above that initially required for biological existence. Again, man's consumption now increases faster than the biosphere expands, and man faces another "resource crisis"—unless he again acts to accelerate biosphere growth. This requires a further acceleration of his own consumption, and so forth. The two cones "chase each other" into hyperbolic horns.

Third, interruption of this process at any point creates ecological holocaust, causing the entire biosphere to collapse down to rates at best somewhat below those prevailing prior to the emergence of man.

The minimal condition for man's continued existence is therefore a double hyperbolic horn, in which the surface for man leads that for the biosphere by a certain function of faster growth rates. The conical function of increasing relative potential population density (the increasing ability of a given society to support more people per square kilometer) subsumes an ordered sequence of such double horns. The sequence of "infinities" and changes of metric across these horns corresponds to jumps in the free energy (above that required to maintain a given system) available

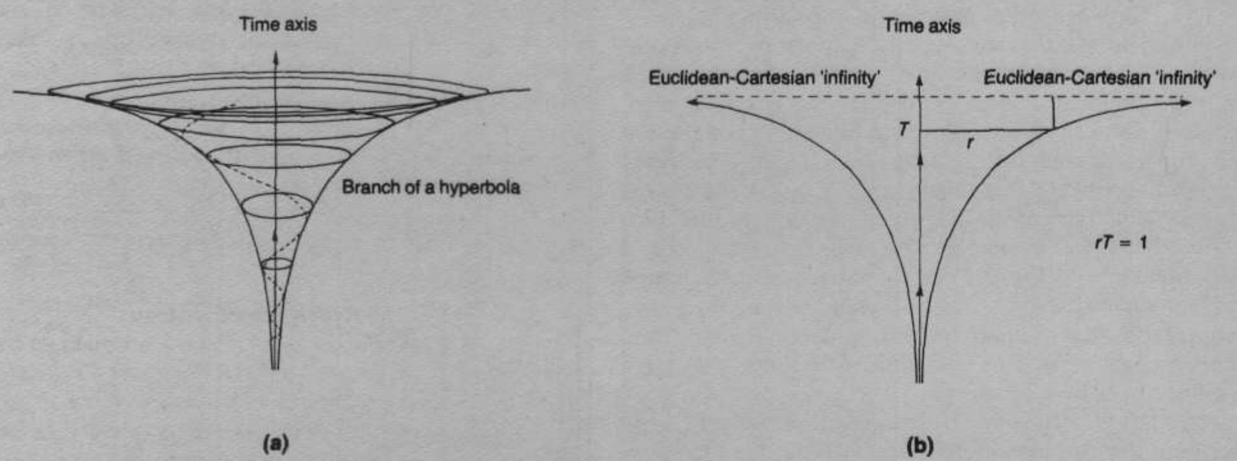


Figure 5
MODEL OF AN ORDINARY HYPERBOLA
Single branches of the hyperbola are shown in (a). *The surface of revolution of one branch is the least-action representation of the process of the flaring horn. This surface is characterized* (b) *by the condition that the radial distance* r *from the central axis to any locus on the surface is equal to the reciprocal of the distance along the axis between the axial projection of the locus and the "flare" point of the horn.*

to the economy by the creation of new species of technologies (scientific revolutions).

These historical world-line conditions for man's existence express the fact that we live in the best possible universe. Ours is a universe in which only negentropic processes of accelerating rates can have continued existence. All other processes are "eaten up" for the benefit of such negentropic processes. In our universe, *the good is necessary*; only the good can subsist. Since our universe exists, this is proof that the good is self-subsisting.

The Simple Hyperbolic Horn

Topologically speaking, the hyperbolic horn can be thought of as the locus of a continuous series of simple cones, whose apex-angles increase continuously up to the value 180°. At that value, the corresponding cone is completely flat; the hyperbolic horn "flares" to infinity (Figure 4).

The least-action representation for this process, in visual space, is the surface of revolution of one branch of an ordinary hyperbola, as shown in Figure 5 (a). This surface is characterized by the condition that the radial distance r *from the central axis to any locus on the surface is equal to* the reciprocal of the distance along the axis between the axial projection of the locus and the point of "flaring" of the horn, Figure 5 (b).

The hyperbolic horn forms an envelope for Riemannian shock wave formation, as shown in Figure 6. The succession of tangents to the hyperbola at P_1, P_2, P_3, and so on, corresponds to slopes of a wavefront that is developing into a shock wave. Note that the "crest" of the wave Q_1 is moving forward *faster* than the base of the wave R_1. At time T_0, the shock is formed. As Bernhard Riemann emphasized (in his 1859 paper "On the Propagation of Plane Air Waves of Finite Amplitude"), *the formation of the shock transforms the* metric of the process. Hence, the subsequent propagation of the wave proceeds within a new manifold, identified by the so-called Dirichlet Principle.

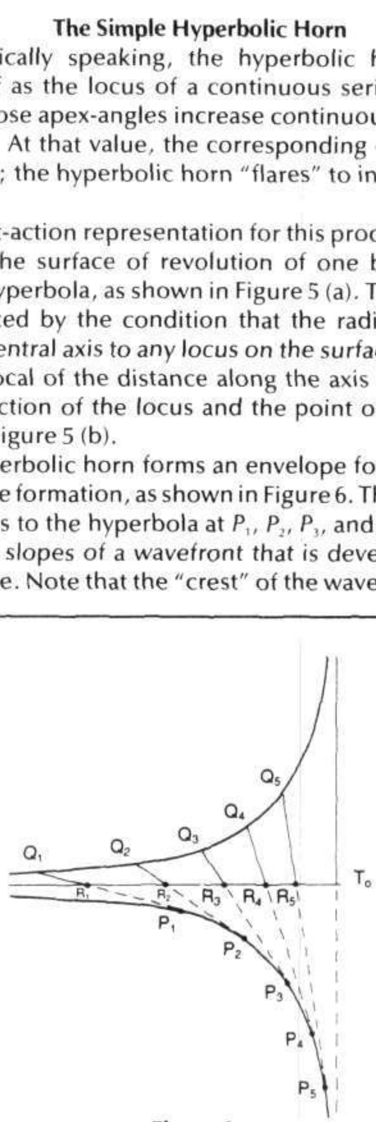


Figure 6
RIEMANNIAN SHOCK WAVE FORMATION AND THE HYPERBOLIC HORN
The hyperbolic horn forms an envelope for the formation of a Riemannian shock wave. The succession of tangents to the hyperbola (P_1, P_2, P_3, and so on) correspond to slopes of a wavefront that is developing into a shock wave. The crest of the wave, Q, is moving forward faster than the base of the wave, R. The shock forms at time T_0, transforming the metric of the process.

Hyperbolic Spirals

The most direct extension of the self-similar (logarithmic) *spiral to a hyperbolic cone is defined by a curve whose* angle of ascent, relative to the central axis, is constant, as in Figure 7 (a). (To visualize this, simply imagine a series of cones whose vertex angle is expanded, on which a spiral with the same pitch is located. As the cone gets wider, the number of windings of the spiral will diminish proportionally.) In other words, as shown in Figure 7 (b), the spiral cuts each circular section of the horn at a fixed angle ϕ. This hyperbolic spiral makes only a finite number of turns as it approaches the singularity, diverging to "infinity" at a critical value of rotational angle around the central axis. Projected onto the asymptotic plane through the singular point, *the spiral appears as in Figure 8.*

The projected curve is characterized by the condition, that the angle ψ between the curve and any radial line, decreases with increasing radial distance according to the function $\tan \psi \sim 1/r$ (a *constant* value for ψ corresponds to a simple logarithmic spiral). A projected hyperbolic spiral is thus a variable logarithmic spiral, whose exponent (negentropy rate) is constantly increasing. The relationship between angular displacement θ_0 around the central axis, and radial distance from the axis, is given by

$$r \sim 1/\sqrt{C - \lambda\theta}.$$

C and λ depend on the chosen pitch and starting point of the spiral; the critical angle is determined by $C - \lambda\theta_0 = 0$.

Note that for the harmonic values $r = 1, 2, 3, 4, \ldots$ the corresponding angular values are $\theta_n = 1/\lambda(C - 1/n^2)$. Thus, the angular displacements $\theta_n - \theta_m$ between these values are proportional to the frequency-values for the spectral lines of hydrogen:

$$\theta_n - \theta_m = 1/\lambda\,(1/m^2 - 1/n^2).$$

The Hypergeometric Mean

Let A and B be two circular cuts on a normalized hyperbolic cone, $rT = 1$, as shown in Figure 9. Choosing the starting point and inclination of a hyperbolic spiral so as to trace one full rotation between A and B, we find for the radius C of the circle corresponding to the halfway (180°) point along the spiral to be:

$$C = AB/\sqrt{(A^2 + B^2)/2}.$$

We shall call this value the *hypergeometric mean* of A and B, following Gauss's use of the term hypergeometric for a class of functions generating exponentials of all orders. It should be obvious then that

$$\underset{(A+B)/2}{\text{arithmetic mean}} > \underset{\sqrt{AB}}{\text{geometric mean}} > \underset{AB/\sqrt{(A^2+B^2)/2}}{\text{hypergeometric mean}}.$$

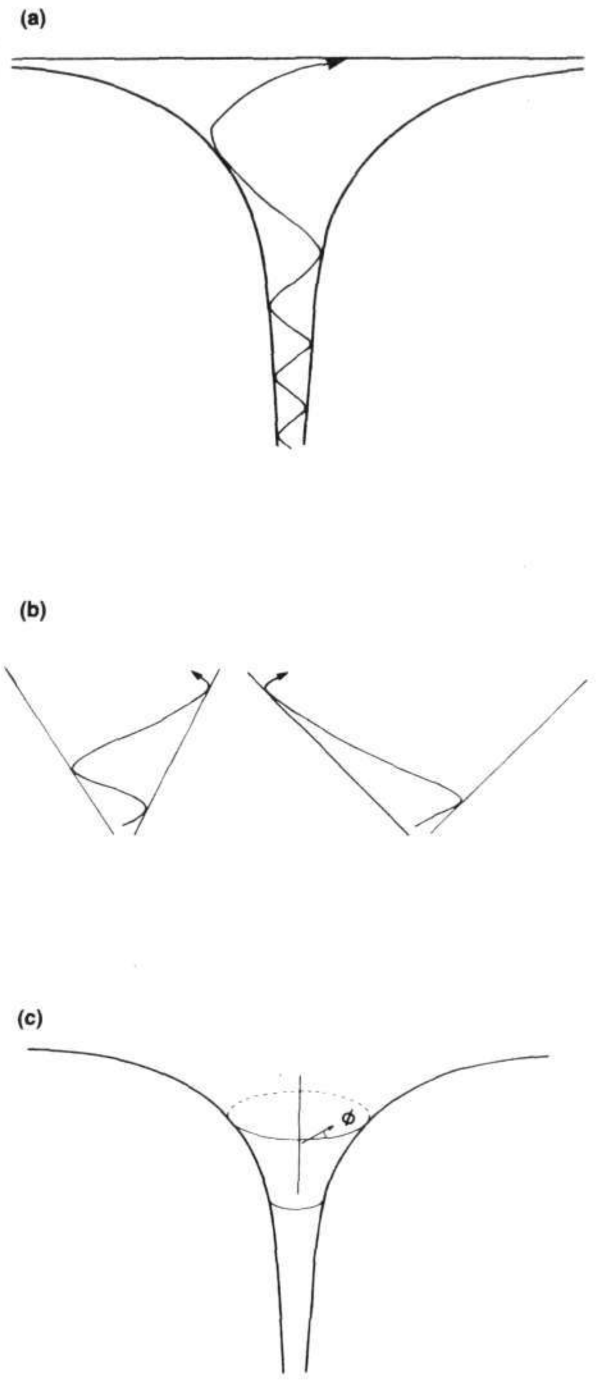


Figure 7
SPIRALS ON A HYPERBOLIC CONE
A self-similar spiral on a hyperbolic cone is defined by a curve that has a constant angle of ascent, relative to the central axis (a). As the cone gets wider, the number of windings of the spiral will diminish proportionally (b). The spiral cuts each circular section of the horn at a fixed angle

In fact, one can think of the hyperbolic cone as the envelope of a continuum of ordinary cones of increasing apex angles. These cones will be tangent to the hyperbolic surface. The hypergeometric mean is smaller than the geometrical mean because the apex-angle of the tangent cone at B is larger than that at A. The apex-angle of the outer cone, spanned by the two circles, is intermediate between the conical angles at A and B.

Hyperelliptic Cuts

The diagonal cut, from circle B to circle A through the hyperbolic cone, as in Figure 11 (a), is no longer a simple ellipse, but a fourth-order curve appearing as a "mean" between two ellipses that have a *common focus* (corre-

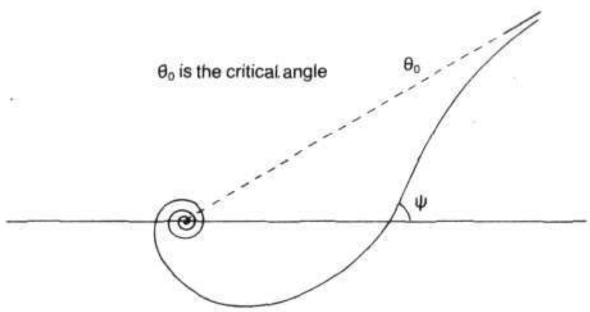


Figure 8
HYPERBOLIC SPIRAL PROJECTED ONTO A PLANE
When the spiral in Figure 7 is projected onto a plane, the angle ψ, between the curve and any radial line, decreases with increasing radial distance according to the function $\tan \psi \sim 1/r$. A projected hyperbolic spiral is thus a variable logarithmic spiral whose exponent, or negentropy rate, is constantly increasing.

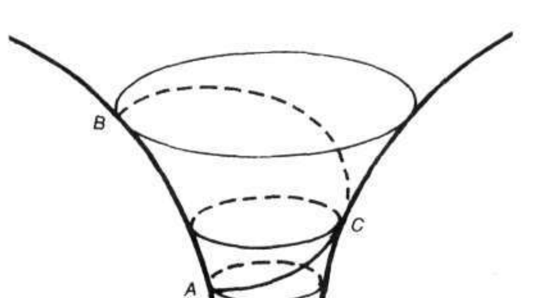


Figure 9
THE HYPERGEOMETRIC MEAN
If A and B are two circular cuts on a hyperbolic cone, and a hyperbolic spiral traces one full rotation between A and B, the radius C of the circle corresponding to the halfway point along the spiral equals the hypergeometric mean of A and B.

sponding to the central axis of the horn). These ellipses, e_A, e_B in Figure 11 (b), are cuts of the two tangent cones, at A and B. The transformation $e_A \rightarrow e_B$, subsumed under the hyperbolic-conical action, corresponds to a displacement of focal-point f_1 to f_2. This is the simplest form of Gauss's *modular functions*, transformations from one elliptical function to another.

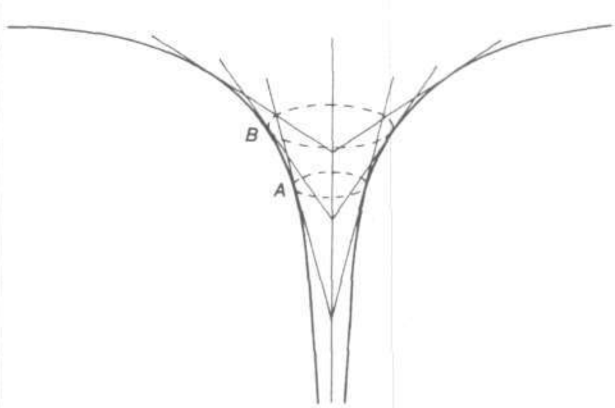


Figure 10
THE HYPERBOLIC CONE AS AN ENVELOPE FOR A CONTINUUM OF ORDINARY CONES
The hyperbolic cone can be viewed as an envelope for a continuum of ordinary cones of increasing apex angles. These cones will be tangent to the hyperbolic surface.

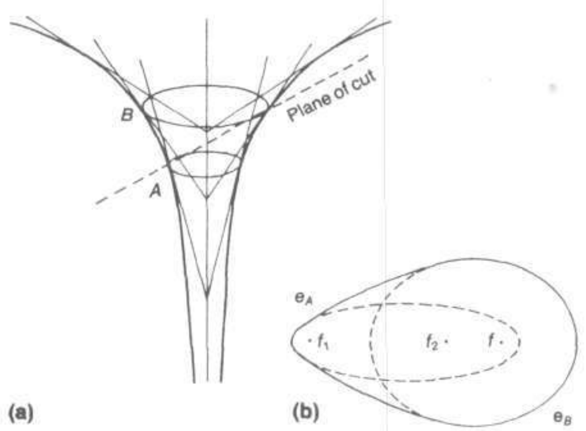


Figure 11
HYPERELLIPTIC CUT THROUGH A HYPERBOLIC CONE
The diagonal cut from circle A *to circle* B *through the hyperbolic cone (a) is a fourth order curve appearing as a mean between two ellipses that have a common focus (the central axis of the horn). These ellipses,* e_A *and* e_B*, shown in (b), are cuts of the two tangent cones at* A *and* B*. The ellipses have one focus in common, f, which corresponds to the central axis of the horn.*

Self-Similar Series of Cuts and Tangent Cones

Contrary to the case of simple cones, where the location of the elliptical cuts must be supplied as additional data (extrinsic to the conical geometry itself), hyperbolic cones have *intrinsically determined cuts*, defined by the planes and cones tangent to the surface (Figure 12). These cuts

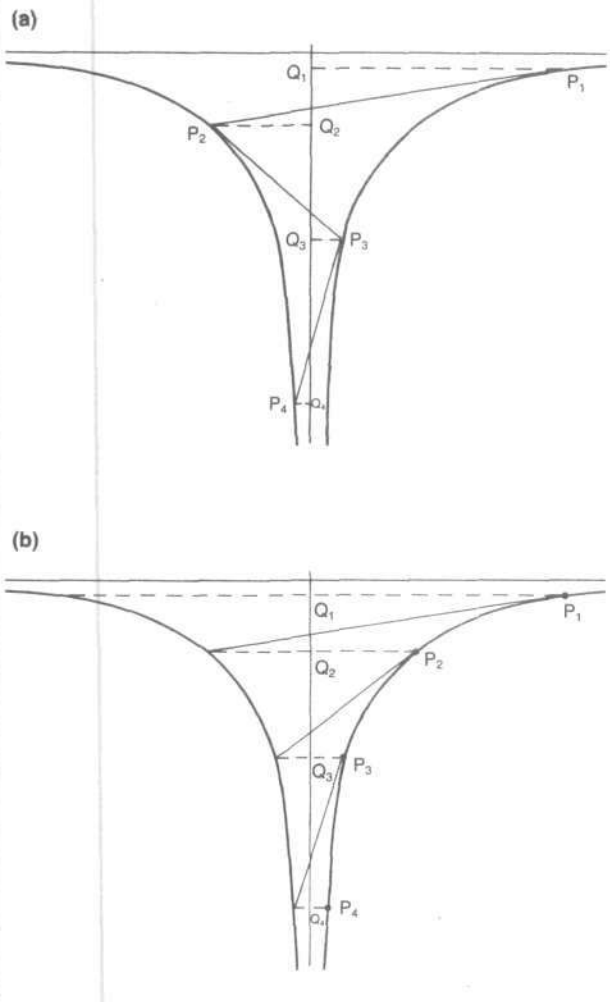


Figure 12
TWO MODELS OF SELF-SIMILAR SERIES OF CUTS AND TANGENT CONES ON A HYPERBOLIC HORN
Hyperbolic cones have intrinsically determined cuts defined by the planes and cones tangent to the surface, which form self-similar series, as shown in both (a) and (b). The tangent at P_1 *intersects the cone at* P_2*, which intersects the cone at* P_3*, and so on. In terms of the distances along the central axis,*

$Q_2 = (1 + \sqrt{2})Q_1$
$Q_3 = (1 + \sqrt{2})Q_2 = (1 + \sqrt{2})^2 Q_1$
$Q_4 = (1 + \sqrt{2})Q_3 = (1 + \sqrt{2})^3 Q_1$, *and so on.*

form self-similar series: The tangent at P_1 intersects the cone at P_2, the tangent at P_2 intersects at P_3, and so on. In terms of distances along the central axis (measured backwards from the singularity),

$$Q_2 = (1 + \sqrt{2})Q_1,$$
$$Q_3 = (1 + \sqrt{2})Q_2 = (1 + \sqrt{2})^2 Q_1$$
$$Q_4 = (1 + \sqrt{2})Q_3 = (1 + \sqrt{2})^3 Q_1, \text{ and so on.}$$

Another version of the same construction can be seen in Figure 12 (b).

Starting from any location on the hyperbolic cone, a uniquely determined series of tangent cones can be constructed, subject to the condition that each succeeding cone (moving upward) begins at the point of tangency of the preceding cone (Figure 13). The distances of the conical apexes from the singularity go as powers of 2. Each succeeding conical segment has one-half the length and twice the breadth of the preceding segment (moving upward on the horn).

Hyperbolic Volumes

The hyperbolic volume on the normalized horn $rT = 1$, bounded by circles of radii A and B (Figure 14), is given by

$$V = \pi(B - A).$$

Taking $A = 1$ and the normalized volume $V = \pi$, the condition for a succession of equal volumes, as shown in Figure 15, is

$$B - A = 1, C - B = 1, D - C = 1, \ldots .$$
$$\text{or } A = 1, B = 2, C = 3, D = 4, \text{ and so on.}$$

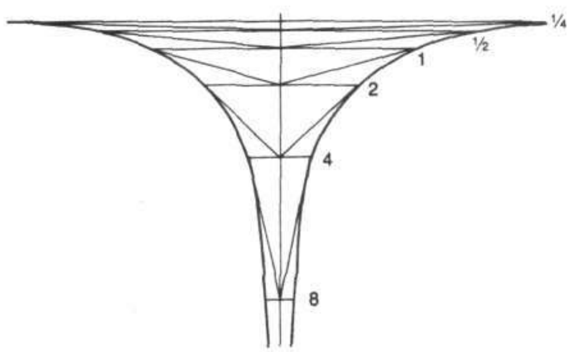


Figure 13
TANGENT CONES ON A HYPERBOLIC HORN
A uniquely determined series of tangent cones can be constructed starting from any location on the hyperbolic horn, if each succeeding cone, moving upward, begins at the point of tangency of the preceding. The distance of the conical apexes from the singularity go as powers of 2. Each succeeding conical segment has one-half the length and twice the width of the preceding segment.

These circles are located on the axis at distances of 1, ½, ⅓, ¼, and so on. (These harmonic values $r = 1, 2, 3$, and so on, bounding equal hyperbolic volumes, determine, in terms of angular displacements along the hyperbolic spiral, the spectral frequencies of hydrogen.)

Riemannian-Spherical Mapping of Ordered Series Of Hyperbolic Singularities

Triply self-reflexive, self-similar conical action generates harmonic series of hyperbolic cones. A planar cut through such a series, taken along the time axis, is shown in Figure 16. Since infinities of the sort typified by a hyperbola "going off to infinite distances" at the singularity, do not exist in our universe, the process must be projected in such a fashion as to eliminate such false artifacts of Euclidean-Cartesian space.

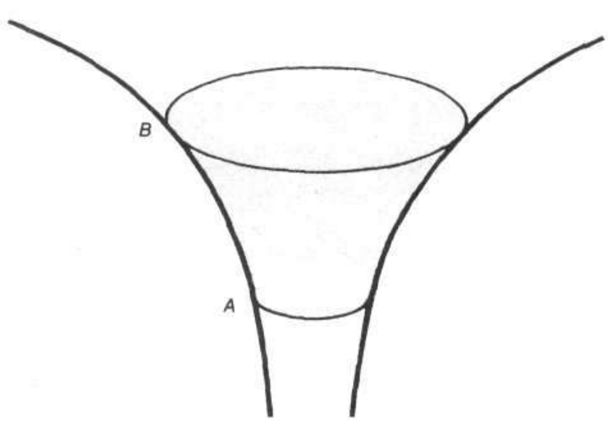


Figure 14
VOLUME OF THE HYPERBOLIC HORN
The hyperbolic volume on the normalized horn rT = *1, bounded by circles* A *and* B, *is* $V = \pi(B - A)$.

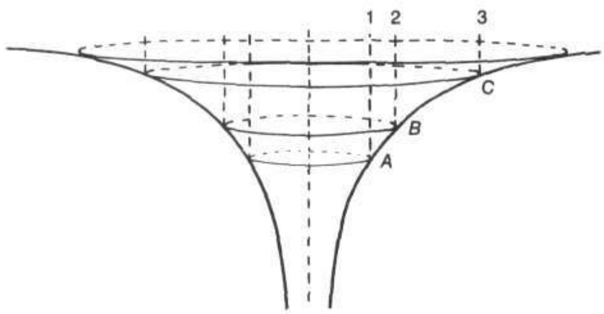


Figure 15
SUCCESSION OF EQUAL-VOLUME HYPERBOLIC SECTORS
Equal-volume hyperbolic sectors on the horn are found by taking A = 1 *and the normalized volume* = π *when* B − A = 1, C − B = 1, D − C = 1, *and so on.*

The simplest procedure is stereographic projection onto the Riemann sphere, as illustrated in Figure 17. The negentropic displacement, from one hyperbolic singularity to the next, corresponds to certain angular displacement on the sphere. The rate of negentropy is given by the density of singularities within a given angular interval on the sphere. As the density of hyperbolic singularities increases in a negentropic process, the process from one Riemann sphere to a Riemann sphere of higher density "grows." Thus, a negentropic process corresponds to a series of concentric Riemann spheres.

Jonathan Tennenbaum is editor-in-chief of the German-language Fusion.

Notes

1. The notion of resource must be understood in terms of processes of *creation* of resources, not from the standpoint of consumption of material objects, as the case of mining minerals might mislead one to think. A resource is any negentropic process that "feeds" or provides necessary boundary conditions for the human economy. Insofar as human development constantly accelerates beyond average biosphere rates, such "feeder" processes generally fall behind rates of consumption, tending to be "used up" and exhausted. We must either accelerate a given such process, or turn to other ranges of resources.

   The biosphere provides much more than raw materials: the biosphere is the basic infrastructure of the economy, providing the oxygen, water flows, temperature stabilization, and so forth, to all of man's activities. (The layered organization of the atmosphere, for example, functions as a combination lens, filter, and polarizer for sunlight input to photosynthesis.)

   It should also be understood, that just as the technological level of all productive activities in an economy tends to rise with the overall advance of the economy, so also do individual organisms within the biosphere tend to reflect the negentropic level of the whole system. We should therefore not be astonished to find, upon close examination, that even the lowliest moth in today's biosphere displays a most remarkable degree of "electrodynamic" sophistication. This is not the same primitive moth of 50 million years ago, but an advanced moth operating as a singularity in a biosphere that produced man and is maintained by man. These observations bear directly on the dangers inherent in the phenomenon of a biological holocaust.

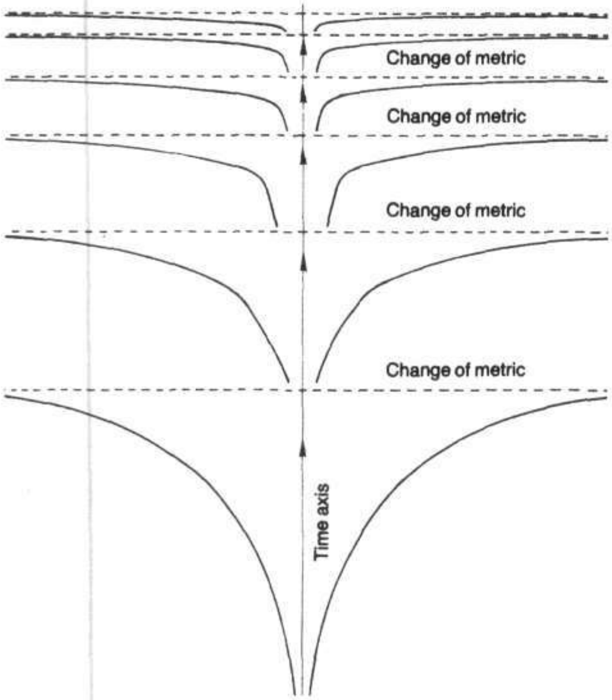
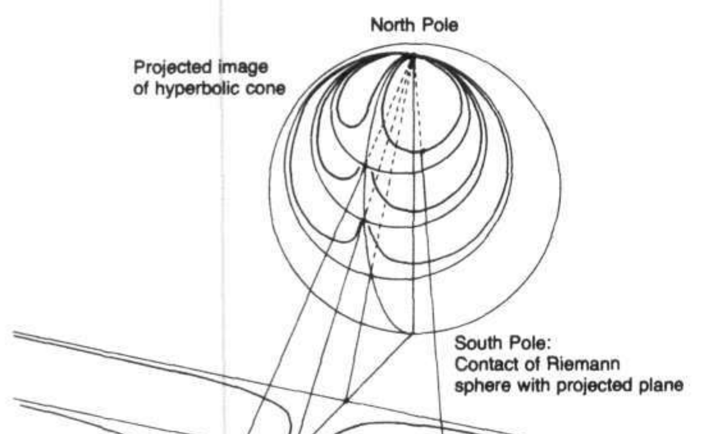


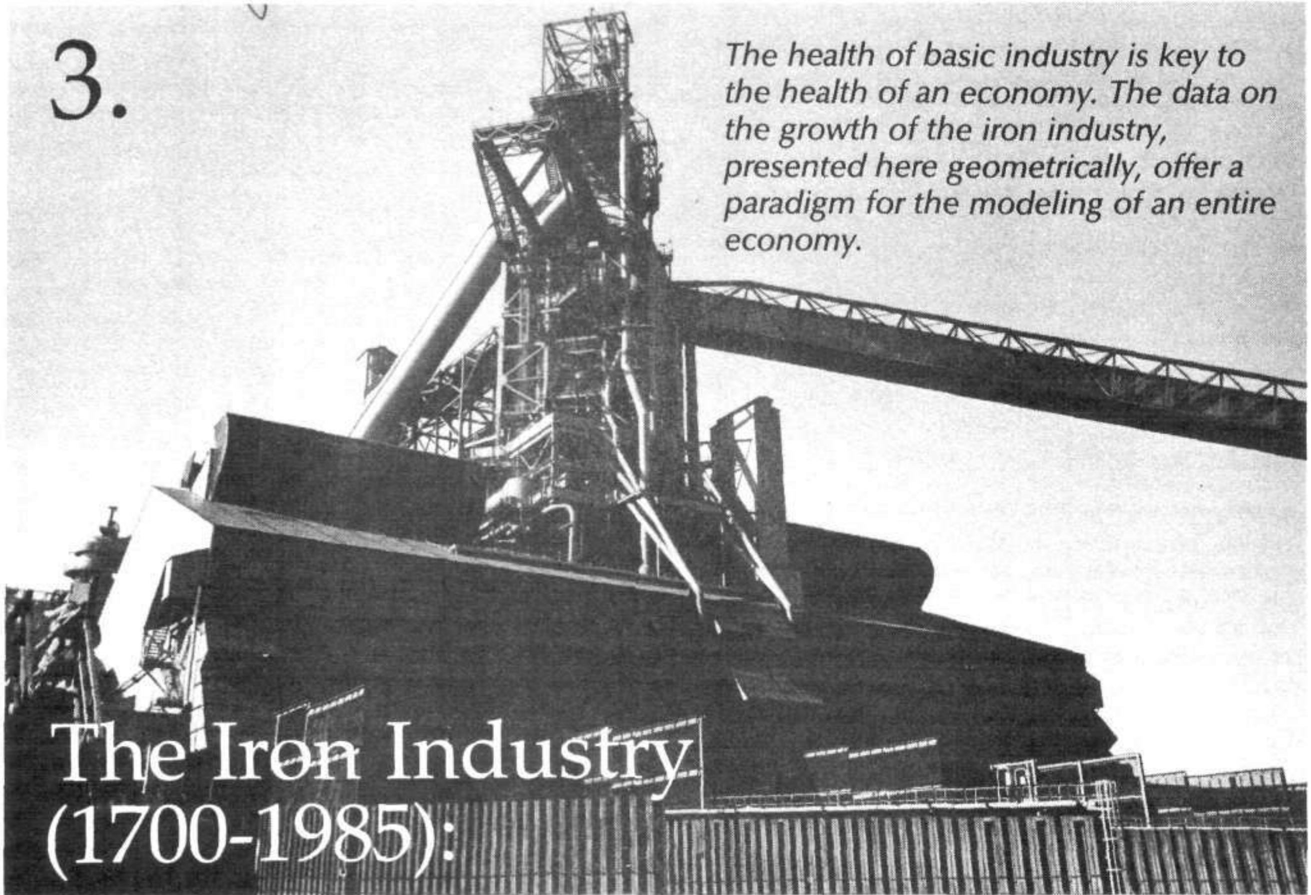
Figure 16
PLANAR CUT THROUGH A SERIES OF SELF-SIMILAR CONES
Triply self-reflexive self-similar conical action generates a harmonic series of hyperbolic cones. This is a planar cut through such a series, taken along the time axis.

Figure 17
STEREOGRAPHIC PROJECTION OF HYPERBOLIC CONE SERIES ONTO A RIEMANN SPHERE
The simplest way to illustrate the infinity of the sort typified by a hyperbola flaring to infinite distances at the singularity is to project the process onto a Riemann sphere. Such infinities do not exist in our universe, but are false artifacts of Euclidean-Cartesian space. The rate of negentropy is given by the density of singularities within a given angular interval on the sphere. Note that the projected hyperbolae approach a circle as their rate of ascent increases.



3.

The health of basic industry is key to the health of an economy. The data on the growth of the iron industry, presented here geometrically, offer a paradigm for the modeling of an entire economy.



Courtesy of Inland Steel Co.

The Iron Industry (1700-1985): A Model of Economic Growth —and Decline

by Robert Gallagher

Inland Steel Company's Indiana Harbor Works in East Chicago, Madeline No. 7, dedicated in September 1980, was the Western Hemisphere's largest blast furnace.

In 1982, a joint task force of the Fusion Energy Foundation and the *Executive Intelligence Review* magazine, established by Lyndon H. LaRouche, Jr., began to investigate the characteristics of the transformations in technology that occurred in agriculture, transportation, iron and steel, power generation, and other industries throughout U.S. history. The task was to investigate, over the existence of an industry, the relationships among relative energy consumption; relative energy flux density; relative capital intensity; and output per capita, per member of the labor force, and per industrial operative.

The goal of the task force was to define a mathematical function in which the content of "work" measured is measured in "units of negentropy."

Self-Similar Growth

Although the results reported here are preliminary, the project has achieved, so far, the identification of self-reflexive conical (hyperbolic) work functions in each of the industries cited above. Particularly in the investigation of the iron and steel industry, we were able to pin down each of the metrics initially proposed. As a result, LaRouche's hypothesis, that the history of industrial technology is a history of a transfinite succession of distinct species of reducing power, leapt out of the data with a clarity and certainty that no other present-day economic or physical theory has achieved.

Figure 1 shows the historical development of energy flux density in American blast furnaces from 1710 to 1980. We are interested in *relative* energy flux density, for energy per se is a mere scalar quantity. "Relative energy" begins to identify the vector characteristics of technology transformations. Since development is self-similar, the energy flux density data are shown on a logarithmic axis. Before the technology discussion below, energy flux density was measured as the coal-equivalent (in British thermal units) of carbon-based reductant passing through a horizontal cross-sectional area of a furnace.

Figure 1 shows four species of exponential growth in energy flux density, which appear as distinct, approximately linear curves on the logarithmic graph. The first is in charcoal-fired and water-wheel-powered blast furnaces over a 120-year period; the second, the development of anthracite-fired furnaces over a 40-year period; the third, the most rapid development, of coke-fired blast furnaces, from 1880 to 1910; and last, the World War II mobilization that produced relatively minor improvements over the late 19th century work of Andrew Carnegie.

These four curves each represent distinct logarithmic spirals that could be traced on a cone. Note that the steepness of ascent increases from the first curve to the third curve, representing the Carnegie era, when the greatest advances in reducing power were made. These could be represented as three spirals with the same rate of ascent but on three distinct cones, each with a wider apex angle than the previous one. This begins to show "hyperbolic flaring" in physical economy.

However, in the transition from the third curve to the fourth (the effects of the World War II mobilization), the rate of ascent declines. The economy jumps back to a previous regime of growth, geometrically of the same form as that of the early years of the introduction of anthracite furnaces. As the figure shows, relative energy flux density in blast furnaces in the United States has not changed significantly since 1907.

Figure 2 shows the development of relative capital-intensity expressed by the work supplied per operative, measured here by the iron output per primary iron and steel wage earner, over the same historical epoch. Since we are interested in *relative* capital-intensity, its self-similar development, the productivity data is shown on a logarithmic axis. This graph also shows distinct epochs of increase in productivity, with an added feature. The fact that the curves are not linear in the logarithmic representation, shows that after the initial introduction and relative perfection of each species of reducing power, *relative* capital intensity (and productivity) could only increase by an apparently discontinuous transformation of technology into the next species of reducing power.

Figure 3 proves this. The graph shows productivity in iron production as a function of energy flux density, each shown on logarithmic axes, for the entire development of U.S. iron-making and for Japanese iron-making since 1950. (The

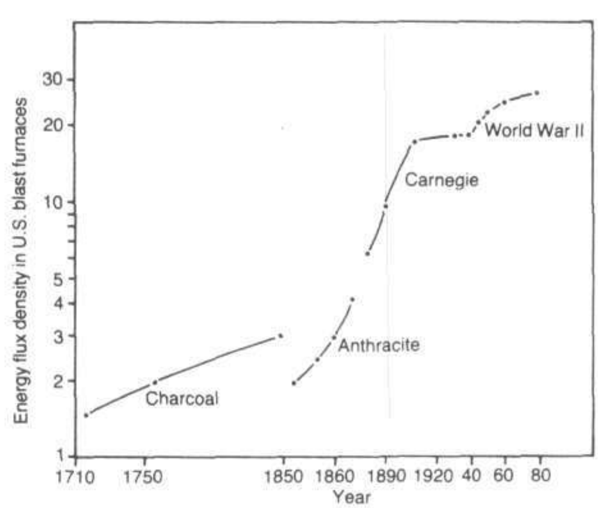


Figure 1
THE DEVELOPMENT OF ENERGY FLUX DENSITY IN U.S. IRON-MAKING, 1710-1980
Four species of exponential growth in energy flux density appear as distinct, approximately linear curves on the logarithmic graph. In the transition from the third curve to the fourth curve, the rate of ascent declines, and the economy jumps back to a previous regime of growth, geometrically of the same form as that of the early years of the introduction of anthracite furnaces.

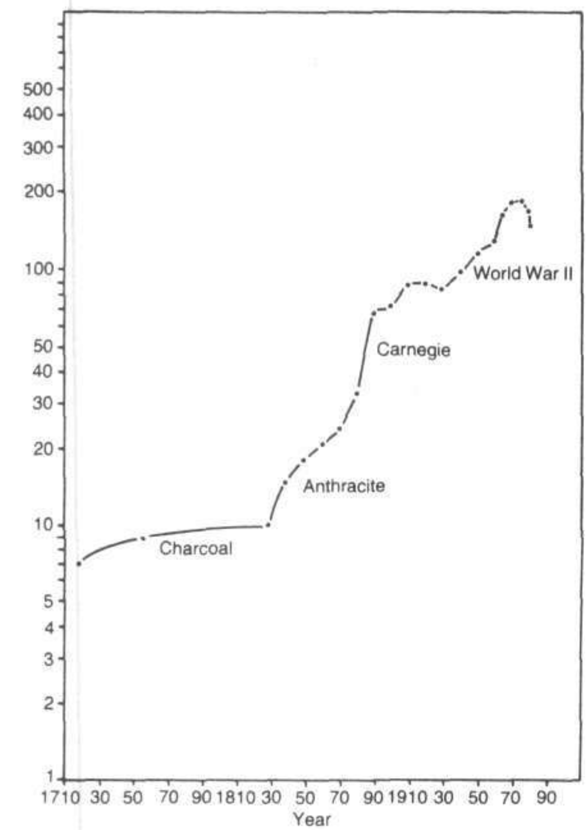


Figure 2
THE DEVELOPMENT OF PRODUCTIVITY
Iron output per primary iron and steel wage earner (logarithmic) is shown. The fact that the curves are not linear in the logarithmic representation shows that after the initial introduction and relative perfection of each species of reducing power, relative capital intensity could only increase through an apparently discontinuous transformation of technology into the next species of reducing power.

Japanese data are discussed below.) A data point on Figure 3 is defined from the measured average energy flux density of several furnaces in operation in a given year and the productivity of labor in iron-making in that year.

For the U.S. data, the figure shows the internal development of each of the four distinct species of reducing power discussed above to have the geometric form of hyperbolae. The figure also reveals a short-lived fifth regime, discussed below, whose development has been truncated by investment policies over the past decade, as shown by the sharp downward hook in productivity at the top of the graph. The most significant lesson to be learned from this figure is that *from a geometric standpoint, the rate of increase in reducing power has declined since 1910.*

Figure 3 can be represented geometrically as a nested sequence of five hyperboloids; as the spirals climb the hyperboloid, their rate of ascent slows as they are pulled outward with the flaring of the hyperboloid, the exhaustion of

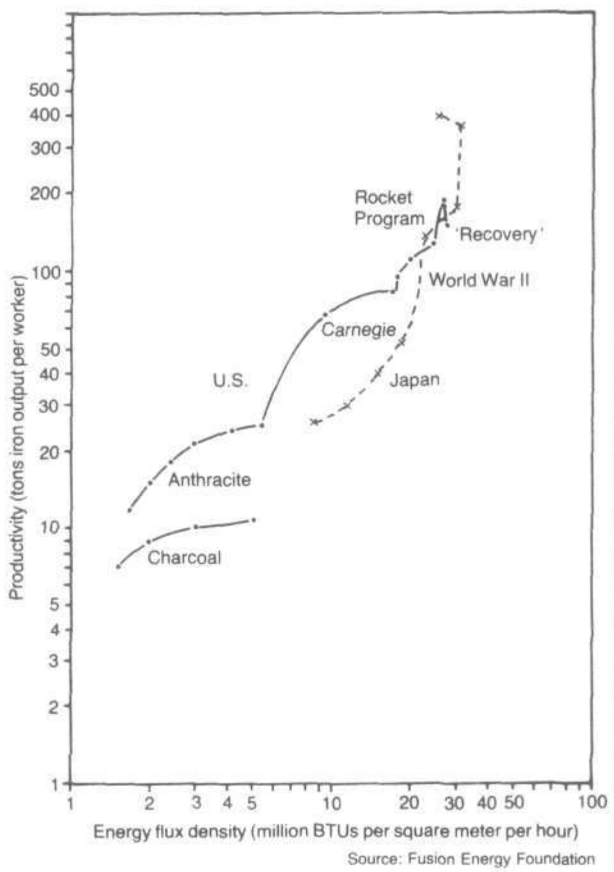


Figure 3

HOW TECHNOLOGY ELEVATED THE POWER OF LABOR IN BLAST FURNACES IN THE UNITED STATES AND JAPAN

Productivity (iron output per worker per year) jumps with the introduction of new technologies, as measured by energy flux density in blast furnaces. The graph shows a series of hyperbolic relationships between the two parameters; for the United States, one hyperbola for each of the following blast furnace types: charcoal fueled, anthracite-coal fueled, the coke-fueled furnaces built by Andrew Carnegie, the World War II period, and the period of the rocket program; for Japan, their postwar reconstruction. U.S. data points are indicated with dots along a solid curve; Japanese with crosses along a dashed curve. Energy flux density data measure total energy passing through a cross section of the bosh of a blast furnace.

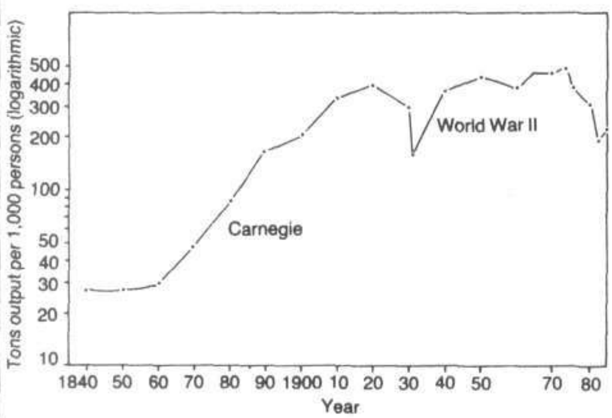


Figure 4

U.S. IRON PRODUCTION PER CAPITA, 1840-1980

U.S. iron production has not changed much on a per capita basis since 1910.

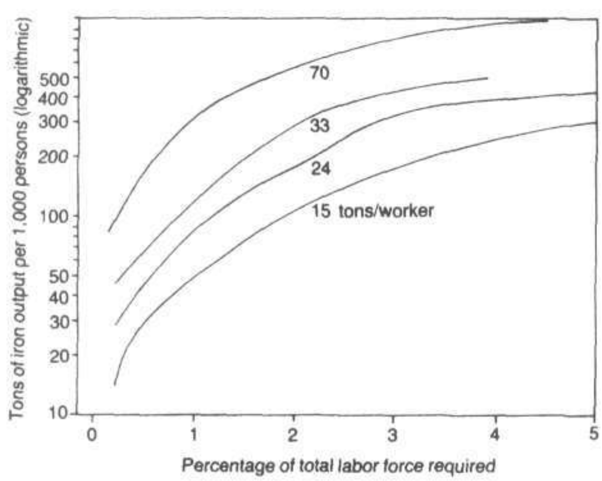


Figure 5

PERCENTAGE OF TOTAL LABOR FORCE REQUIRED IN IRON AND STEEL PRODUCTION

Shown is the percentage of the total labor force required in iron and steel production to achieve per capita output levels at the four productivities indicated. For each frozen level of technology, the progression is hyperbolic: it races off toward 100 percent of the labor force! In reality, this does not occur. Either the existing level of technology is transcended, or a depression ensues.

that phase of the development of reducing power. The drop in the rate of ascent of reducing power with the fourth and fifth curves can be shown with smaller hyperboloids, closer and closer to the previous figure. The top of the figure shows the hyperbolic collapse of U.S. industry that ensued in the mid-1970s.

As can be seen, the period of most relative development occurred in the Carnegie period already cited, indicating that no *fundamental* technology transformation has taken place in iron-making since then. Figure 4 demonstrates this more clearly by a logarithmic graph of iron production per capita since 1840. The relative (that is, the self-similar, logarithmic) rate of change of iron production per capita is a crude, though useful metric of the relative rate of change of reducing power of the economy as a whole. This metric is the closest that the task force has come to identifying what LaRouche terms "the relative rate of negentropy generated per capita."

Figure 4 shows that relative reducing power per capita has, on the average, remained roughly the same since 1910. In other words, the relative rate of change of reducing power per capita has averaged out to zero since 1910. This fact illustrates the dominant, problematic characteristic of the U.S. economy today. As LaRouche put it, "To the degree, an economic process is doing the same thing over and over again, it is, to that degree, entropic, and is dying."

(It is interesting to note that the "freezing" of U.S. blast furnace technology coincides with the formation of the Federal Reserve System in 1913.)

'Infinities' in Economic Processes

To further illustrate the hyperbolic principle in physical economy, we calculated the percentages of the labor force required to produce the levels of iron production per capita shown in Figure 4, under conditions where blast furnace technology was permitted to develop up to a specific level and was then frozen at that level with a specific productivity of labor. Could the American economy have continued to exist were the power of labor held at a specific value?

Table 1 shows that since 1840, the percentage of the labor force comprised of primarily iron and steel wage earners, has remained between approximately 0.4 percent and 1.0 percent of the total labor force. We froze the productivity of labor at four distinct levels associated with four distinct phases in the development of blast furnace technology:

(1) charcoal-fired blast furnaces of 1840 with a productivity of labor of 15-tons output per worker per annum;

(2) anthracite-fired furnaces of 1870 with a productivity of labor of 24-tons output per worker per annum;

(3) coke-fired furnaces of 1880 with a productivity of labor of 33-tons output per worker per annum; and

4) coke-fired furnaces of 1900 with mechanization of furnace charging and a productivity of labor of 70-tons per worker per annum.

For each level of technology, we calculated the percentages of the labor force required to be deployed into the iron and steel industry to produce the per capita production levels that had actually occurred over the 70 to 80 years following the transcendence of the cited, frozen levels of

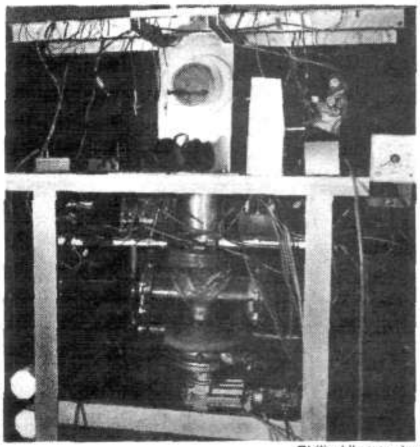
Table 1
U.S. IRON MANUFACTURING PRODUCTIVITY AND LABOR FORCE (1840-1982)
Productivity in net tons of iron per primary iron and steel wage earner per year (number of wage earners from Historical Statistics of the U.S.).

Year	Productivity (net tons of iron per iron and steel worker)	Iron and steel workers as % of total labor force
1980	174	0.37
1970	183	0.59
1960	127	0.72
1950	119	0.84
1940	97	0.86
1930	83	0.77
1920	88	1.1
1910	88	0.82
1900	70	0.76
1890	69	0.64
1880	33	0.75
1870	24	0.60
1860	21	0.39
1850	18	0.42
1840	15	0.42

Table 2
PERCENTAGES OF U.S. LABOR FORCE REQUIRED IN IRON AND STEEL MAKING TO PRODUCE VARIOUS PER CAPITA LEVELS FOR SELECTED LEVELS OF TECHNOLOGY (PRODUCTIVITY)

		Percentages of labor force by level of tons per worker			
Year	Tons iron per 1,000 persons	(1) 15/worker	(2) 24/worker	(3) 33/worker	(4) 70/worker
1980	302				0.92
1970	448				1.54
1960	373			2.77	1.30
1950	431			3.03	1.43
1940	356		3.47	2.53	1.20
1930	289		2.66	1.94	0.91
1920	388		4.0	2.93	1.40
					1.03
1910	331			2.2	
1900	203	3.55	2.22	1.61	0.76
1890	164	2.94	1.84	1.34	0.64
1880	86	1.65	1.0	0.75	
1870	47	0.96	0.6	0.96	
1860	29	0.55		0.55	
1850	27	0.5		0.5	
1840	27	0.42		0.42	

Chris Lewis



Philip Ulanowsky

The choice for America is plain. It can continue to demolish its basic industries and leap into devolution, or it can develop the available next-generation technologies. Here is U.S. Steel's National Tube Plant under demolition in McKeesport, Pa. Inset is a scale model of a plasma steel furnace, ready for development.

technology. The results are shown in Table 2 and Figure 5. To produce the per capita production levels of 1910 with 1840-circa charcoal-fired blast furnace technology would require almost 5 percent of the labor force—clearly an unattainable "infinity." To deploy such a relatively huge percentage of the labor force into iron and steel production, would have resulted in a fantastic labor shortage in other areas of the economy, so as to make the level of production per capita of iron and steel unsupportable, even with an "infinite" effort. It would exceed the maximum constructible economic activity at the cited level of technology. Or, viewed from another standpoint, the minimum required technological level to reach these per capita production values had not been achieved.

Such "infinities" are shown for each of the chosen levels of technology in Figure 5. The vertical axis is a "time axis," measured logarithmically in self-reflexively increasing per capita levels of production of iron. The horizontal axis is the percentages of the labor force required to supply the per capita levels of production at the levels of productivity cited. For each "frozen" level of technology, the progression is hyperbolic. *The percentage of the labor force required to meet the imposed demands of per capita production, races off toward 100 percent of the labor force!*

In reality, this does not occur: either the existing level of technology is transcended, or a depression ensues. As Figure 4 indicates, it is precisely into such a depression, that the U.S. economy is now tumbling, with the Reagan administration's "economic recovery" appearing as, at best, a tiny bounce upwards in the course of a general collapse. Figure 5 shows such a succession of technology transformations. It begins to get at what the concept of triply self-reflexive, conic, self-similar spiral action.

Artificial Productivity Increases

As we emphasize, there has been no fundamental change in the reducing process since Carnegie. In fact, almost all *the productivity increases in the 1960s and early 1970s are artificial*; they are entirely attributable to automation. For example, the Bethlehem Steel Co. "L" furnace at Sparrows Point achieved a slightly higher energy flux density than previous furnaces only because computerization eliminated loss of time in charging and tapping the furnace.

Since the perfection of the Carnegie blast furnace, only *operational* changes have been introduced, such changes as those proposed by the proverbial "time-and-motion" study. No new "ordering principle" by which to reduce ore (usable rock) into materials for social reproduction has been introduced. This is one reason that the U.S. iron and steel industry has been on a roller-coaster since then (Figure 4), and why it is now falling like a rock.

The Japanese Model

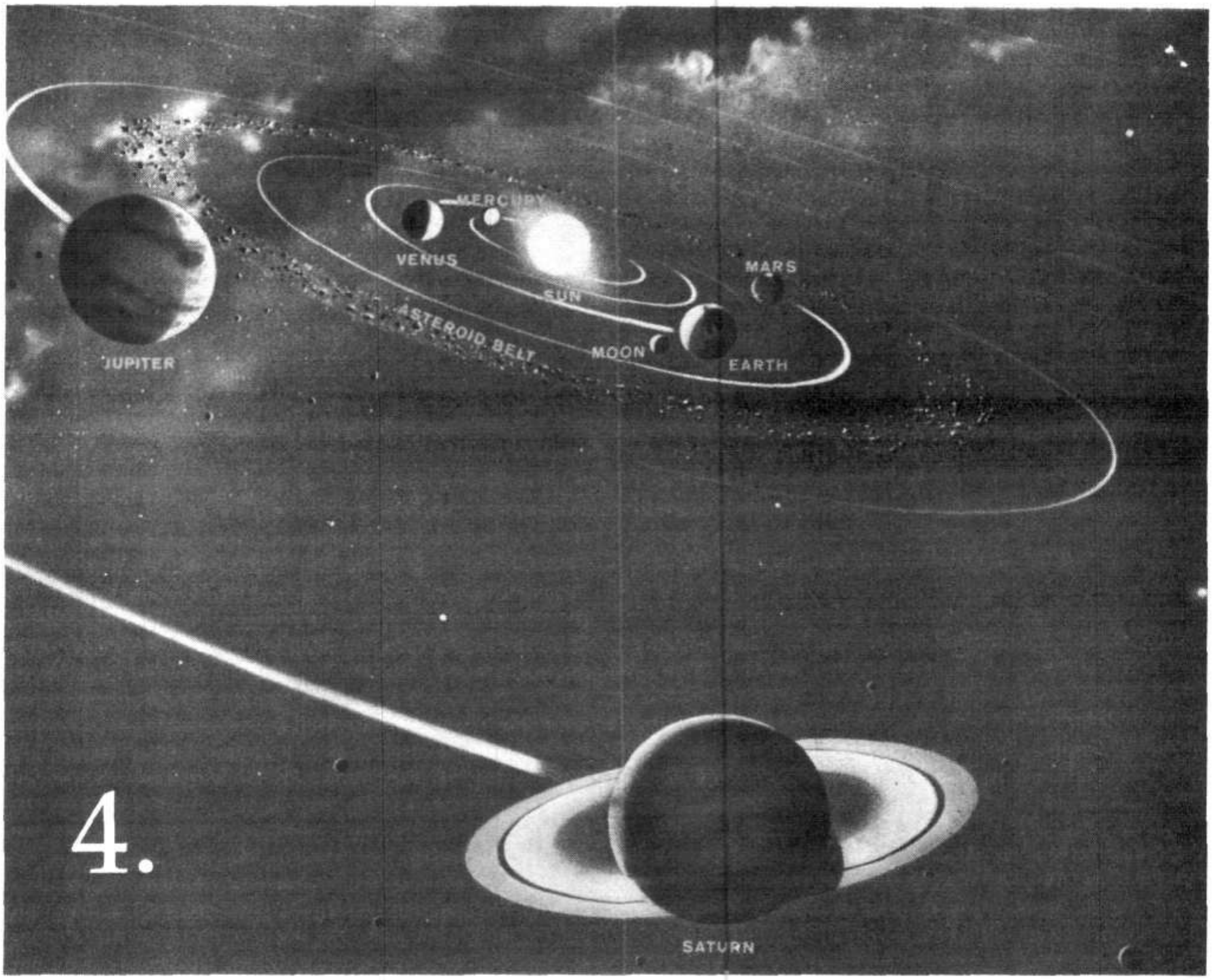
The Japanese, on the other hand, have made improvements in the reducing process itself. In the early 1970s, they began to inject heavy oil into the area of the blast furnace hearth to increase the density of carbon reductant. Confirming the fact that energy is not equivalent to work, this addition of heavy oil, with other operational improvements, produced a huge leap in productivity, without a significant increase in energy flux density (the Japanese development is the dotted curve in Figure 3). Figure 3 also shows that the Japanese, in their postwar rebuilding program, have followed the method of Carnegie: as soon as a technology could be implemented to increase productivity and throughput, they ripped down old furnaces and built new ones. After the oil embargo of 1972, the growth of Japanese iron-making came to an end, and energy flux density has actually declined in their blast furnaces since then.

Clearly, the defense mobilization of the West requires many new blast furnaces and new "greenfield" iron and steel mills, along the Japanese model. At the same time, however, the economy must turn to the future or face "entropy." The environmentalists are correct in pointing to the exhaustion of a given resource base, but they fail to grasp that their very existence, as human beings, is based on the transfinite succession of technology transformations that our forebearers forced through.

U.S. industry is near the end of the effectiveness of mere chemical reducing power. Future development requires the creation of a new genus of reducing power, transcending even the impressive achievements of Japanese industry. The obvious candidate for such an industrial process is the fusion torch, the reduction of ores in the plasma state to directly refine purified metals and other materials.

Robert Gallagher is on the staff of the Fusion Energy Foundation.

Johannes Kepler gave us modern astronomy and posed the problems that modern mathematical physics had to resolve. His method was entirely geometrical and therefore is completely compatible with the most advanced modern physics.



The Application of Hyperbolic Geometry to Kepler's Model of the Universe

by Carol White

To a high degree of approximation, the distances of the planets from the Sun are given by Titius and Bode's statement of the Keplerian distance law: $r = 3(2)^n + 4$, bearing in mind that the distance of Mercury is assigned the value 4. (This means that the first value of *n* is negative infinity; then *n* takes the value 0, 1, 2, and so on.) The numbers are chosen so as to normalize the Earth's distance from the Sun as 10. Thus Venus is 7; Mars is 16; the asteroid belt is 28; Jupiter is 52; Saturn is 100; and Neptune is 196.

A hyperbolic cone, whose radii have the dimensions *r*, and whose central axis is denoted by *R*, will be created by the revolution of one branch of a hyperbola whose expression is $r = 1/R$. A succession of tangents to such a hyperbolic cone (or horn, as we shall refer to it), can be constructed to intersect the axis, such that each successive segment is twice the length of the preceding one. (see page 34, Figure 13.)

If such a horn is placed inside a right-angle cone, as in Figure 1b, then the distances of the planets will be determined by points laid out on the central axis by a series of such tangents, with Mercury occurring at the intersection of the horn and the cone. This explains the anomalous position of Mercury. (Otherwise, it is necessary to locate the planets according to the intersections of a logarithmic spiral on a cone translated up the central axis by four units, which appears to be an arbitrary procedure.) A projection of these orbits onto a plane is shown in Figure 2.

Kepler's Second Law states that an orbiting planet sweeps out an equal-area sector of an ellipse in an equal amount of time. This is equivalent to the statement that the planet's rotational velocity decreases proportionally with the increase of its distance from the Sun. The horn shows this relationship.

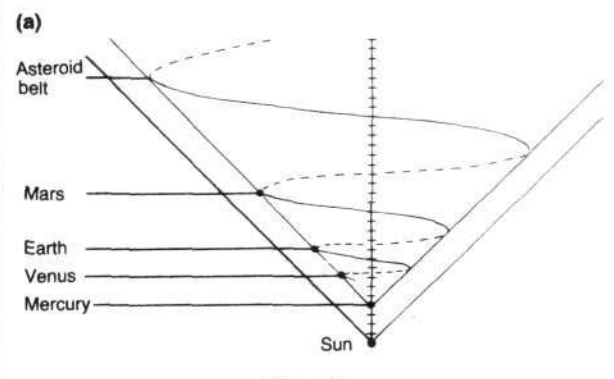
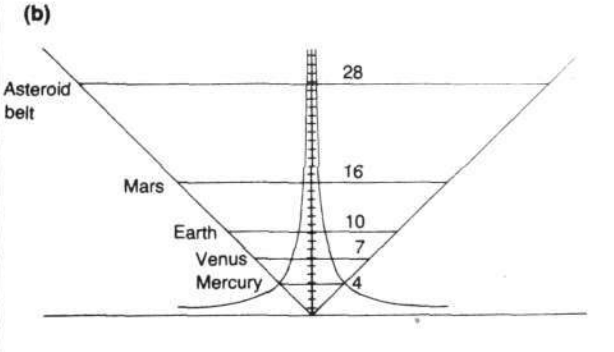


Figure 1
GEOMETRIC MODEL OF THE ORBITS OF THE PLANETS

In this model of the planetary orbits there are two cones. The inner cone is positioned four units from the vertex of the outer cone so that the planet Mercury is located at the vertex of the inner cone. The planets are then located on this cone on a logarithmic spiral. A hyperbolic horn placed within the two cones reflects the action of the orbiting planets.



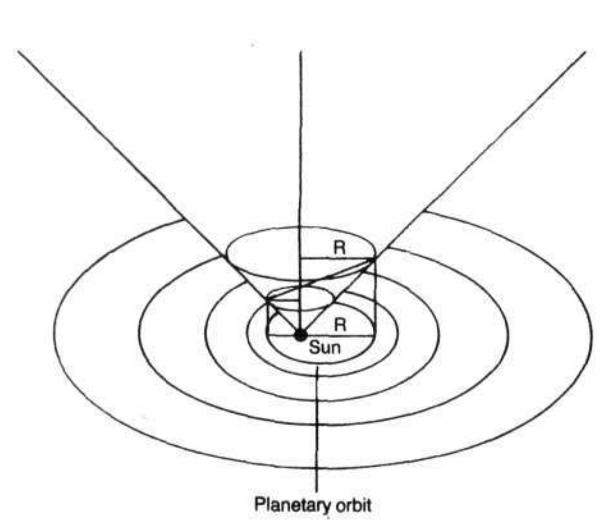


Figure 2
THE PLANETARY ORBITS PROJECTED ONTO A PLANE

The radius R of the level circles in the cone that bound an ellipse project in the plane to the radial distance from the Sun of a planetary orbit.

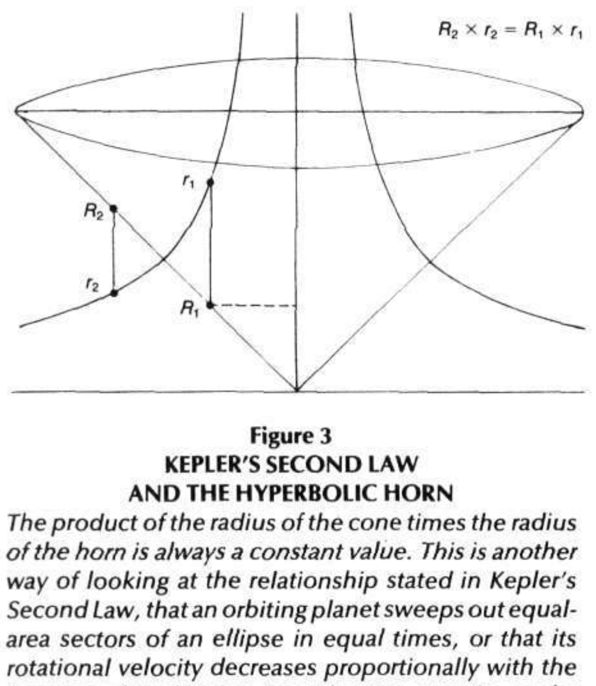


Figure 3
KEPLER'S SECOND LAW AND THE HYPERBOLIC HORN

The product of the radius of the cone times the radius of the horn is always a constant value. This is another way of looking at the relationship stated in Kepler's Second Law, that an orbiting planet sweeps out equal-area sectors of an ellipse in equal times, or that its rotational velocity decreases proportionally with the increase of its distance from the Sun. (For the reader who is not familiar with these concepts, note that the planet's orbit is seen as the projection of an ellipse in a three-dimensional cone. The radii of the projected orbital ellipse are equivalent to the radii of the level circles in the three-dimensional cone.)

The radius of a velocity circle on the horn is denoted by r, *that of the orbital distance by* R.

Another way of stating this is that angular momentum will always be constant. This is shown nicely when one looks at the relationships as they project from the horn to the cone (Figure 3).

A cone has characteristic values that are determined by self-similar spiral action. These are the arithmetic, geometric, and harmonic means (Figure 4). The beginning and ending points of one complete revolution of the self-similar spiral on the cone define bounding circles on the cone. What is the harmonic mean between them? Cut the cone with a surface tangent to both circles (producing an ellipse on the cone). The harmonic mean occurs at the point that the cone's axis intersects this ellipse. Projected to the ellipse in the plane, the harmonic mean represents the semilatus rectum (that is, the radius of the ellipse that is perpendicular to the major axis and extends from the position of the Sun). Kepler's Second Law can also be stated in terms of the rotational action accomplished by an orbiting planet, over a constant interval of time. In one complete rotation, this will equal the logarithm of the rotating self-similar spiral between the bounding values R_1 and R_2; that is, $\log R_1 - \log R_2$. This accords with the common definition of action as $m \int v ds$. Let $m = 1$; since $ds = 2\pi dR$ and $v = 1/R$, $2\pi \int 1/R\, dr = \log R$.

The semilatae-recta of the ellipses in the solar system, vary in distance from the Sun as the square of the angular momentum of the planets, respectively. Once the horn is introduced, we see that the distance of the planets from the Sun is determined on the cone by a projection from the tangential values marked off on the hyperbolic cone or horn. The harmonic mean is, in fact, the arithmetic mean of the bounding velocity circles on the horn: $\frac{1}{2}[(1/R_1) + (1/R_2)]$ or $\frac{1}{2}(r_1 + r_2)$. This is the inverse of $(R_1 \times R_2) \div \frac{1}{2}(R_1 + R_2)$.

Kepler understood the planets to be swept along in their elliptical orbits by a vortical field created by the electromagnetic action of the Sun. (Actually he viewed it as a magnetic field.) Unlike Isaac Newton, he saw the apparent attraction of a planet to the Sun as only an epiphenomenon of this vortical action.

Gravity is not a universal force, nor is force a self-evident existence in our universe. Force appears when work is done, as in moving something uphill.

If we consider the rotational action of an orbiting planet, then the time rate of change of this action is proportional to v^2. This can be represented as the area of the circle on the horn with the given velocity v.

Carol White is editor-in-chief of Fusion.

(a)

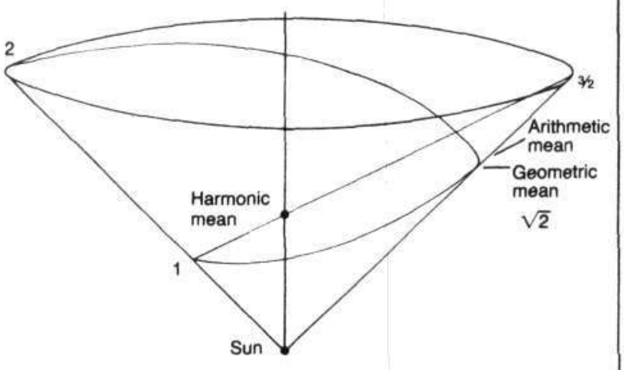
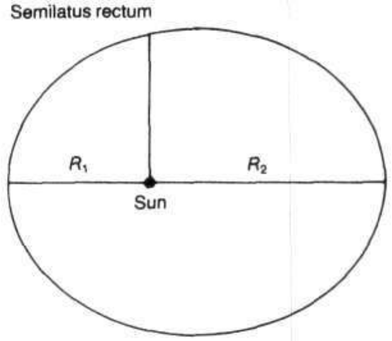


Figure 4
ARITHMETIC, GEOMETRIC, AND HARMONIC MEANS

One revolution of a self-similar spiral on a cone denotes the bounding circles of an ellipse. The ellipse is represented here by its central axis. When orthogonally projected onto the plane (b), the semimajor axis of the ellipse produced is the arithmetic mean of the bounding circles and its semiminor axis is their geometric mean. The vertex of the cone becomes the focus at which the Sun is located, and the radius perpendicular to the major axis is the semilatus rectum.

(b)



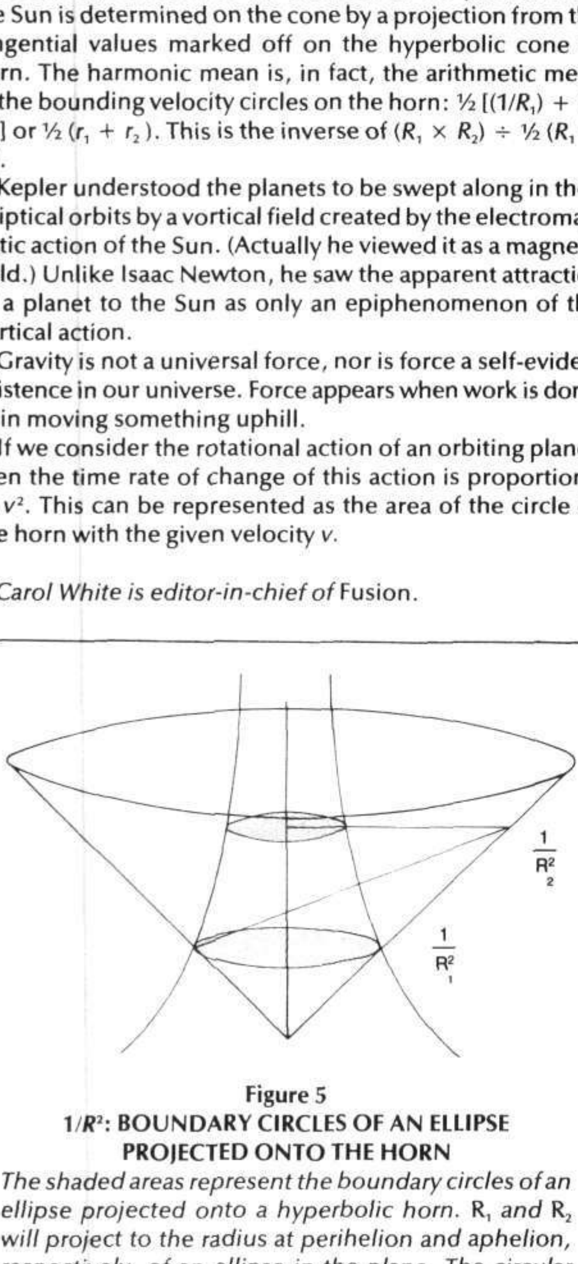
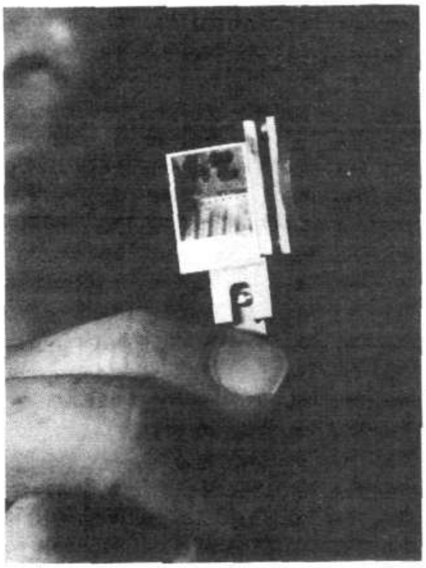


Figure 5
$1/R^2$: BOUNDARY CIRCLES OF AN ELLIPSE PROJECTED ONTO THE HORN

The shaded areas represent the boundary circles of an ellipse projected onto a hyperbolic horn. R_1 *and* R_2 *will project to the radius at perihelion and aphelion, respectively, of an ellipse in the plane. The circular velocity at these points will be* $1/R_1^2$ *and* $1/R_2^2$ *respectively.*

Beam weapon missile defenses are much nearer than most people think, President Reagan's science advisor, Dr. George Keyworth, announced in late May. In fact, Keyworth noted, some systems could be developed within three years. The system that has achieved the most rapid rate of progress is that of the thermonuclear-powered X-ray laser.



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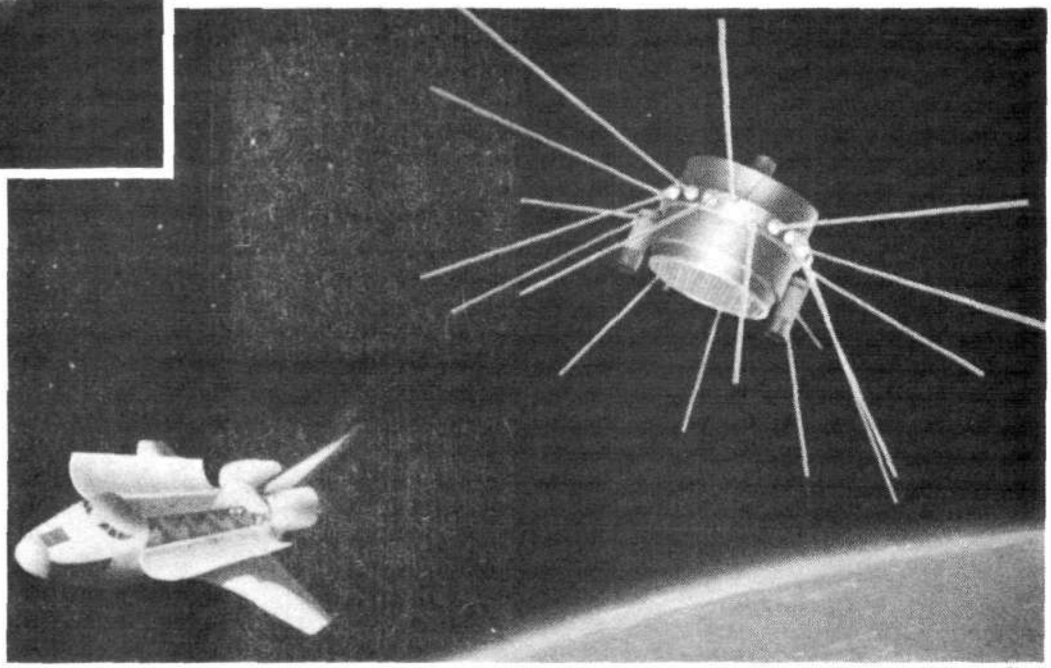


The X-ray laser has incredible capabilities for defense as well as science and industry. Here, an artist's depiction of an X-ray laser beam weapon. Inset is a soft X-ray laser target at Lawrence Livermore National Laboratory, which has produced the shortest wavelengths ever produced in a laboratory.

Illustration by Christopher Sloan

The X-ray Laser: A Revolution in Beam Defense And the Laboratory

by Charles B. Stevens

For some time, it has been realized that first-generation X-ray lasers could be deployed by the mid-1980s as an effective shield against some types of missiles. But recent tests, as reported by William Broad on the front page of the *New York Times* May 15, have dramatically shifted this perspective. X-ray laser lenses have been perfected that make "third generation" X-ray lasers a near-term prospect.

The incredible capabilities of the X-ray laser as a beam defense weapon were outlined to Congress by Dr. Lowell Wood of Lawrence Livermore National Laboratory, several months before the recently successful tests. Wood told Congress:

> Even more striking prospects are being seriously studied. One contemplates the functional (and per-

haps physical) destruction of entire fleets of ICBMs with a single weapon module lofted by a single defensive missile. Each of these primary prospects has significant, albeit early, experimental results behind them at the present time. They are not dreams, nor are the corresponding applications studies naive.

Now, the scientists working under Wood have apparently perfected a lens for focusing X-ray laser beams that makes the X-ray laser a trillion times "brighter" than the hydrogen bomb and a million times brighter than the Sun. As a result, a single X-ray laser module based on the Moon could destroy a missile being launched from Earth. Or, popped-up into near space, a single module costing a few million dollars could destroy hundreds of offensive missiles.

X-ray Optics

The science establishment critics of President Reagan's program to render offensive nuclear weapons "impotent and obsolete" have consistently claimed that high-power X-ray optics are physically impossible. For example, in one of the most often cited anti-beam-defense reports, "Directed Energy Missile Defense in Space—A Background Paper," Dr. Ashton Carter of the Massachusetts Institute of Technology claims, "Since X-rays are not back-reflected by any kind of mirror, there is no way to direct the X-rays into a beam with optics like the visible and infrared lasers." Scientists at Los Alamos National Laboratory issued an official critique of this report, which was published by the congressional Office of Technology Assessment, pointing out, among other things, that "experimental X-ray optics have actually been developed."[1] Yet, all the leading critics of beam defense have continued to echo Carter's assertions. Now, Livermore scientists have actually demonstrated such optics on a weapons scale.

The details of the Livermore experiments have been kept top secret. However, the Fusion Energy Foundation has described in previous publications many approaches to high power X-ray optics.[2] For example, fusion scientist Friedwardt Winterberg, in a 1981 book on thermonuclear explosive devices, discusses in detail how X-ray optics have been the primary means of improving nuclear weapons for the past four decades.

The most likely form of X-ray optics utilized by Lawrence Livermore in the latest set of experiments is that of a *magnetic plasma lens* by which the X-ray laser beam self-focuses. Such self-focusing is a well-observed phenomenon with all high-power lasers. It is found that an intense laser pulse will nonlinearly alter the optical characteristics of a medium through which it is propagating, such that the laser pulse is focused. In infrared glass lasers, this self-focusing process must be avoided because it will destroy the glass laser amplifiers that make up the laser.

Recent Livermore experiments on the Novette fusion glass laser showed that the nonlinearity of this self-focusing process increases dramatically as the laser is shifted to shorter wavelengths; for example, from 1.0-micron infrared to 0.25-micron ultraviolet. In the case of the X-ray laser with a .0001 micron wavelength, the self-focusing nonlinearity theoretically should be much, much greater—and it is.

Magnetic plasmas can be used as lens material because, unlike any normal material, a plasma can absorb unlimited amounts of energy and maintain its structure. This type of self-organizing process can be seen in a wide range of magnetic fusion devices (spheromaks, reversed field pinches, and so on) and has led one leading fusion researcher, Dr. Tihiro Ohkawa at GA Technologies in San Diego, to discuss the possibility that astromagnetic plasmas demonstrate some characteristics of living processes.

From the standpoint of Gauss-Riemann relativistic physics, the self-focusing of X-ray laser pulses in plasmas is an expected phenomenon. Within a dense plasma, the X-ray laser pulse cannot propagate in an ordinary fashion. As a result, it does "work" on the plasma. In this process, the beam focuses and produces a channel through which it can propagate. This so-called self-induced transparency is a primary form of physical action.

Soviet X-ray Lasers?

That the Soviets do not have an X-ray laser capability has been an argument used to explain why the Soviets—who have been working on beam defense research for 20 years—are so adamantly opposed to the U.S. Strategic Defense Initiative. However, all the evidence points in the opposite direction, that the Soviets have thoroughly investigated the X-ray laser possibility. At a late May presentation to the Conference on Lasers and Electro-Optics in Baltimore, Dr. Mark J. Eckart reviewed the Livermore experiments demonstrating a laboratory-scale X-ray laser, and he discussed the scientific papers that provided the basis for its realization. *Almost all these papers were by scientists in the Soviet Union.* Eckart noted that the Soviets have not published many papers on X-ray lasers since 1980, shortly before Lawrence Livermore was first reported to have demonstrated a bomb-powered X-ray laser.

Most experts agree that the Soviet Union has led the world in work on X-ray lasers and have devoted far greater resources to this work than the West has. It is inconceivable, therefore, that the Soviets would be far behind. Also, there can be little doubt that if the Soviets have perfected the X-ray laser, they will not deploy it. (Given the range and demonstrated capabilities of the X-ray laser, it is almost impossible to detect them before they are utilized.) Therefore, it is most likely that both the United States and the Soviet Union have within their grasp the capacity to render offensive nuclear weapons impotent and obsolete. The political question that remains is whether the Soviets will accept President Reagan's offer "to work together" on this, or will they continue to oppose the Strategic Defense Initiative while they rush to deploy the X-ray laser first, thereby gaining an overwhelming strategic superiority?

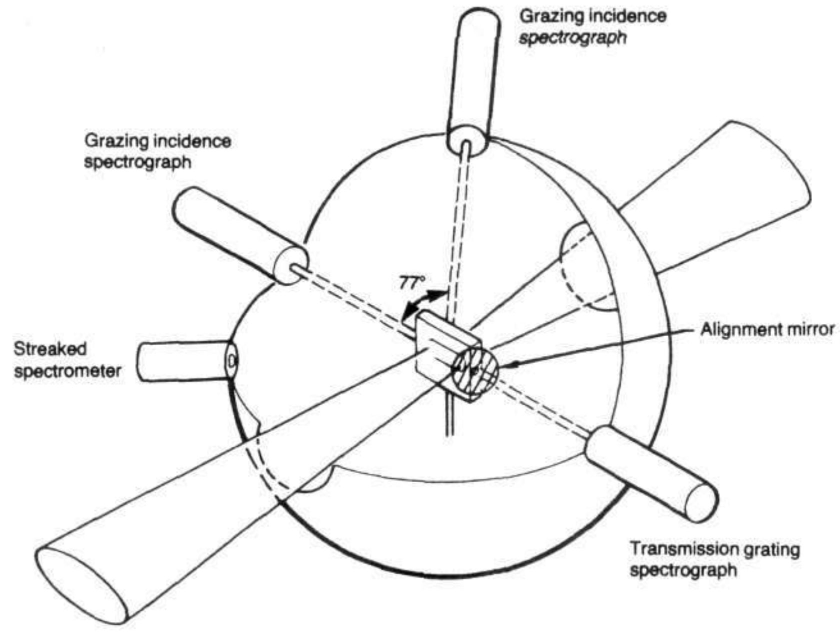


Figure 1
LAWRENCE LIVERMORE'S X-RAY LASER CONFIGURATION
Illustrated here schematically is the setup of the Livermore X-ray laser experiment and the placement of the most important diagnostics. The selenium foil is held in a metal block behind the alignment mirror. The two cones incident upon the metal block represent the two beams of the Novette laser. The selenium plasma lased along the axis between the transmission grating spectrograph and the grazing incidence spectrograph at the upper left. The other grazing incidence spectrograph is making measurements off axis.

It is clear on this basis that propagation through a substantial portion of the Earth's atmosphere should also be possible.

Defensive Weapons Implications

It is well known that a "diffraction-limited" .0001 micron X-ray laser has the ultimate potential of achieving a power brightness 1,000 trillion times that of the Sun—in the range of 10^{40} watts per steradian. (In comparison, nuclear weapons primarily generate X-rays at a power of about 10^{20} watts per steradian.) This means that anything within the cone defined by the laser beam will be hit by a beam that is a trillion times brighter than the H-bomb and more than a million times brighter than the Sun. An X-ray laser beam of this brightness could destroy a missile booster from as far away as the Moon, and much harder targets, such as warheads within reentry vehicles, could be destroyed within a range of 10,000 miles.

In fact, it is well known in directed-energy theory that the number of targets a laser weapon can kill increases as the inverse square of the ratio of different ranges. For example, if one X-ray laser module could kill a booster from a 100,000-mile range, theoretically it could destroy 10,000 boosters within a range of 1,000 miles. And as was demonstrated in the case of mobile cannons with grapeshot against infantry two centuries ago, targeting problems rapidly disappear in the face of such gigantic firepower potentials.

In any case, the full-scale targeting and pointing system can be deployed and tested over the coming year or so without the need of any simultaneous test of the X-ray laser itself. Already deployed space-based communication lasers of low power would provide an adequate substitute.

The Laboratory X-ray Laser Advances

The laboratory advances of the X-ray laser have been just as spectacular as the defense experiments. Last fall, fusion scientists from Lawrence Livermore National Laboratory in California and Princeton Plasma Physics Laboratory in New Jersey announced that they had demonstrated for the first time the physical conditions needed to construct X-ray lasers in the laboratory. The Livermore achievement represents not only a fivefold increase in the electromagnetic frequency that lasers can reach, but also a potential impact many orders of magnitude greater in terms of its application to science and industry.

Although laboratory X-ray lasers will attain microscopic outputs compared to the H-bomb powered one, the same qualities of coherent X-ray radiation that make the X-ray weapon so effective, will make the laboratory X-ray laser possibly the most powerful tool for science and technology yet realized by man. Today living processes on a microscopic scale are opaque to human observation. Similarly, the atom itself is opaque; atomic processes must be inferred from observations of the effects of atomic transformations on other materials. X-ray laser microholography, for example, will make it possible for the first time to see the dynamics of living processes on an atomic scale—spatially and temporally.

In the Livermore advances announced last fall, scientists made the first unambiguous measurement of amplified spontaneous emission of X-rays obtained in a scientific laboratory. The configuration utilized consisted of irradiating a thin, metal foil with a concentrated beam of ultraviolet laser light (Figure 1). The ultraviolet laser pulse transformed the thin foil into an expanding plasma. Collisions between free plasma electrons and ions produced inner orbital excited states. When the expanding plasma—and this was the trick—reached a specified density and temperature, which determine the ion-electron plasma collision rate, X-ray lasing was generated.

One of the major experimental difficulties was that this density-temperature condition had to be generated uniformly throughout a lengthwise region of the expanding foil plasma and maintained over a sufficient period of time to permit the emergence of the amplified stimulated emission X-ray laser beam.

This lasing was achieved with foils made from two elements, selenium and yttrium. Selenium lasing was observed at two wavelengths, 0.02063 micron and 0.02096 micron; while for yttrium, the lasing was observed at 0.01549 and 0.01571 micron. Generally, the foils were 1.1 centimeters in length. The total output of an X-ray laser—and therefore the ability to measure lasing even on a microscopic scale—is determined by its length. The 1-centimeter length appears to be the minimum that can be used. This is an important consideration, because the size of the ultraviolet laser pulse required for setting up the plasma is determined by the size of the X-ray lasing foil that must be transformed into a plasma.

The strategy Livermore employed was to vary the selenium foil thickness from 0.0750 to 0.3 micron and to vary the ultraviolet laser input from intensities of 12-trillion to 250-trillion watts per square centimeter in pulse lengths of 120 to 750 picoseconds. The foil is created by depositing selenium vapor on one side of a Formvar plastic substrate 1.5 microns thick.

In the course of some 100 target shots, it was found that the optimum for X-ray amplification was the 0.0750-micron thickness irradiated with 50-trillion watts per square centimeter for double-sided irradiation, and 100 trillion watts per square centimeter for single-sided irradiation, both with a pulse length of 450 picoseconds. The experimental results are shown in Figure 2.

Some Initial Problems

The expanding foil plasma has a wide variation in plasma density across its width, called a *gradient*. Previous Livermore studies had shown that the gradient should be flat as possible at the time that the region producing the X-ray lasing reaches its optimal conditions. The reason is that changes in plasma density strongly refract the X-ray lasing beam. The "steep" density profile across the width of the expanding plasma in effect looks like a hill down which the X-ray beam will fall. This X-ray beam diffraction disperses the plasma, taking it out of the region where the beam can extract more X-ray lasing energy.

However, producing flat density profiles in rapidly expanding plasmas generated by optical laser light is extremely difficult. Doing it uniformly in a particular region, and at a particular time, is even more difficult. As the Livermore scientists note, "Admittedly, because of the limited range of parameter space studied, we have by no means achieved the ultimate performance of these amplifiers."

In fact, only a small portion of the incident ultraviolet laser light from the two-beam Novette laser was utilized effectively to produce X-ray lasing. Most of the Novette beam passed through the expanding foil plasma, once the plasma had been established by the initial part of the beam. Also, the lasing conditions were not generated at the point of maximum plasma density—the point that contains most

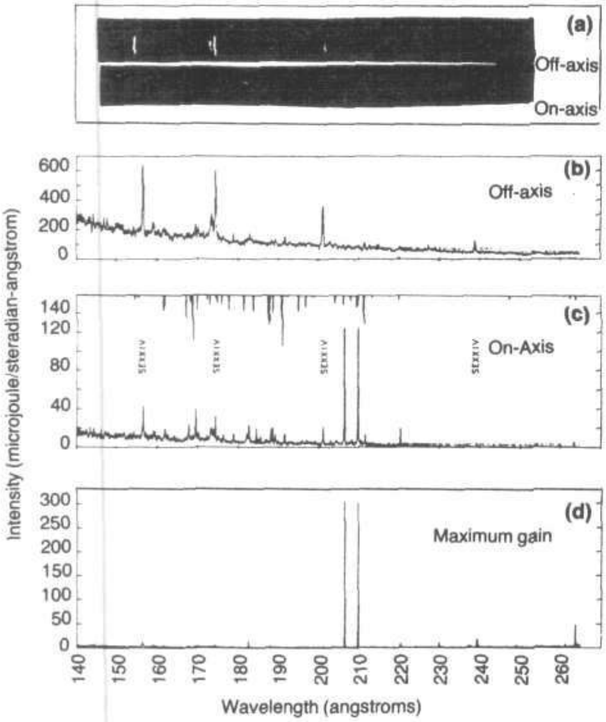


Figure 2
EXPERIMENTAL RESULTS FROM THE LIVERMORE X-RAY LASER

These experimental results from the Lawrence Livermore X-ray laser work were presented at the fall 1984 meeting in Boston of the Plasma Physics Division of the American Physical Society in a paper, "Demonstration of a Soft X-ray Amplifier," by D.L. Matthews et al. The data show that 206.3 and 209.6 angstrom wavelength X-rays were substantially generated only along the axis of the selenium plasma column. They also show that these wavelengths were amplified, "maximum gain," along this axis.

Shown in (a) is a film recording the X-ray output, according to wavelength in angstroms, from the selenium plasma. The film gives the X-ray output taken both from a direction off the axis of the laser beam and along the axis of laser beam. The same data are shown in (b) represented in more detail spectrally for the off-axis case. Note that the two lasing lines, at 206.3 and 209.6 angstroms, are not seen off-axis. The X-ray output along the axis of the selenium plasma column is given in (c). Note that the two lasing lines, 206.3 and 209.6 angstroms, are quite prominent, which demonstrates that the plasma was generating X-ray lasing. The upper part of (c) shows, upside down, the calculated spectrum of neon-like selenium undergoing spontaneous emission—that is, not lasing. The on-axis output with a maximum gain 2.2 cm long selenium plasma is shown in (d).

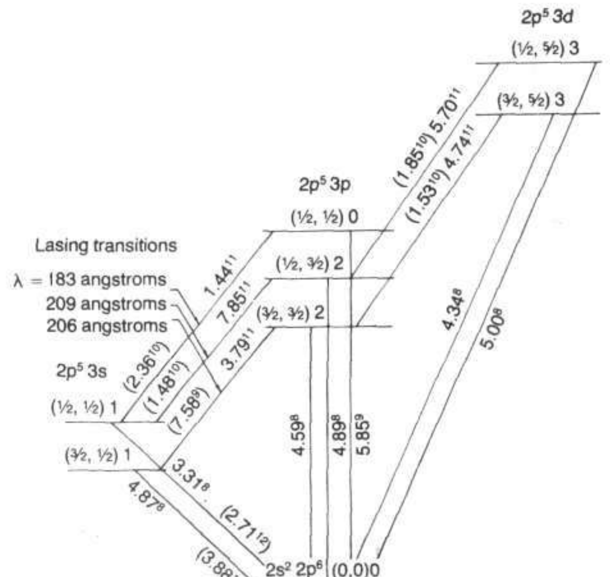


Figure 3
SIMPLIFIED ENERGY DIAGRAM OF SELENIUM IN X-RAY LASING

In this diagram, selenium has been stripped of outer electrons so that its remaining outer electrons have the same configuration as neon. Shown (horizontal lines) are only eight of the hundreds of levels that are included in the theoretical calculations by Lawrence Livermore. Collisional excitation rates and radiative decay rates (in parentheses) are given for plasma electron densities of 5×10^{20} per cubic centimeter and plasma electron temperatures of 1 keV. The other numbers refer to spin, orbit, and shell levels.

Three potential lasing lines are shown (183, 209, and 206 angstroms), but in the experiments, only lines 209 and 206 were seen.

of the absorbed Novette laser light.

One as yet unexplained result was that the particular wavelength predicted to have the greatest potential for X-ray lasing with selenium generated no measurable output. Numerous recalculations of the atomic physics involved have provided no significant reason for this. A simplified energy diagram for the inner-shell electron energy levels of ionized selenium is shown in Figure 3. The 0.0183-micron line, measured in angstroms in the figure (1/10,000th of a micron equals an angstrom) is shown as having the greatest potential for lasing. Because of the unexplained failure for this particular wavelength, X-ray mirrors that had been designed for the 0.0183 micron wavelength and placed on either side of the foil did not function.

Finally, the overall energy efficiency of this initial X-ray laser was 10^{-12}. That is, only one trillionth of the energy put into the Novette ended up as X-ray laser output.

The Princeton X-Ray Laser

X-ray laser experiments are being carried out at the Princeton Plasma Physics Laboratory with lasing based on plasma recombination pumping, instead of the plasma electron pumping method used at Livermore. In the Princeton experiments, a thin rod of carbon is irradiated by a powerful pulse from a 10-micron-wavelength carbon dioxide laser. The resulting plasma is confined by a powerful magnetic field (on the order of 100,000 gauss), which at first consists of completely stripped carbon ions and free plasma electrons. The incident laser light is sufficiently powerful to remove all 12 of the carbon atom's electrons. But on a very short time scale, many of the free electrons will recombine with the completely stripped carbon ions to form lower-charged ions. These *recombination ions*, when formed, constitute excited-state ions capable of X-ray lasing (Figure 4).

Princeton scientists have produced carbon plasma columns 2 to 5 centimeters in length that are held to a 1- to 2-millimeter diameter by the 100,000-gauss magnetic field. A 100-fold increase in the 0.0182 micron X-ray wavelength is observed.

The X-ray laser work at Princeton is headed by Dr. Szymon Suckewer, who emigrated from Poland in 1975. Suckewer's research has now attracted considerable attention from the national weapons Labs and he is preparing to put X-ray mirrors designed by scientists at the University of California at Berkeley on his future experiments.

Also, it has recently been reported that experiments at the Rochester University Laboratory for Laser Energetics, designed along the same lines as those of Livermore with expanding plasma foils, may have inadvertently generated a recombination X-ray laser. It appears that stimulated emission may be coming from the material contained in the plastic substrate upon which the foil is mounted.

Laboratory Feasibility Now Documented

Contrary to those who doubted the 1981 reports of Livermore's bomb-pumped X-ray laser, laboratory experiments have now demonstrated that X-ray lasers are not only feasible but will be made fully operational for laboratory experiments and applications within the coming year. This schedule is underlined by the X-ray laser applications workshop held by Lawrence Livermore in February, to which the world's leading experts in appropriate scientific fields were invited. The remaining question is to what extent and at what rate can X-ray laser capabilities be proliferated throughout industry and academia. An important determinate of this is how quickly X-ray lasers can achieve higher outputs and shorter wavelengths.

Ironically, in terms of pioneering concepts in the field, the Soviet Union has been the world's leader in X-ray laser as well as in gamma ray laser research. Even since the initiation of President Reagan's Strategic Defense Initiative, the Soviet Union still maintains a wide lead in the number, quality, and total material resources devoted to X-ray and gamma ray laser R&D. In particular, the Soviets have emphasized extending the atomic and nuclear physics base needed for developing these systems.

Although the issues involved are complex, the path to further development of X-ray lasers, pumped by electron collision and by recombination, is fairly clear. And other concepts such as photoexcitation may provide the means

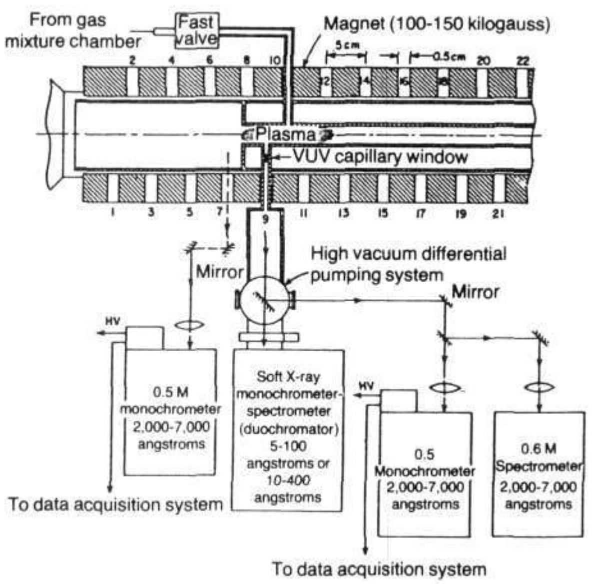


Figure 4

PRINCETON'S SOFT X-RAY LASER EXPERIMENT

The placement of various experimental diagnostics on the carbon X-ray laser at the Princeton Plasma Physics Laboratory. The laser consists of the ionized carbon (plasma), which is trapped by the large magnetic field (100 to 150 kilogauss).

to proceed to higher outputs, greater efficiencies, and shorter wavelengths.

Nonlinear Pumping: The Rhodes Experiments

A totally new possibility involving nonlinear pumping processes is being explored by Dr. Charles Rhodes of the University of Illinois at Chicago to produce efficient X-ray lasers. Rhodes has attained inner shell excitations in atoms and molecules in a manner that seems to contradict all existing theoretical models of the atom and quantum physics. According to Dr. James Ionson of the Strategic Defense Initiative Office Division of Innovative Science and Technology, the Rhodes nonlinear pumping method could be demonstrated before the end of 1985.

Rhodes's experimental success opens up new vistas for X-ray lasers, but at the same time underscores the present dearth of knowledge on how these processes actually work. Normally, efficient pumping of the high energy level inner atomic electrons needed for X-ray lasing is limited to energy inputs that are qualitatively comparable to the output. Utilizing longer wavelength inputs, such as radiation at wavelengths longer than that of X-rays, leads to a large wastage. This is because the outer electron energy levels interact most strongly with the longer wavelengths and emit radiation in the longer wavelengths that escapes the lasing medium. That is, only a small portion, if any, of the input will end up pumping the required inner electron orbitals. One way around this is to ionize the atoms so that only the inner electrons remain. This, however, involves a lot of energy and makes X-ray lasing quite inefficient.

In a number of simple experiments, Rhodes showed that contrary to accepted theory, long-wavelength radiation could efficiently pump inner electron levels. Recent developments in producing high-power, extremely short pulses of extreme ultraviolet laser light (0.193-micron), provided the key technology for Rhodes's experiments. Once these experiments established the new phenomenon at this particular wavelength, it could then be shown that similar processes were occurring at longer, 1.06- and 0.53-micron wavelengths.

Rhodes irradiated various gases with 5-picosecond, 3-billion-watt pulses of 0.193-micron argon-fluoride laser light. The pulses were focused to intensities of 1,000 trillion to *100,000 trillion watts per square centimeter in* the experimental volume of the gas. Stimulated emission from the irradiated gas at wavelengths shorter than 0.193 micron was measured. More than 1 percent of the input energy was measured in each of the stimulated emission wavelengths. This means that this pumping method could be *100 million times* more efficient than the Livermore collisional pumping method, where less than 10^{-11} of the input optical light ended up as X-ray laser output.

A wide range of elements were irradiated, demonstrating that the absorption-emission was highly dependent on the atomic shell structure.

The Failure of Existing Theory

According to Rhodes, the data show that the outer atomic shells are absorbing many photons and conveying this input to inner shells in a manner apparently in contradiction to present theoretical models. Rhodes noted that:

> The data strongly indicate that an organized motion of an entire shell, or a major fraction thereof, is directly involved in the nonlinear coupling. With this picture, the outer atomic subshells are envisaged as being driven in *coherent* oscillation by the intense ultraviolet wave. An immediate consequence of this motion is an increase in multiphoton coupling resulting directly from the larger magnitude of the effective charge involved in the interaction. In this way, a multielectron atom undergoing a nonlinear interaction responds in a *fundamentally different fashion* from that of a single electron counterpart. The strong highly nonlinear coupling which develops between the radiation field and the atom can result in the transfer of energy by a direct *intra-atomic* process to inner-shell excitations. . . . Although all standard theoretical approaches fail to provide a description of the observed phenomena, a relatively simple model, valid at sufficiently high intensity, can be contemplated.

How is the phenomenon explained? First, the time scale of the interaction is such that interatomic processes like collisions must be excluded. Next, it appears that the interaction between the outer shell electrons and the ultraviolet laser light is like that found in plasmas, where the electrons are not bound to atomic shells but are free electrons, with the stipulation that the electrons are forced to follow a restricted path defined by the shell's orbit! The result, according to Rhodes's "simple model," is that the motions of the outer electrons produce giant current densities in the range of 100 to 1,000 trillion amps per square centimeter. These nonquantum outer-shell electron currents apparently produce the efficient excitation of the inner electron orbitals.

Higher Levels of Interaction

Another possibility is that the Rhodes experiments are also revealing a new level of energy transfer on an atomic scale. Specifically, spectroscopic analysis of his findings shows that three excited levels of xenon gas coalesce to form another level that has a different spectroscopic line. This violates the Pauli exclusion principle, which holds that three electrons cannot have the same orbit. Apparently, however, three levels of xenon at outer orbits form a new orbit together at a higher energy level. With the increase in energy, this new, unstable orbit gets closer to the nucleus.

In particular, the high current, plasma-pinch-like atomic processes that Rhodes has derived from his experimental results may be taking place in all lasers, but the time scale for this process may have been too short to readily detect it.

One explanation, suggested at a recent Fusion Energy Foundation seminar on astrophysics by Lyndon H. LaRouche, Jr., was that this higher level of electromagnetic interaction could be responsible for all lasing, and that the quantum processes, previously thought to be determinate, may be only acting as a medium to retard the evolution of this higher level of electrodynamic action.

Rhodes points out that when intensity levels of 10^{19}-10^{20} watts per square centimeter become available in the near future with the development of femtosecond rare gas halogen lasers, the irradiated electrons would act as completely free particles accelerated in the intense electric field of the incident laser beam. This could make possible the efficient pumping of a range of X-ray laser wavelength inner energy levels. Furthermore, Rhodes notes, this new process could be very important in providing a picture of how rotating neutron stars accelerate cosmic rays.

The Classification Barrier

The X-ray laser will provide an entirely new context for unraveling the mysteries of atomic structure and electrodynamic interaction on the microscopic scale. Now that operational X-ray lasers are within sight, along with the possibility of producing even shorter-wavelength gamma ray lasers in the laboratory, this work must be accelerated as rapidly as possible. One barrier is that of top secret classification in the area of X-ray generation and interaction with matter. This is ostensibly because X-ray blackbody and line radiation generation are key to the creation of efficient thermonuclear explosives—especially in terms of related hydrodynamics questions. However, these same areas are crucial to the successful development of X-ray lasers.

There is no real basis for security classification of this material. It was amply demonstrated in 1976, in the course of the so-called Rudakov case, that the Soviet Union is quite familiar with this material, and that the classification impeded the progress not of Soviet research, but of U.S. research. L.I. Rudakov, an electron-beam specialist from Moscow, while touring the U.S. fusion labs had presented to American scientists the details of how X-ray blackbody radiation can be generated and utilized to achieve inertial confinement fusion. His open presentation was then classified top secret—to be kept from American scientists!

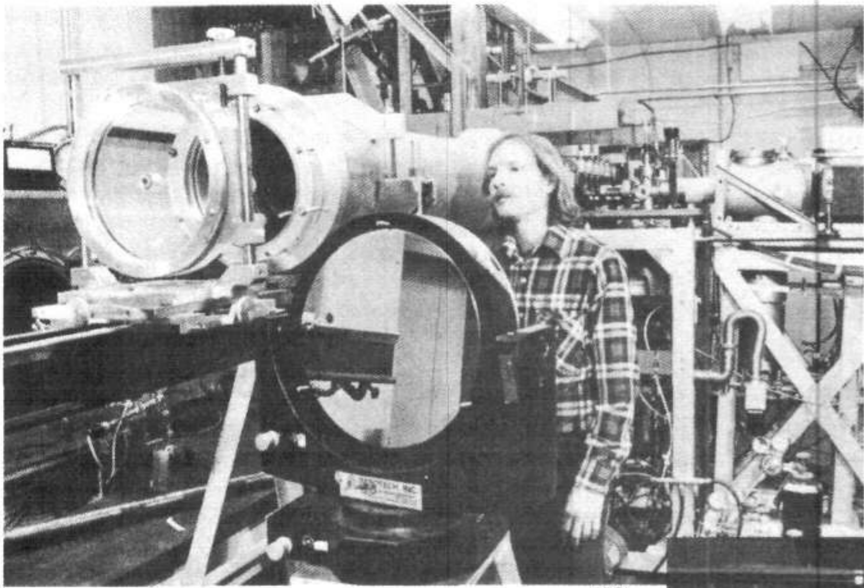
The result of such classification—as has been pointed out by prominent scientists like Dr. Edward Teller—simply squelches the kind of scientific discussion and thinking that will produce new advances and applications that can raise the overall scientific level of society. But this, of course, was part of the aim of such classification policies, which were intensified under the antiscience administration of President Jimmy Carter and Energy Secretary James Schlesinger.

X-Rays and Their Interaction With Matter

It is ironic that many of today's classified concepts pertaining to both the beam defense X-ray laser and the laboratory X-ray laser are available in the 19th-century works of Bernhard Riemann. For example, Riemann in his 1859 paper, "On the Propagation of Plane Air Waves of Finite Amplitude," presented for the first time the idea that shock waves are the best means of isentropically compressing matter to super densities; in other words, shock waves are the primary means of reaching the highest material energy flux densities, such as those used to produce net-energy-producing thermonuclear fusion reactions. In terms of attaining the highest *energy flux densities*, however, radiation provides the best means.

Therefore, the key to attaining isentropic shock compression of matter is primarily that of coupling intense radiation to matter. Apparently, any wavelength of radiation can be focused to any desired energy flux density, but that which couples most efficiently to matter is limited to soft X-rays. The reason for this is that soft X-rays represent the wavelength most closely matched to that of the energy of ionization of atoms—1 to 100 electron volts. This means that soft X-rays will be most efficiently absorbed by atoms. And since pressure is roughly a measure of energy contained within a volume, soft X-ray absorption will lead to the greatest applied pressures, and thus compressions, of matter.

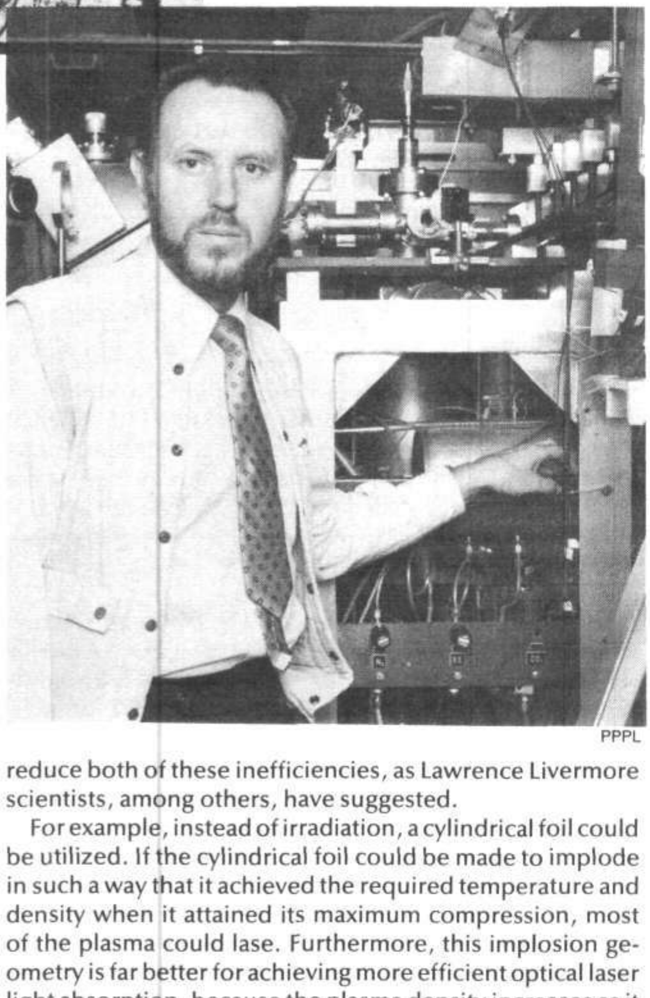
Also, given intense absorption rates, the process of coupling radiation must involve transiting low-density plasmas to arrive at the region of highest density. The idea is to avoid absorption before the solid-density plasma material surface is reached. In general, plasmas interact with radiation according to whether their corresponding frequencies are matched. A higher-frequency electromagnetic wave will penetrate a plasma that has a lower frequency. The plasma frequency is proportional to the square root of the plasma electron-density. Ordinary solid-density plasmas have frequencies that correspond to the soft-ray spectrum. Therefore, soft X-rays are best for both transiting low-density plasmas and being absorbed within the smallest volume in



PPPL

Princeton's X-ray laser is based on plasma recombination pumping, where a thin rod of carbon is irradiated by a carbon dioxide laser and the resulting plasma is confined by a magnetic field. The recombination ions formed in the process are capable of X-ray lasing. Below, Dr. Szymon Suckewer with the X-ray laser system he developed.

Left: an engineer checks the alignment of the carbon-dioxide laser mirror used in the X-ray laser experiments at the Princeton Plasma Physics Laboratory.



PPPL

solid-density plasmas.

In addition, radiation interacting with matter does not simply cascade away to shorter and shorter wavelengths. Instead, it arrives at metastable configurations that are denoted by a high degree of symmetry. In other words, a particular spectrum of radiation can be maintained in an evenly dispersed (isotropic) state. The point is, that while all sources of electromagnetic radiation have a specific directionality embedded in the process of their generation, this is removed in the process of interaction and transformation to the blackbody configuration. This means that blackbody radiation can provide an extremely symmetric means of irradiating a material target. And symmetric irradiation leads to symmetric compression of matter, which is essential for attaining high energy densities.

Actually, this is just a first approximation to the problem. For example, if shock compression is producing densities greater than solid, then shorter-wavelength, harder X-rays could be used to penetrate this shock front and further drive the implosion. A range of specific-wavelength, incoherent X-rays, called line radiation, can be readily generated simply by irradiating foils made from specific elements either with optical laser light or a broad spectrum of soft X-rays. With X-ray lasers, this ability to penetrate with hard line radiation becomes even more significant, because it is important to "tune" the temperature, as is done, for example, with collisional pumping to achieve X-ray lasing. With more advanced X-ray laser pumping schemes, "tuning" X-rays to directly excite specific atomic energy levels is also crucial.

Advanced Collisional Pumping Designs

As discussed above, there are a number of readily correctable features of the expanding plasma foil, collisionally pumped X-ray laser that make it quite inefficient. First, only a small portion of the produced plasma lases. Second, most of the incident laser light simply passes through the expanding plasma. Reversing the plasma motion from an outward expansion to an inward implosion could substantially reduce both of these inefficiencies, as Lawrence Livermore scientists, among others, have suggested.

For example, instead of irradiation, a cylindrical foil could be utilized. If the cylindrical foil could be made to implode in such a way that it achieved the required temperature and density when it attained its maximum compression, most of the plasma could lase. Furthermore, this implosion geometry is far better for achieving more efficient optical laser light absorption, because the plasma density increases as it is imploded.

Another improvement would consist of utilizing a combination of incoherent soft X-rays and hard line radiation. In this case, the X-ray laser foil would be surrounded by a number of other foils. These outer foils would absorb the incident optical laser light and generate various spectra of X-rays—a sort of X-ray flash lamp. They can also act as filters to screen out undesired wavelengths and provide a means for pulse-shaping the input to the inner foil.

Although this general configuration has application to various X-ray laser pumping methods, its potential can readily be seen for the Livermore collisional X-ray laser. As demonstrated by the Japanese cannonball laser fusion hohlraum target, designed at the Institute for Laser Engineering at Osaka University, configurations already exist for both effectively trapping and converting optical laser light into X-rays.

Also, the steep density gradients produced by efficient soft X-ray implosion could provide the most efficient assembly of the desired X-ray laser plasma. In this case, the plasma implosion would be designed to create a sort of square wave density profile—steep on the edges and flat across the plasma width. As a result, most of the plasma would X-ray lase. Concomitantly, most of the energy absorbed by this plasma would generate X-ray lasing. Most significant, it would appear that soft X-rays are the best means of producing this most desirable plasma density configuration.

In addition, a variety of specific hard X-ray line radiations could be generated simultaneous to that of the soft X-ray spectrum. Foil layers acting as filters could further limit and thereby tune the actual hard lines that irradiate the X-ray laser foil. These hard lines would provide the means of penetrating and heating the interior of the dense, imploded plasma. As a result, the ability to "tune" the plasma temperature within a specific density configuration would be greatly improved.

The great symmetry of blackbody X-rays provides the means of producing great uniformity throughout the full dimensions of the imploded plasma column. Along these lines, the X-ray flashlamp provides a ready means of temporally and spatially shaping the energy flux incident upon the imploding X-ray laser foil. This last capability will become increasingly important as the lengths—and consequently the gains and total outputs—of X-ray lasers are increased.

It must be remembered that the X-ray laser plasma must maintain its uniformity in density and temperature within very tight tolerances while the growing X-ray laser pulse transits its length. One means of achieving this is to arrange for the required plasma conditions not to be attained simultaneously along the length of the X-ray lasing region, but rather for them to evolve along the length over time. More specifically these required conditions should evolve at the speed of light—the velocity of the X-ray laser pulse—along the length of the plasma column. X-ray flashlamps could provide a practical means to do this.

It can be seen from the above descriptions that the achievement of plasma conditions required for collisionally pumped X-ray lasers are primarily determined by carefully arranging the hydrodynamic evolution of an imploded plasma. X-ray flashlamps and blackbody radiation are currently the most effective and versatile means of hydrodynamically imploding matter. At the same time, the methods and means of predicting the atomic physics side of X-ray lasing are demonstrably at a very primitive stage of development. Therefore, it is essential that this hydrodynamic capability be most extensively explored in order to provide the experimental base for realizing collisionally pumped X-ray lasers. The classification policy currently prevents this from being done most efficiently.

Resonantly Pumped Photoexcitation Schemes

Another approach to X-ray laser pumping follows from the idea of the X-ray line radiation flashlamp. By producing incoherent lines that are resonant with ion excited states that are candidates for X-ray lasing, pumping could be achieved directly with photons. This more direct method of X-ray laser pumping has both a higher potential efficiency and capability of being scaled to shorter wavelengths. The most advanced designs along these lines have been developed by a team headed by Dr. Peter L. Hagelstein of Lawrence Livermore.

Here, the line flashlamp constitutes the top and bottom of a rectangular box. The X-ray laser medium consists of gas that is passed through the interior of the box. Optical laser beams irradiate the top and bottom flashlamps. Line radiation is generated and irradiates the gas in the box. Because these lines are resonant with the desired excitation levels of the gas, efficient X-ray laser pumping is attained.

Initial experiments along this line failed to produce the desired results, but it appears that this was because of mechanical flaws in the gas target design. Further experiments are planned on the new Livermore Nova laser system, which has just come on line.

Future Prospects

If the classification barrier is torn down, a wide range of existing facilities will produce operational laboratory X-ray lasers over the coming year: Lawrence Livermore National Lab's Nova Laser, Japan's Gekko XII laser at Osaka University, and the University of Rochester's Omega laser. Once mastered, the capability could be rapidly expanded to scores of other existing high-power laser facilities throughout the world, that operate at about one tenth the power level of the mainline systems.

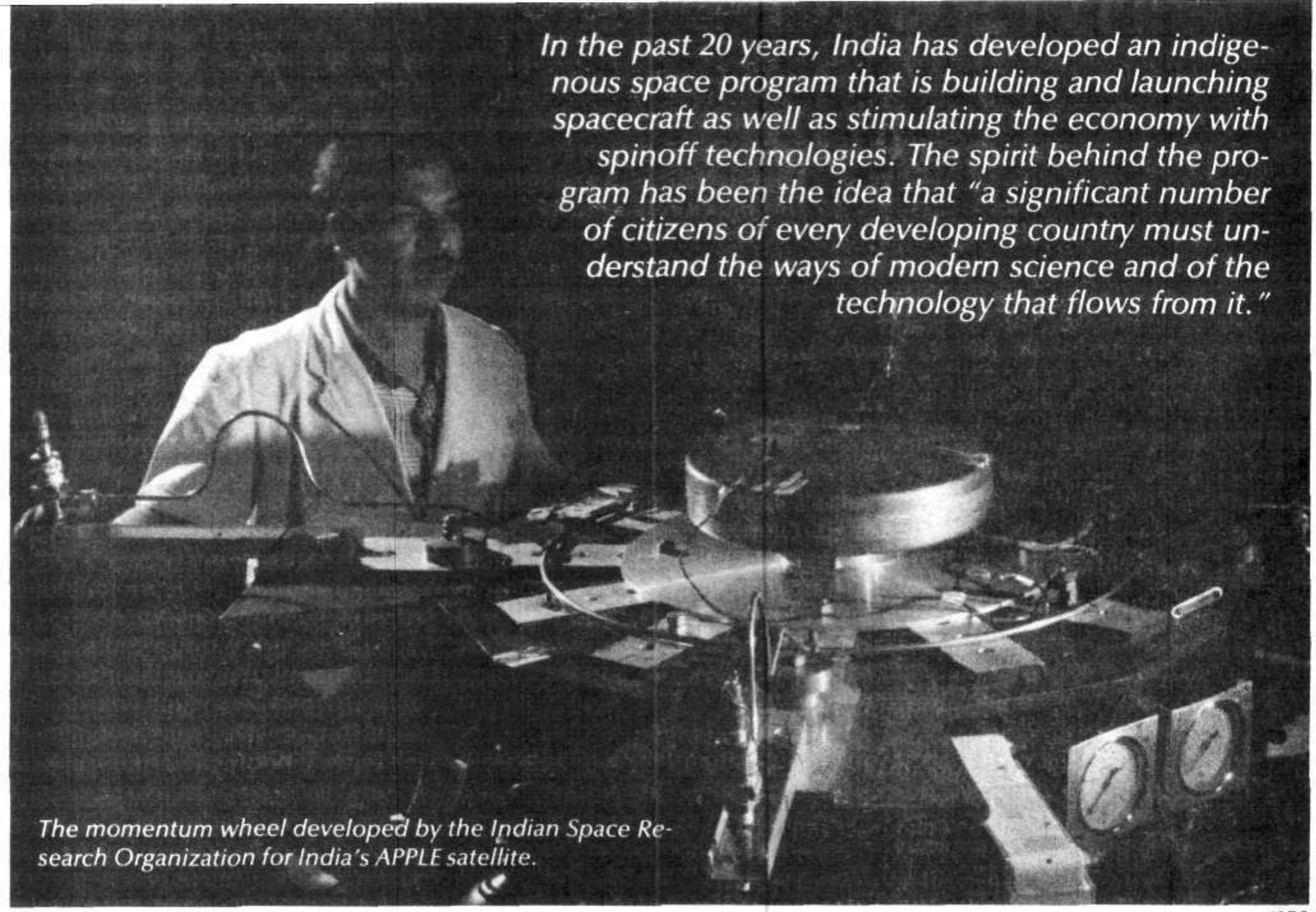
Another possibility is to use pulsed-power devices, like those used for electron and light ion beam generation. These machines can be readily reconfigured to implode cylindrical foils. Successful X-ray laser demonstration on these types of machines could increase the proliferation of research by orders of magnitude, because hundreds of them already exist. Even more exciting, success with the more revolutionary Rhodes pumping approach could make X-ray lasers available to every university and research facility in the country.

Charles B. Stevens is director of fusion engineering for the Fusion Energy Foundation.

Notes

1. A review of the Los Alamos and other refutations of the anti-beam-weapon arguments appears in "Beam Defense Works! A Point-by-Point Refutation of the SDI Critics" by Paul Gallagher in *Fusion*, Nov.-Dec. 1984, p. 19.
2. For example, see the FEF-authored book, *Beam Defense: An Alternative to Nuclear Destruction*, published by Aero Publishers (Fallbrook, Calif.) in 1983; and *The Physical Principles of Thermonuclear Explosive Devices*, by Friedwardt Winterberg, published by the FEF in 1981.

In the past 20 years, India has developed an indigenous space program that is building and launching spacecraft as well as stimulating the economy with spinoff technologies. The spirit behind the program has been the idea that "a significant number of citizens of every developing country must understand the ways of modern science and of the technology that flows from it."



The momentum wheel developed by the Indian Space Research Organization for India's APPLE satellite.

ISRO

India's Space Program —Boosting Industry

by Ramtanu Maitra

As early as 1968, the architect of the Indian space program, Dr. Vikram Sarabhai, predicted the great industrial benefit that space technology would bring India. In a speech dedicating the Equatorial Rocket Launching Station at Thumba, Sarabhai described how a satellite communications system would involve only one-third the capital cost of conventional communications systems and allow India to "leap-frog" into a position of dealing on equal terms with more developed countries. In addition, he discussed the broad economic spinoffs that would accompany the investment in space:

> I might illustrate this from the experience which we are gaining in the development of rockets. This requires new disciplines and an understanding of materials and methods; of close tolerances and testing under extremes; the development of guidance and control and the use of advanced information techniques. Indeed, I often feel that the discipline and the culture of the new world which emerges through the pursuit of activities of this type are among the most important from the standpoint of a developing nation.

Nearly 20 years later, Indian industry has begun to reap the benefits of such spinoffs in significant quantities. The Indian Space Research Organization, ISRO, has transferred a variety of technologies to Indian industry—more than 67 processes and products have been licensed to 33 different industries so far. This includes know-how in chemicals, polymers, special materials, instruments, telecommunications and TV equipment, electronic subsystems, electro-optic hardware, computer software, and special purpose machines. In addition, nearly 30 new items are in the pipeline for imminent transfer to industry.

Moreover, in the past two or three years, the program's direct demands on industry have led to the establishment of two chemical plants as well as new divisions within private and public sector industrial corporations devoted exclusively to supplying the space program. An estimated 50 to 60 industries are involved across the nation.

PIB India

Political and scientific leadership combined to make India's space program a success. Prime Minister Indira Gandhi championed the space effort, ensuring it the necessary support during the critical 1970s period when the program came on line. Left: Dr. Vikram Sarabhai (right), architect and first head of the space program, with Prime Minister Gandhi in 1968 at the Thumba Equatorial Launching Station. Below: Dr. Satish Dhawan (left), who just retired as head of the program, and Dr. U.R. Rao, present chairman of ISRO.

PIB India

Starting with a modest annual budget of $20 million in 1962, India's space program has jumped to what will be $300 million annually under the Seventh Plan, beginning in 1986. Although not large in absolute terms in an annual plan budget that totals $60 billion, this 15-fold jump in the space budget's dollar value gives a kind of baseline definition of the growing impact the program has had on the country's economy. It is expected that nearly half of this will go directly to the Indian engineering industry for supply of goods and services.

Actually, the impact is geometrical. Not only are ISRO's direct requirements providing an increasingly direct spur to industry, but the program's applications in comunications and remote sensing are coming to fruition in telecommunications, education, agriculture, meteorology, and resource identification—and this translates into an explosion of demand for user systems and technologies.

Fundamental Impact

In all countries, advanced technology and especially space technology have acted as a growth catalyst to existing industries, creating new industrial potential by generating new technologies. The organization and implementation of the European space program during the last two decades, led by France and West Germany, has resulted in a remarkable strengthening of the industrial base and the ability to compete in international markets. Studies have shown that for every dollar invested in space technology, the industries there have already reaped nearly fourfold benefit. Similarly, U.S. studies show that every dollar in NASA's Apollo program returned $14 to the economy.

A direct comparison between the American, European, or even Soviet program and the Indian program is not possible. But it is perhaps not an overstatement to say that ISRO's impact on the Indian economy may be even more profound. In the United States, Europe, and the Soviet Union, a sophisticated technological and industrial base had already been built up by the postwar period as a result of defense programs; the space program built upon this base, giving it a new dimension. In contrast, the Indian space program was launched in conditions of an extremely weak economic infrastructure. The sophisticated industrial base was not there to be augmented and shaped; it had to be built from scratch.

From the outset, the Indian program's basic principle was "self-reliance." Not in the sense of re-creating the wheel, ISRO scientists explain, but in the sense that India must master indigenously all the essential technologies involved in being in space. Like the decision to invest in space in the first place, the considerations were eminently practical. Sarabhai, who with Dr. Homi Bhabha was the space program's "moving spirit," was the most articulate exponent of this approach. Sarabhai wrote in 1966:

> Clearly the development of a nation is intimately linked with the understanding and application of science and technology by its people. It has sometimes been argued that the application of technology itself can contribute to growth. This is certainly true as an abstract proposition, but fails in practice. Witness the state of development and social structure of countries of the Middle East where for decades resources of oil have been exploited with the most sophisticated technology. History has demonstrated that the real social and economic fruits of technology go to those who apply them through understanding. Therefore a significant number of citizens of every developing country must understand the ways of modern science and of the technology that flows from it.

A Three-Phase Process

India's space planners started to work on all four of the basic fronts at once—applications, satellites, launch vehicles, and mission support—to simultaneously build up an all-round capability. It was a carefully orchestrated process projected over three decades.

The first 10 years, during the 1960s, were a learning process. The space effort emerged out of the Department of Atomic Energy's Indian National Committee for Space Research, set up by government order in 1962 to advise and help organize the program. Under the leadership of Homi Bhabha, then chairman of the Department of Atomic Energy, and Vikram Sarabhai, the space program was conceptualized and the people and expertise recruited.

By 1963, the Experimental Satellite Communication Earth Station was established at Ahmedabad to develop ground support and applications know-how. The Thumba Equatorial Rocket Launching Station was established at the same time to give impetus to work with sounding rockets. Both projects involved international assistance. Given strict resource constraints it was imperative to take maximum advantage of opportunities for international cooperation at each step, while simultaneously building indigenous capabilities.

As the pace of activities accelerated, the Indian Space Research Organization was set up, and by 1972, the government created an independent Department of Space under a Space Commission to encompass ISRO. During the 1970s, a series of time-bound projects and goals were defined, in what ISRO officials call the "projectization" phase of the space program.

The key was to undertake a series of projects that would give crucial hands-on experience at minimal investment risk. The 1975-1976 Satellite Instructional Television Experiment, using the U.S. geosychronous satellite ATS-6, is a good example of this, as is the 1977-1979 Satellite Telecommunications Experiments Project, which used the Franco-German satellite, Symphonie. The ground systems for these experiments were essential in preparing the way for the Indian National Satellite System, INSAT.

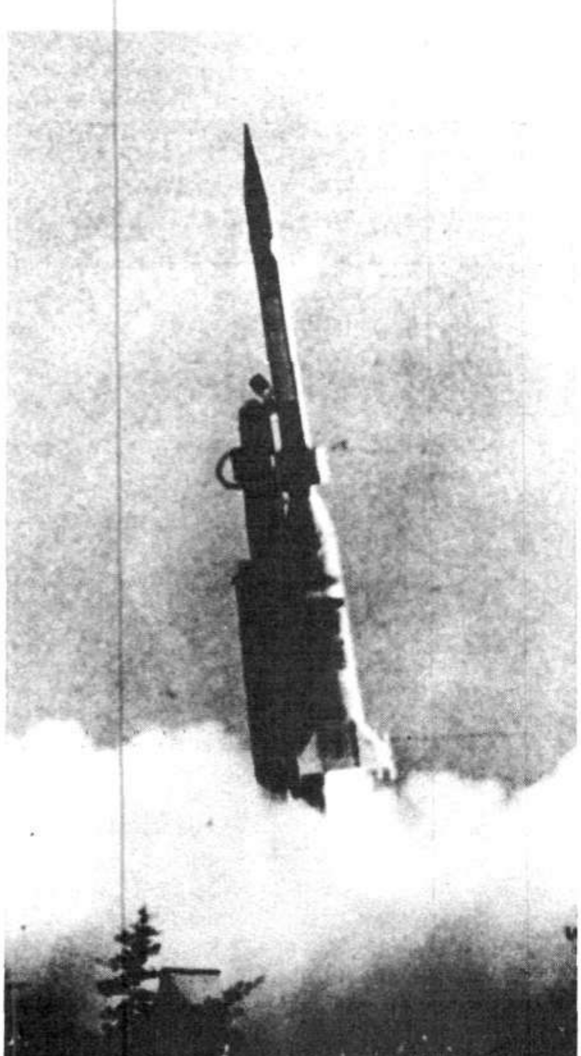
Similar steps were taken in satellite technology, with time-bound plans laid to design, build, and test satellites for scientific experiments, beginning with Aryabhata in 1975. Work on launch vehicle technology also proceeded, beginning at the "test-tube" level in 1962. This area, where the technological complexity of the job is even greater than its high cost, presented the greatest challenge. With worldwide development so closely tied to military applications, the details of the technology are less readily available and one is forced to proceed on one's own from the known basic science of the matter.

It is the project phase of the 1970s that shaped ISRO into a dynamic functioning team, managed by scientists and engineers, with a constant ratio of scientific and technical staff to administrators of more than 2:1. By the end of the decade, ISRO had built up capabilities in the four basic areas mentioned above and had developed a concrete notion of what users want and need.

The 1980s are viewed as the "operationalization" phase. In this decade the national satellite system has become fully operational, and the Indian remote sensing system will be deployed. With indigenous launch capability established in the 1983 success of the SLV-3, three more advanced launch systems are now under development. Their completion,

"Some of the fundamental problems which concern scientists today are not different from those that have excited man's curiosity from earliest times. We would like to understand the creation of the Universe, the solar system, the stars, and the planets, the origin of life itself and the seemingly mysterious influences through which the Sun affects the course of human existence on Earth. Space research is related to all these."

—Dr. Vikram Sarabhai
architect of India's space program



RH-560, part of the Rohini Sounding Rocket program, lifting off from Sriharikota Range.

and the design and indigenous production of more advanced satellites, will place Indian's space program on a completely developed and entirely self-reliant footing by the early 1990s. Appropriately, a full-fledged Ministry of Space has now been established to direct the program.

Maximizing Use of Indian Industry

Until 1978, when the Department of Space decided that all space projects would make maximum use of Indian industry, ISRO did everything "in house." Gradually, capabilities were developed in industry such that an ISRO-made prototype could be reproduced in quantity on order, with its close collaboration. Now, ISRO will increasingly be giving only functional specifications to industry for a component or subsystem, thus involving industry more in the development as well as fabrication of the required items.

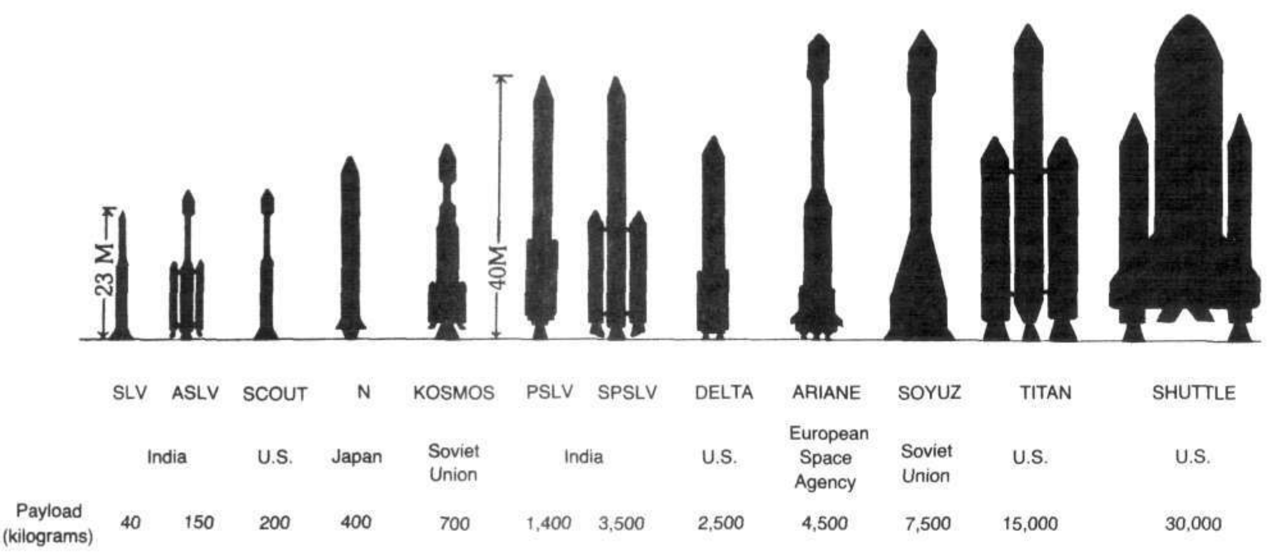
Today, ISRO is involved in direct technology transfers to industry of products and processes developed by ISRO, either on a buy-back basis or for developing spinoffs. They place orders with industry directly, and offer technological consulting services. This program is paying off in the expansion of high-technology production capabilities in a kind of multiplier effect over a wide range of industries. The space program now buys back a large amount of mechanical precision equipment, electronic subsystems, chemicals, and other items that its own scientists had helped industrial houses to develop or improve.

For example, unsymmetrical dimethyl hydrazine, a liquid propellant fuel, is now being produced by Indian Drug Products Ltd. and is also finding applications as an agricultural chemical. Similarly, process know-how for an epoxy-based insulation coating and resin hardener was successfully transferred to United Electricals Ltd. of Quilon, while Bharat Electronics Ltd. has established a separate space electronics division to support ISRO, supplying power supplies, telemetry receivers, helical filters, various antennae types, and more.

Hindustan Aeronautics Ltd. is making 19 special chemicals, adhesives, and sealants, in addition to precision miniature-rate gyroscopes.

The Case of Maraging Steel

ISRO scientists are constantly on the lookout for entrepreneurs who have the capability to produce space-quality technology, with its high level of precision and low tolerance. The case of maraging steel, developed for use in the future launch vehicle motor casing, is an eye opener in terms of mobilizing a nation's industry to solve a problem. Maraging steel, a lightweight steel alloy, is extremely economical for certain requirements, but a difficult alloy to fabricate. India had no experience with this alloy, and had to work out its composition, forging, welding, heat treatment parameters, and the composition of the welding rods. Then a firm had to be found to roll the plates, make the



INDIAN LAUNCH VEHICLES COMPARED WITH WORLD LAUNCH VEHICLES

India's rocketry development started modestly in the 1960s with the development of a variety of sounding rockets for exploration of the upper atmosphere and ionosphere and for astronomy experiments. In 1980, the rocketry program came of age with the successful launch of the Satellite Launch Vehicle-3, SLV-3, which put a 40-kilogram satellite into near-Earth orbit. Once the basic satellite launch vehicle technology was mastered, Indian scientists began to develop a bigger and stronger rocket, the Augmented Satellite Launch Vehicle, ASLV, scheduled for launch later this year.

The next goal of India's rocket research is the Polar Satellite Launch Vehicle, PSLV, which is 44 meters in length and more than 16 times the weight of the previous class of rockets. PSLV is expected to be the "bread and butter" of the space program, giving India a capability to offer commercial launch services to other nations.

rings of 3 to 4 meters diameter, and fabricate the motor casings.

ISRO mobilized its own scientists from the metallurgical and science divisions as well as the Welding Research Institute and Bharat Heavy Electricals Ltd. to get the job done. Now India possesses the manufacturing technology and the fabrication capability for maraging steel, and in the future, it will be used not only for making motor casings for rockets but also in defense and probably in the nuclear industry.

For the most part, ISRO has developed a needed technology when it was not available in the country. One exception, however, is a technology transfer agreement with France to produce transducers. France agreed to give ISRO the technology to manufacture transducers, on condition that the product would be exported to France, which needed them. So for the past 10 years, the Department of Space has supplied the French with transducers. Now, under the terms of the agreement, the technology will be disseminated to industry and India will possess the capability to export transducers to the world market.

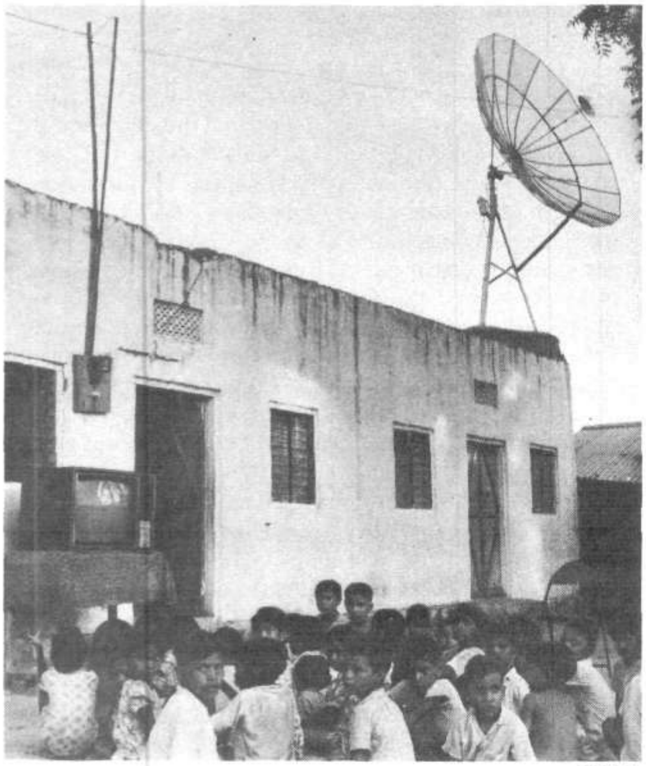
There are many areas where such developments have taken place involving private industry and ISRO scientists. In fact, according to ISRO officials, there has hardly been a single product that has not had a buyer. On the contrary, the difficulty is choosing among the number of applicants for each offering.

Among the ISRO-developed items now in regular production in various industries are pressure and thrust transducers (until now the major bottleneck to the development of a control-technology industry in India); ISRO dry powder, a unique extinguisher effective against both metal and oil fires; a range of different adhesives and sealants that can effectively bond a variety of substrates such as rubber, metal, plastic, cloth, and so on and provide very high structural-peel strength under adverse environmental conditions; a remote multiplexing encoding unit; 13 different TV studio equipment pieces, including digital time base correctors; high power amplifiers; UHF communications equipment; a data collection, storage, and transmission system for satellite meteorological data collection platforms; and satellite radio networking terminals.

Recently, ISRO also transferred its "spacetruder" technology, an automatic "pultrusion" machine to produce fiber-reinforced plastic structural sections of uniform cross section in a continuous manner, to an industrial firm in Hardwar. These fiber-reinforced sections have the advantage of a high strength-to-weight ratio, electrical and thermal insulation, corrosion resistance and energy-storing capability, and they will thus have a wide variety of uses in different sectors of industry.

The space program is also making a significant contribution to the electronics industry. A whole range of precision instruments have come on line, mainly for control devices, and have been improved for use in the space program. Here ISRO does not so much develop new devices; rather, it develops new systems to use the items the industries are developing, and it fosters quality improvement by virtue of the stiff space-quality requirements.

What this has meant for the future was described by Dr.



PIB India

The Satellite Instructional Television Experiment reached 2,400 villages in six states.

PIB India

Work at the Space Research Center at the Thumba Equatorial Rocket Launching Station.

Satish Dhawan in a 1983 speech to industrialists, when he was chairman of the Space Commission:

> Those industries which undertake to work with the space technologies invariably find that the demands of extreme reliability or complex specifications and performance force innovation. For example, in fabrication tasks, extreme tolerances would be required, calling for special tooling and measurement techniques. Similarly, high strength and light weight requirements lead to use of special materials such as special steels, titanium or beryllium, or composites. The processing of such materials requires changes in metal cutting, heat treatment and forging processes, etc. The successful solution of such problems brings into being new industrial technology with wider applicability. In this area we are still in the beginning stages in India, but the process has begun and if industry looks ahead and seizes the opportunity there are many exciting things possible in the coming years.

An idea of this potential can be gleaned from a look at the Indian Remote Sensing program, which will come into its own in the 1980s. A preliminary survey in 1983 showed that the initial requirements for simple optoelectronics ground-truth equipment (like radiometers), and interpretation equipment (like color additive viewers), will amount to as much as $10 million by 1988. Much of this equipment has been indigenously developed by ISRO, and the technology is now being transferred to capable manufacturers. In addition, there will be a market for as many as 100 computer-based interactive systems worth tens of millions of dollars for processing, recording, and disseminating the data from the remote sensing program, as well as a new demand for high quality printing and photographic products for the generation and distribution of data.

These dollar amounts are conservative if one considers the amount of information that will be generated by the remote sensing program on a daily basis. In each pass over India—seven or eight times per day—the Indian Remote Sensing satellite will send down the equivalent of 4,000 volumes of 300 pages each of data, amounting to a library of 10,000 books each day. Within 10 years, with the use of active microwave sensors that can gather data at night as well as during the day and in any weather condition, this information flow will increase by an order of magnitude.

Ramtanu Maitra, a nuclear engineer, is the editor-in-chief of Fusion Asia *magazine. This article is adapted from the cover story of the January 1985 issue of* Fusion Asia.

An Ancient Tradition of Space Science

Indian astronomers' interest in planetary motion and phenomena in the sky was recorded as early as the Vedic days. There are several references in the Rgveda and in the Brhmanas of the Sun's path through the heavens. Rgveda's authors recognized that the Moon, the most conspicuous object in the night sky, has no light of its own. It assumes the brilliancy of the Sun, as they put it, or "is adorned with Surya's [the Sun's] arrowy beams."

The rejection of lunar-centered cosmology and the evidence of polar long-cycle astronomical calendars from this period—which historian Bal Gangadhar Tilak has shown could have been no later than 4500-4000 B.C.—points to a development of science that was unequaled in the much later Mesopotamian and other cultures ordinarily cited as the cradle of civilization. The depth of this heritage is further indicated by the brilliance of later figures about whom more is known. Among them, Aryabhata (b. 476 A.D.), Varahamihira (b. circa 505 A.D.), Bhaskara (b. circa 600 A.D.), and Brahmagupta (b. circa 598 A.D.) excelled in mathematical-astronomical work.

While Europeans were disputing the revolutionary hypotheses of Kepler, Raja Sawai Jai Singh (1686-1743), himself a skilled astronomer, built a string of observatories in five cities in India. Jai Singh found that the calculation of the places of stars in the Persian and Hindu, as well as the European source books, were in many cases widely different from those determined by observation, and he sought to right the records.

In 1767, the nucleus of what later developed into the Survey of India was set up, and years later, in 1823, the Colaba Observatory was opened at Bombay. This was followed in another 50 years by creation of the Indian Meteorological Department. In 1916, ionospheric studies began at Calcutta University. From this time onward, research on the upper atmosphere and astrophysics began in earnest.

By the late 1950s, a strong base had already been formed within the country in the field of near-Earth and outer space science and related areas. Most of this work was based on ground-based techniques for ionospheric and magnetospheric studies. With the launching of sounding rockets from the new launch station in Thumba and the build-up of the space program in the 1960s, Indian scientists were able to significantly deepen their basic research studies.

Some of the areas where significant studies have been carried out are the temporal behavior of ionospheric irregularities and their association with the spread of conditions in the ionosphere; the behavior of electrojet current systems and their effect on the dynamic of the upper atmosphere; the study of magnetosphere-ionosphere and ionosphere-thermosphere interactions, including their energetics; and the role of inner constituents, such as ozone, nitrous oxides, and metallic ions.

MORE ENERGY, MORE PEOPLE
Why Solar Energy Won't Work

by Marjorie Mazel Hecht

If you were born in the year 1850, you might expect to live until you were 40—if you were lucky. And if you lived very long ago, in a primitive society, you probably would not live to see your 20th birthday, because the life expectancy for such societies was below 20 years.

Today in America, of course, most people can expect to live an average of 73.7 years.

It is not hard to imagine some of the consequences of living in a society where the oldest inhabitants are only 20 years old, or even 40 years old. The process of growing up, getting an education, working at something, marrying, and having a family becomes very condensed under these circumstances. A grandparent would be a very rare person.

And just staying alive in a stone-age culture would be a full-time job—keeping warm in the winter, gathering food, fending off wild animals—without much time for reflection or "fun."

Looking back thousands of years on a time scale, we can see that the ability of populations to grow, and to extend their lifespans by improving their living conditions, depended on their development and use of increasingly advanced technologies. In particular, populations prospered and grew as their energy use per capita increased.

As you can see in Figure 1, there is a direct relationship between the rise in *energy use* per capita and the increase of population density, or what is more accurately called the *potential relative population density*. This term, potential relative population density, refers to the maximum number of people in a given society who can be supported by an average square kilometer of land.

In the primitive society mentioned above, there was a total potential population of perhaps 10 million persons, and the relative potential population density was 1 person for every 10 square kilometers. Later, when man developed animal husbandry, the population density increased to about 8 persons per square kilometer; and with the development of a primitive form of agriculture, the population density level was brought up to about 20 persons per square kilometer.

After the industrial revolution, there was a big leap, and modern agriculture, making use of more intense energy sources, made it possible to support *100 persons per square kilometer* (or 1 person for every 2.3 acres). This meant that the relative potential population of the Earth jumped to about 10 billion.

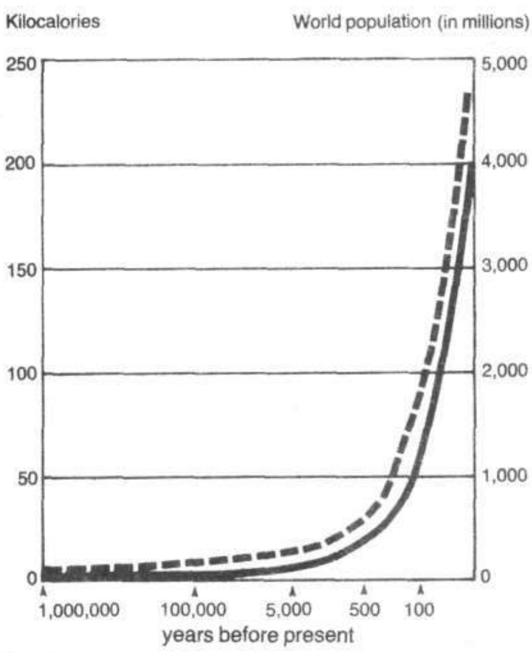


Figure 1
ENERGY CONSUMPTION PER PERSON AND POPULATION GROWTH
The energy consumption per person over man's history is shown here, compared with population growth. Energy consumption is measured in kilocalories; 1 kilocalorie equals 1,000 calories. As you can see, the amount of available energy remains the same for about 900,000 years. Then, in less than 200 years, new technologies make the available energy jump up to its present level. The population "jumps" with the increase in energy. The scale of years on the graph is distorted, condensing the first 900,000 years.

Capturing Energy

Generally, the growth of energy and population on the chart depends upon more and more efficient ways of capturing solar energy, directly or indirectly, for use in sustaining a population. First there was hunting and gathering and fishing.

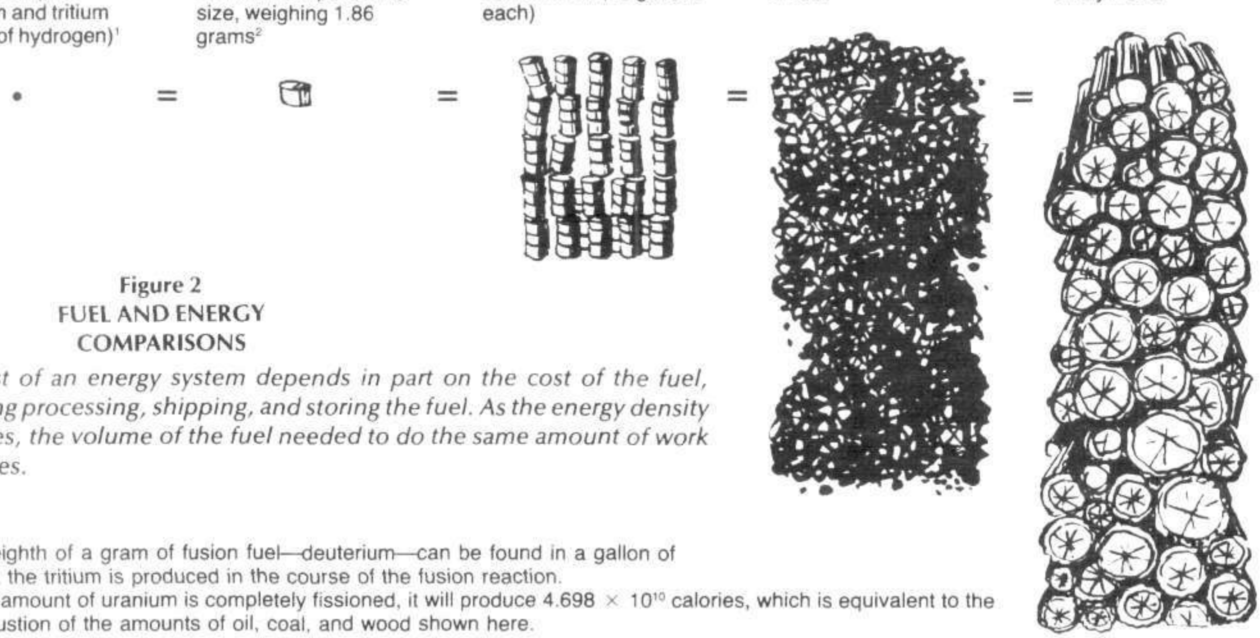


Figure 2
FUEL AND ENERGY COMPARISONS

The cost of an energy system depends in part on the cost of the fuel, including processing, shipping, and storing the fuel. As the energy density increases, the volume of the fuel needed to do the same amount of work decreases.

1. One-eighth of a gram of fusion fuel—deuterium—can be found in a gallon of water; the tritium is produced in the course of the fusion reaction.
2. If this amount of uranium is completely fissioned, it will produce 4.698×10^{10} calories, which is equivalent to the combustion of the amounts of oil, coal, and wood shown here.

Source: Dr. Robert J. Moon

Then man domesticated animals and later plants. Later, after the agricultural revolution where seeds were used to grow crops, man used water power and wind power to increase agricultural production.

Then, entirely new resources were created to capture energy. For example, fossil fuels were "created" to take the place of wood, when wood was near depletion and in limited supply. (I use the word "created," because until the technology was invented to burn coal, coal was really not a resource; to a stone-age culture, a piece of coal would be just a shiny rock.) Then the steam engine was invented, and later in the 1870s, there was the development of electrical power. More recently, from the 1940s on, we have the atomic age, making use of nuclear fission energy; and today we have the promise of nuclear fusion.

Each advance in energy development enabled society to support more people at increased living standards. Why is this the case? Because each advance in energy technology enabled man to apply an increasingly dense energy source to agriculture and industry, to produce more and better products, with less and less input. The increased quality of energy means that each person could produce more.

One of the most important thinkers in history who was concerned with defining this process and guiding societies and nations to grow was the scientist Gottfried Wilhelm Leibniz (1646-1716). Leibniz developed the concept of technology and the science of economics, stressing the importance of creating new machines that could use energy efficiently to do the work of 100 men. His object was to free human beings from back-breaking manual labor in order to develop their creative powers—the power of reason.

Energy As Work

Energy is not simply "heat" or "calories"—1 calorie being the amount of heat needed to raise the temperature of a cubic centimeter of water 1 degree. Energy is actually the ability to do work.

As energy sources have advanced, they have increased their ability to *focus* or *concentrate* this energy and do work more efficiently. You can think of this concentration of energy in simple terms with the example of a knife—the sharper the knife is, the more concentrated its cutting power will be on a surface. A sharper knife can concentrate more energy onto a smaller work surface than a blunter knife can.

The Solar Hoax

Since the 1970s, it has become fashionable to say that we should use solar energy because it is "natural" and "renewable." What I will show here is that supporters of solar energy don't understand the ABCs of energy. Solar energy may be the oldest form of energy, but it is also the least concentrated and the most costly.

Contrary to the happy storybook tales, solar energy is too inefficient to power a modern industrial society and a growing population. It should be no surprise, therefore, that the advocates of solar energy are often opponents of industry who think that there are too many people and that the world population should be reduced.

Today we can measure very precisely the efficiency of various types of energy and how they contribute to the development of industry and the population in general. There is no need to rely on "opinions" about what type of energy is better. Looking at history, we can see that if we want to continue to make progress, we should choose the type of energy that enables productivity to increase, living standards to rise, and populations to grow.

Scientifically, we can look at two separate measurements. First is *energy density*—the amount of energy delivered from a given volume of the energy source to a work surface. Second, there is the *energy payback time*—how long it takes to "pay back" by the generation of new energy the total amount of energy that was required to build the power plant that produces the new energy.

In order to compare the density of various modern sources of energy, we use a measurement of surface area that a given amount of energy passes through to do work. This is called *energy flux density* (flux comes from the Latin word *fluere*, to flow). It is given in units of *megawatts per square meter*, a measure of the heat that passes through a cross-sectional area of the heat-generating process.

The actual figures in Table 1 should not surprise you, after you have looked at the graph showing the history of energy use and population growth. As you can see, energy density increases with each advance in technology. The oldest form of energy—solar energy—is thus the least dense. It "wastes" heat.

The first category in the table, solar—biomass, refers to the indirect use of solar energy, the conversion of the energy from the Sun to trees and bushes that can be burned as fuel. There are about 800,000 watts of sunlight that fall on an average acre, and of this energy, only about 0.7 percent is embodied in the tree matter. This is not a very efficient source of fuel.

The next three categories, solar—Earth surface, solar—near-Earth orbit, and solar—near-solar orbit, refer to the direct use of solar energy, capturing it through arrays of mirrors, reflectors, or other fuel cell devices that store the solar energy for use as fuel. Here, the energy density improves, but it is still miniscule compared to more advanced energy sources.

With fossil fuels, coal and oil, you can see a big leap in energy density—4 to 5 orders of magnitude greater than wood burning. (When something increases by an order of magnitude, it means it is 10 times greater; 4 orders of magnitude means 10^4 or 10,000 times.) This gives you an idea of the vast increase of living standards and industry that was made possible by burning coal.

Fission shows further leaps in energy density, and fusion would increase this by another 10 orders of magnitude—10^{10} or 10 billion.

These energy densities also give you a rough measure of the size of the power plant. The greater the energy density of the fuel, the smaller the power plant has to be. So, in order to collect enough sunlight—the least dense, or most diffuse "fuel"—to produce the same amount of electricity that a fossil power plant produces, the solar plant would have to be 4 to 5 orders of magnitude *larger*

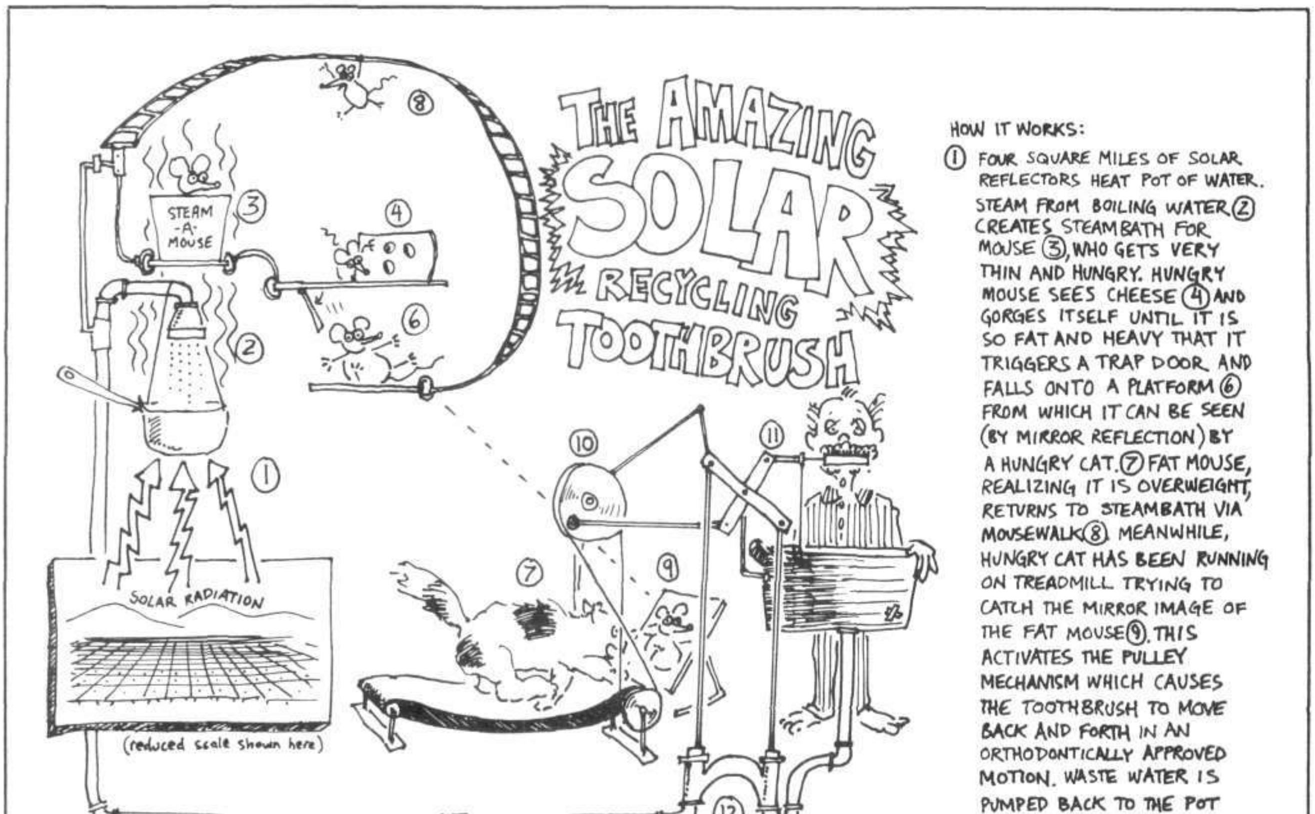


Illustration by Christopher Sloan

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

Table 1
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 collectors are placed in near-Earth orbit, the energy density is still 4 to 5 orders of magnitude below that of fossil fuel.

Energy Source	Energy Payback Time (Years)
Fission	
Pressurized water reactor	1.0
Fast breeder reactor	1.0
Fusion	
Tokamak design	2.0
Fossil	
Coal	2.0
Solar	
Reflectors	8.0
Silicon cells	20.0

Source: Fusion Energy Foundation

Table 2
ENERGY PAYBACK TIMES FOR VARIOUS CENTRAL ELECTRICITY-GENERATING STATIONS*
Between 8 to 20 years are needed for a solar plant to generate the amount of energy that was required to construct and operate the plant, whereas only 1 year is needed for nuclear and 2 years for a coal power plant. A fusion plant will also require only 2 years or less.

* Plant electrical output is 1,000 megawatts, plant lifetime is 30 years, and capacity factor is 65 percent; based on 1981 data.

in size than the fossil-fuel plant.

The actual designs for solar plants, in fact, show that *millions of square feet* of collector surface must be spread out over *hundreds of acres* of land in order to collect the required amount of sunlight. Where would you put these huge solar plants to power our cities? And can you imagine the job of dusting and cleaning millions and millions of square feet of solar collectors?

The Question of Quality

There is another aspect to energy density that can be measured, the quality of the energy produced. Nuclear fission and fusion produce a *very-high-temperature* heat that is not possible with the earlier forms of energy. This high-temperature heat opens up the possibility of new, almost incredible methods of processing and producing materials, and also transforming this heat into electrical energy.

For example, the heat from high-temperature nuclear reactors and fusion reactors can be directly converted to electrical energy, without using a boiler or any mechanical parts, in a process called *magnetohydrodynamics*. The temperatures are high enough for magnetic fields to turn the heat, in the form of very high velocity ions, into electricity.

With fusion, the high-temperatures, never before achieved by man, can be used in a *fusion torch* to reduce rock, or ordinary garbage to its constituent elements. This process would provide a virtually inexhaustible source of minerals and other elements that are now considered rare. A year's supply of certain rare elements could be created from only 1 cubic mile of dirt!

Solar energy may be popular, but it is more costly and less efficient. The workmen here are installing solar collectors.

Grumman

The Payback

As you can see in Table 2, the more energy-dense fuels are also less expensive, even though solar energy fuel is "free." Compared here are four current sources for electricity generation: fission, fusion, fossil fuel, and solar. Solar electric generation is last on the list, with a payback time of 8 years for a reflector system and 20 years for a solar-cell-based power plant design. This compares to only 2 years for a standard coal-fueled or oil-fueled power plant and only 1 year for a standard pressurized water fission reactor or a fast breeder fission reactor.

Very conservatively measured, the payback time for current designs for fusion reactors would be 2 years. The recent developments in fusion research using polarized fuel, however, indicate that there is virtually no difference in payback time between fusion and fission.

The basic study of this type of energy analysis was done in 1975 by Dr. Seymour Baron, who compared what it would cost to produce 1,000 megawatts of electrical power using various alternatives (Table 3). He concluded that *the large energy payback time of solar electricity generation essentially removes it from serious consideration when it is compared to the other available alternatives.* In fact, a solar generation plant based on solar cells today, although there has been some improvement since Baron's 1975 analysis, appears to be almost a *negative* net energy producer. In other words, the solar plant produces less energy in its lifetime than the energy it takes to build the plant.

The poor performance of solar electricity generation in these comparisons results from the massive amounts of material that must go into the construction of the acres and acres of reflectors and cells. Solar cells have the additional problem that tremendous amounts of energy are needed in the manufacture of silicon cells, and these cells have to be replaced every 10 years.

The Future

The question of energy cannot be separated from the question of population. Although the advocates of low-technology energy sources—biomass and solar—do not wear buttons that say "kill people," the fact is that if the nations of the world were to institute this low-technology energy policy, killing people would be the result.

If nations begin to build solar power plants and close down fossil-fuel and nuclear plants, within less than a decade there would be massive starvation and death in the developing sector—Africa, Asia, and Latin America—where millions of people are already undernourished and their lives threatened by poverty. And in the industrial nations, the standards of living would plummet, quickly dropping to levels below that of our great-great-grandparents, and lifespans would be shortened.

Fortunately, the majority of people, especially in the developing countries, want progress, not a back-to-the-caves lifestyle. They look upon their nations, the world, and the solar system—the Moon, the planets, the distant stars—and they see a universe that man can develop to keep civilization—progress—growing. There is no limit to growth, but man's creative imagination.

Energy technology	Total general cost (net energy only) (in cents per kilowatt/hour)	Total general costs (actual fuel costs)
Oil	2.7	6.6
Coal	2.7	4.5
Nuclear		
(light water reactor)	4.3	5.0
Oil shale	4.6	11.2
Fusion	6.4	6.4
Solar reflectors	23.1	23.1
Solar cells	38.5	38.5

Source: Dr. Seymour Baron, "Costing Thermal Electric Power Plants," *Mechanical Engineering*, Oct. 1982.

Table 3
ELECTRICITY GENERATION COSTS FOR VARIOUS ALTERNATIVE TECHNOLOGIES

Shown here are 1980 electricity costs based on a recent net energy analysis. The fuel costs (measured in cents per kilowatt hour) in the first column are based on the net energy necessary to produce and ship the fuel. In the second column, the fuel costs include the actual 1980 market price for the fuel. Solar electric power is 8 to 14 times higher in cost than current conventional power plants in terms of net energy costs.

Viewpoint

Continued from page 4

less than 30 percent of our current investment. The value of the program for the same period will be at least $2 billion, and more likely $6 billion or more.

Perhaps more important, U.S. technology leadership will stay in this country instead of going to Japan and France. U.S. firms will be guaranteed access to global resource data, access which is far from assured in the foreign programs. And by 1990, the privatized Landsat program will be working on a fully commercial basis without any government support.

We appear unable to do simple arithmetic. Other nations are more than ready to show us how.

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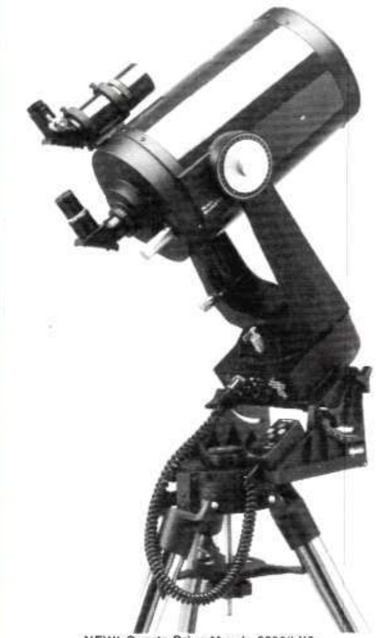

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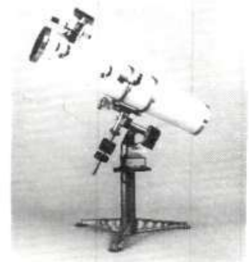

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In This Issue

TECHNOLOGY AND THE ECONOMICS OF GROWTH

The introduction of new technology, as Lyndon H. LaRouche, Jr., and his colleagues demonstrate, can enable a society to do what has previously been thought of as an "impossible" task. In 1820, for example, based on the technology then available, it would have seemed an insuperable task to achieve the standard of living America reached in 1870. Similarly, today it seems "impossible" to bring the developing sector up to the standard of living of Europe or the United States, but such "impossibility" ignores the very possible leap to a plasma economy and fusion power.

Carlos de Hoyos

Author LaRouche (center) and colleagues visiting NASA's Goddard Space Center in Greenbelt, Md.

Lawrence Livermore National Laboratory

Closeup view of a soft X-ray laser target—the size of a postage stamp—as it is being irradiated by the Novette laser at Lawrence Livermore National Laboratory. In half a billionth of a second, the green laser pulses hit the target and the selenium foil explodes off, producing soft X-rays 200 angstroms wavelength.

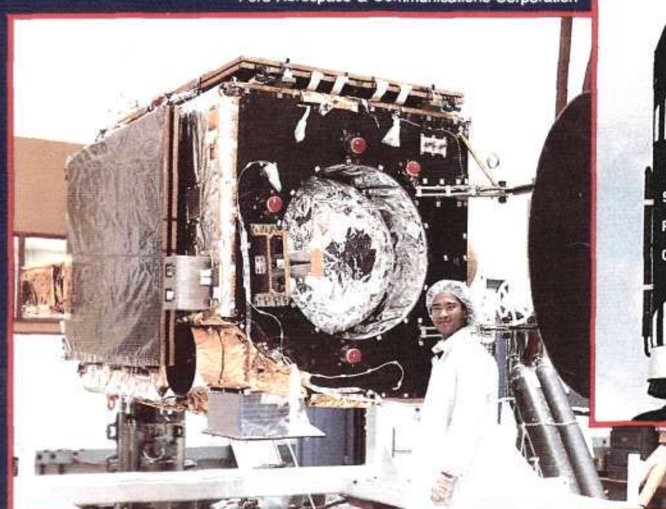
THE X-RAY LASER COMES OF AGE

Recent breakthroughs in the Strategic Defense Initiative program will allow a single X-ray laser module based on the Moon to destroy a missile being launched from Earth, and a single pop-up module to destroy hundreds of offensive missiles. At the same time, advances in experiments with X-ray lasers in the laboratory promise to make available to science and industry the ability to image processes on the atomic scale. Charles B. Stevens reviews the latest developments in defense research and the laboratory.

INDIA'S SPACE PROGRAM TURNS 20

Twenty years ago, India's leaders initiated a vigorous program to give the nation an indigenous capability to move into space. Today, as Ramtanu Maitra shows, India is reaping the industrial spinoff benefits of this farsighted policy. The goal was not just to develop space technology, but to educate the population of this developing nation in the most advanced science and technology.

Ford Aerospace & Communications Corporation



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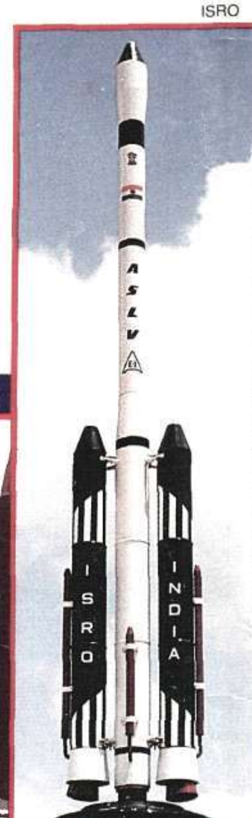

India's Augmented Satellite Launch Vehicle, now nearing completion, and India's 1982 INSAT 1A satellite.