FUSION

SCIENCE • TECHNOLOGY • ECONOMICS • POLITICS

March-April 1983

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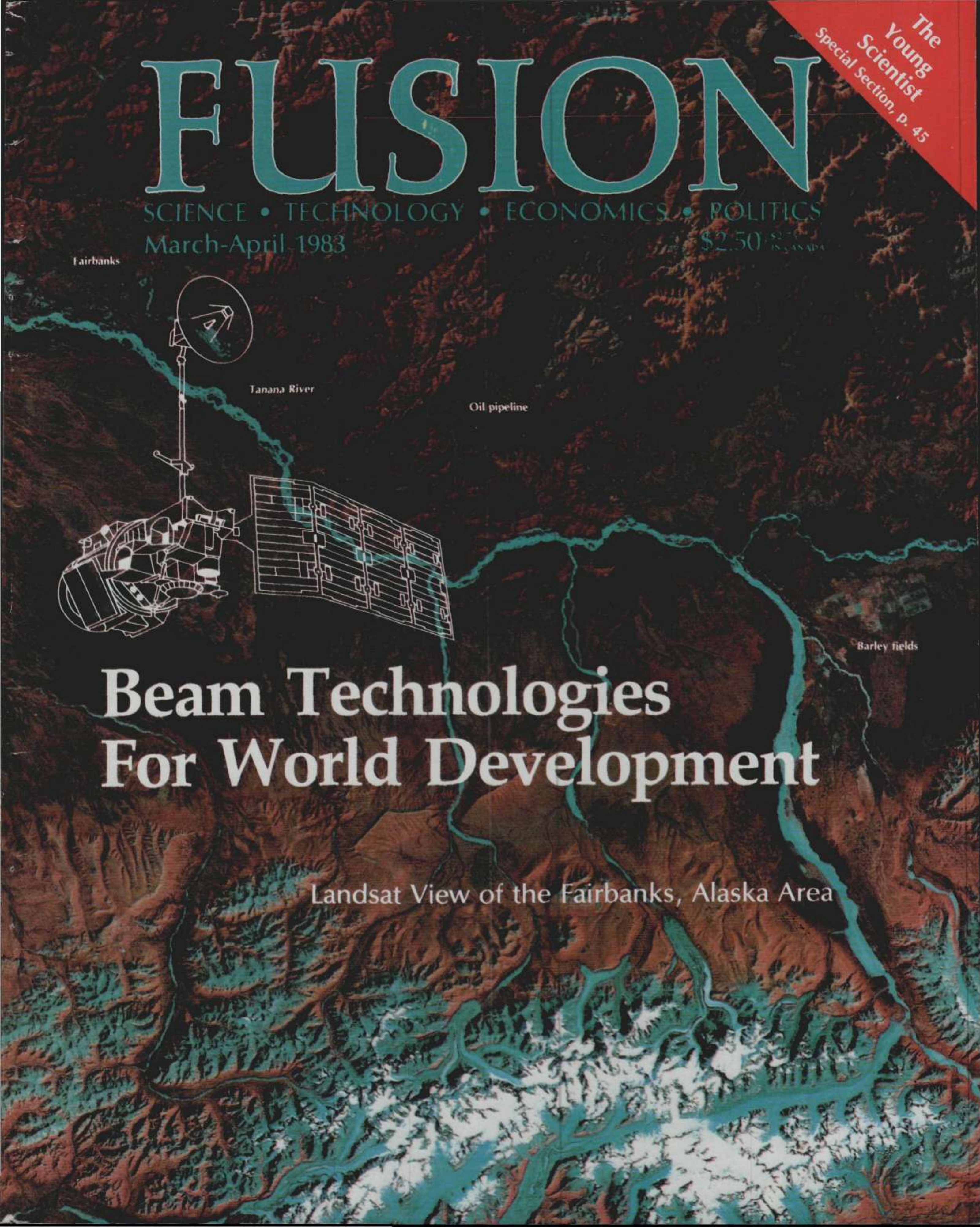
The Young Scientist
Special Section, p. 45



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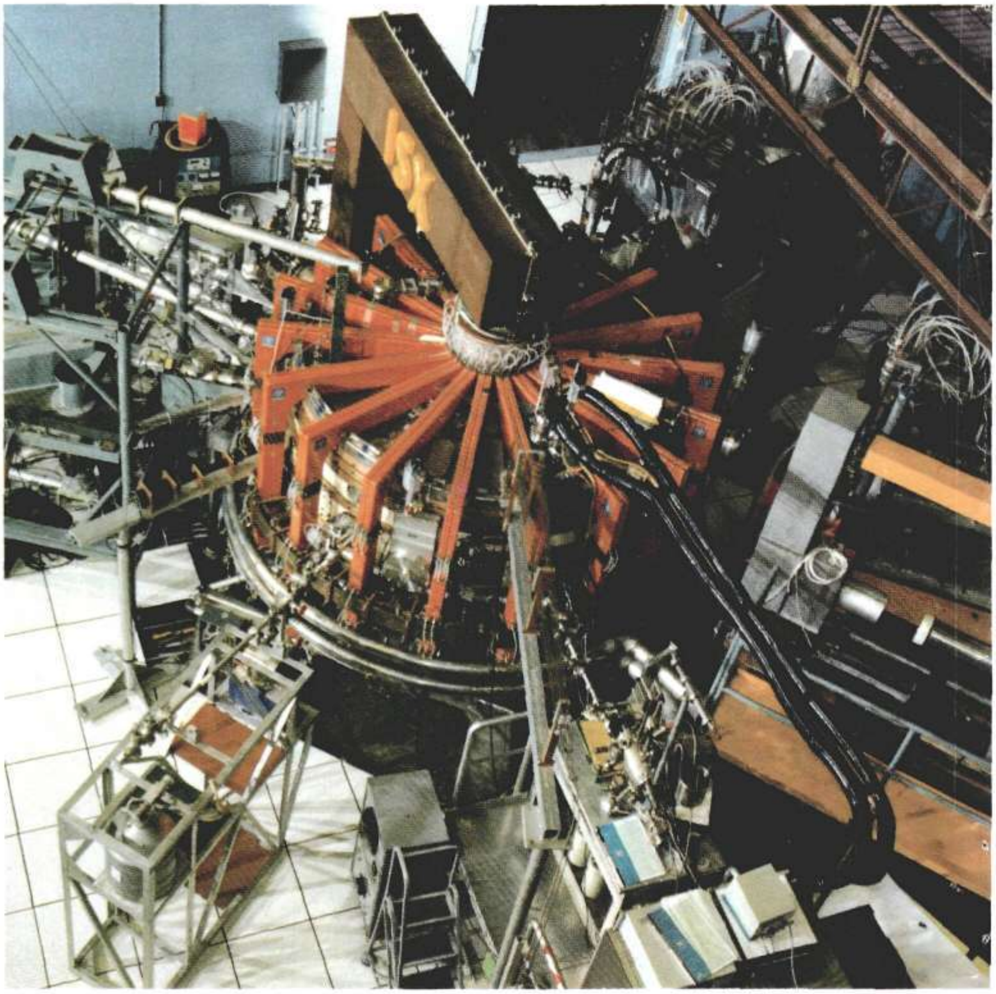

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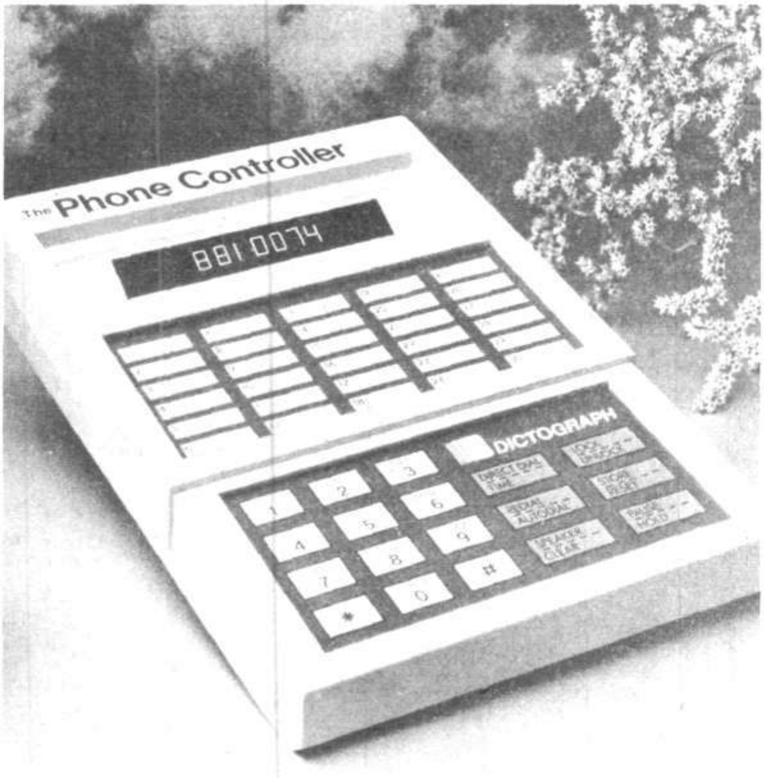

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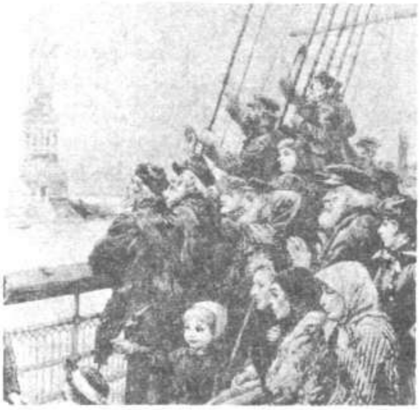
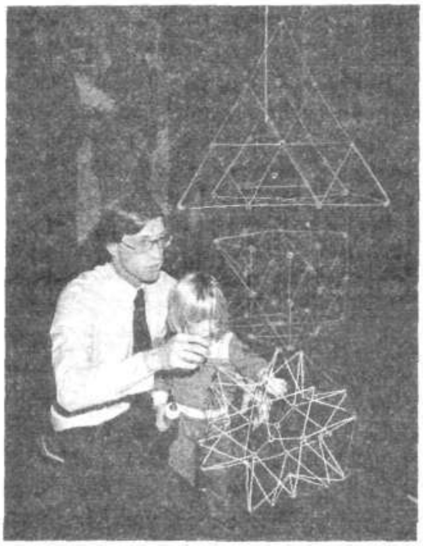


Reinstituting the American System of economics, based on the idea that "people are wealth," is a life or death question today in much of the world where Malthusian policies threaten to kill millions by the year 2000. Here, a contemporary newspaper illustration of Russian-Jewish immigrants arriving in New York harbor in the 1880s.



Stuart Lewis/NSIPS

The present mathematics curriculum is making children incapable of taking on the scientific and engineering tasks required to bring us into the 21st century. Shown here is part of the FEF's pedagogical museum, on display in New York City.

On the cover: A Landsat view of the Fairbanks, Alaska area. The city is in the upper left on the Tanana River. The Trans-Alaska pipeline, a thin white line, is visible running horizontally across the image. Most of the area is covered with permafrost. In the far right are large cleared areas for a barley growing project. Inset is a NASA artist's drawing of the Landsat satellite. Photo © Geopic, property of Earth Satellite Corporation.

Features

News

Departments

From the Editor's Desk

With this issue, *Fusion* returns to its usual format—64 pages and a four-color cover—and to a regular printing and mailing schedule of six issues a year. By popular demand, we are including *The Young Scientist* magazine as a section inside *Fusion,* in order to make this basic science material as widely available as possible.

This issue also inaugurates the formation of a new, international editorial board for *Fusion* magazine composed of scientists and policy makers who are committed to fight for the essential ideas that we are promoting: nuclear energy, world industrialization, space colonization, and the accelerated development of nuclear fusion. Four distinguished individuals have joined the board to date: Dr. Chiyoe Yamanaka, director of the Institute of Laser Engineering in Osaka, Japan; Dr. Hadi Pribadi, head of Pribadi Systems in Indonesia; Dr. Krafft A. Ehricke, space scientist and designer of the Centaur rocket; and Dr. J. Gordon Edwards, an entomologist and professor at San José State College in California, a leading authority on pesticides.

Fusion goes to press at an extraordinary period in our history. President Reagan's announcement March 23 committing the nation to end the era of Mutually Assured Destruction and to develop directed energy beam defensive weapons—a policy we have been advocating since 1977—has given the FEF considerable publicity as well as new responsibilities for educating the American public. *Fusion* and its 200,000 readers are key in this fight to reestablish technological and cultural optimism in this country and defeat those who would return us to a pre-industrial era. We urge you to write or call your congressman and senators on this issue, to organize debates and forums on the high technology alternative to the nuclear freeze, and to send us your contributions!

This issue contains plenty of scientific and political information with which to win this battle. I call your attention to the new department, Profile (page 17), which provides essential information on leaders of the "flat earth" opposition. Also, please note that the original works of American System economists discussed in the feature article (page 36) are obtainable from Augustus Kelley Publishers (see page 63).

Marjorie Mazel Hecht

Marjorie Mazel Hecht
Managing Editor

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The views of the FEF are stated in the editorials. Opinions expressed in articles are not necessarily those of the FEF directors or advisory board.

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Note to Libraries and Subscribers

To comply with postal regulations, the issues of FUSION in Volume 5 are numbered in the order in which they were printed and mailed. March-April 1983, Vol. 5, No. 7, follows December 1982, Vol. 5, No. 6.

Subscribers who purchased a 10-issue subscription will receive all 10 issues. The FEF will publish 6 issues in 1983, but published only 4 issues in 1982.

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Editorial

President Reagan's Initiative to 'Render Nuclear Weapons Impotent and Obsolete'

Just as this issue of *Fusion* magazine went to press, President Reagan embarked on exactly the kind of military program for which we at *Fusion* have been campaigning: a renunciation of Mutually Assured Destruction as the basis of American military posture and the initiation of a directed energy beam weapon program for defense against intercontinental ballistic missiles. In a dramatic, televised speech March 23, the President called on the scientists and technicians of this country "to turn their great talents now to the cause of mankind and world peace: to give us the means of rendering these nuclear weapons impotent and obsolete."

As President Reagan said without exaggeration, this new policy "holds the promise of changing the course of human history." It is our conviction that the development of beam weapons will change human history in three decisive areas: First, it will once and for all remove the specter of a weapon of mass destruction for which there is no defense. Militarily and politically, the threat of accidental or inadvertent annihilation of the human race will be removed. Second, the development of beam weapons will usher in the next industrial revolution, the beginning of the "plasma age," with implications as revolutionary as those brought about by the introduction of electricity. Third, and perhaps most important, the beginnings of a beam weapon program in the United States will rekindle a spirit of "technological optimism," the belief that man and his scientific capabilities can accomplish anything. Beam weapons, and their solution to the problem of nuclear holocaust, are the definitive rebuttal to the pessimism and defeatism spread by the Malthusians.

The next issue of *Fusion* will contain a special report on the lastest information on beam weapons, including:

(1) an assessment of the impact of beam weapons on military strategy and discussions of the military doctrines that will replace MAD;

(2) a point-by-point refutation of the "scientific" objections to beam weapons, including a detailed discussion of the objections raised by the Kosta Tsipis group at the Massachusetts Institute of Technology to beam weapons for ballistic missile defense;

(3) an econometric impact study of the "spinoff" technologies of a beam weapon program, showing that the development of beam military applications will have a profound, revolutionary effect on the civilian economy as well;

(4) a dossier on the opposition to beam weapons in the nuclear freeze movement, exposing the hidden agenda that motivates the freeze movement's opposition to the only way to really prevent nuclear war;

(5) a report on the major conference on beam weapons cosponsored by the Fusion Energy Foundation and the Club of Life in Washington, D.C. on April 13.

Technological Pessimism Versus Reality

The successful start-up of Princeton's Tokamak Fusion Test Reactor Christmas Eve is a splendid example of what the United States can still do when it has a national goal and a mission orientation. The TFTR, the world's largest tokamak and probably the world's most sophisticated construction project, is expected to reach breakeven with deuterium fuel in 1985, moving to reactor-grade fuel the next year. After that, the plans to upgrade the TFTR could meet the mandate of the 1980 fusion legislation for the United States to operate a fusion engineering device by 1990.

Instead of celebrating the birth of the TFTR nationwide, as would seem appropriate to any progress-oriented American, the technological pessimists in the Reagan administration have promoted the myth that fusion "is not possible for 70 years," and that the program is "not ready for engineering." Specifically, presidential science advisor Dr. George Keyworth, over the objections of the Department of Energy, has forced the fusion program onto a track that includes no engineering and no new starts, and eliminates from the budget alternative programs such as the Elmo Bumpy Torus.

On this go-slow track, the U.S. fusion program will not *reach commercial fusion demonstration by the year 2000*—as mandated in the Magnetic Fusion Energy Engineering Act of 1980—and, in fact, may never reach commercial fusion. Yet, as the testimony of the nation's scientists and the official review boards of the Department of Energy confirmed when the fusion legislation was passed and signed into law by President Carter, *there are no scientific obstacles to the development of commercial fusion energy.*

It is ironic that the political obstacles created to block this achievement are coming from an admittedly pronuclear and progrowth administration. Even more ironic is that the cost-accounting/austerity arguments used to justify this go-slow approach to developing the energy source of the next century will ensure not that any money is "saved," but that there is an economic collapse of such large proportions that U.S. industry may never recover.

In fact, unknown to most Americans, as well as to many members of the White House, these budgetary decisions are being made under the blackmail threats of the international banking community. The continued dangerous instability of the international financial markets, combined with the federal government's desperate need for credit, is on the verge of turning our government into a "banana republic" for the International Monetary Fund and the Bank for International Settlements.

This is the strategic reality facing this country today: the possibility of a technological revolution based on the coming of the "plasma age" on the one hand, and, on the other hand, an accelerating depression and financial collapse accepted by an administration so blinded by its fiscal conservatism that it cannot see the coming collapse.

The latest in-depth economic study by the Fusion Energy Foundation has proved exactly this point. Unless the nation gives priority in funding to a "science driver," research and development on the frontiers of science and technology, there is no way to jolt the economy out of the present depression and to keep it growing. It is the development of advances in science and technology and the immediate application of these advances to industry and agriculture, where they raise productivity, that can bring about a "recovery." Whether the science driver is the development of fusion, or the development of the beam technologies required for defensive weapons systems and civilian energy, the principle is the same as it was for NASA's Apollo program in the 1960s and early 1970s: The rate of introduction of new, advanced technologies into the economy determines that economy's growth. To postpone or cut off science and technology projects in the name of cost-efficiency, therefore, ensures the opposite effect.

The American System

This fact is not something that we at the FEF have just discovered. As described in the feature article, "The American System: 'People Are Wealth,'" the scientific principle that the creativity of the human mind would constantly improve society by inventing new technologies was the weapon with which the American System thinkers defeated the Malthusians of their time. It should not be a surprise, therefore, to learn that President Lincoln's advisor Erasmus Peshine Smith, one of the most eloquent American System economists, spent several years in Japan, setting up the national economic principles responsible today for the fact that Japan spends twice as much money on fusion and intends to export commercial tokamaks before the end of the century.

This Japanese technological optimism is the promise of the TFTR, which, barring political obstacles, can lead the way to U.S. commercial fusion by the year 2000.

In August 1978, just after the Princeton PLT tokamak achieved record temperatures, Edwin Kintner, then director of the U.S. Office of Fusion Energy, delivered a lecture to commemorate Lev Artsimovich, the Soviet physicist who had inspired the U.S. magnetic fusion program. Kintner's words are even more appropriate today in the battle to wipe out technological pessimism:

> If we in the fusion community can build on the great beginning which has been made and carry forward with the development of fusion—hopefully, optimistically, enthusiastically working together toward providing unlimited energy, the fundamental energy of the universe, in a controlled, environmentally benign manner—we can once more believe in ourselves and in science as the noblest, most constructive activity to which the mind of man can be turned. We may help reestablish that no one need fear shining the bright search-light of the human mind on the many remaining dark corners of our understanding of the universe around us.

Princeton's TFTR Comes on Line

by Paul J. Reardon

'Twas the day before Christmas and all through the cell, not a creature was stirring, just the warning bell.

The diagnostics were hung on the tokamak with care, in hopes that first plasma soon would be there.

Harold[1] in his coat and I in hard cap, we were looking around for a place to nap.

When out in the cell there arose such a clatter, Don Grove[2] rushed in to see what was the matter.

With ladder in hand, and quick as a flash, he jury-rigged a fix to keep on with the bash.

Minutes later, aha, to our eyes did appear good vacuum, good control, nothing to fear.

On TF, on OH, with EF to steer.[3] First plasma for sure soon will be here.

Now we'll puff in the gas. Does TFTR really have class?

Wait a moment. What's that glow? First plasma, of course, Ho, Ho, Ho.

A Year Ago

A year ago, there was no TFTR machine, just the floor of a test cell. At Christmas 1981, the various support systems for the inner-support structure and the lower poloidal field coils were started. In February 1982, we started the assembly of the poloidal field coils and the equilibrium field coils and the ohmic heating coils for the bottom half of the machine.

We had designed TFTR with 10 sectors so it could go together fast. By June 1982, we had nine vacuum vessel sectors in, not all with coils, but by using a compromise—which was to make a dummy tenth sector that we would measure in place at PPPL and send back to the factory to be used to machine the tenth sector—we could save us two months. This fix got us back from a computer completion schedule of April 1983—four months late—to February 1983—two months late; and to move the schedule up from February to December 1982 was a hard fight, achieved largely by people working very, very hard. Nevertheless, we did pick up the required two months, and in September 1982 we were putting in the last sector. By the time we were putting in this tenth sector, we were able to do it in four hours, demonstrating that tokamaks using a pie-shaped sector design can indeed be installed rapidly.

The Countdown

On December 1, or thereabouts, we started our countdown procedures for the various shots. We had an elaborate integrated systems testing procedure.

Because of the really tremendous integrated effort of the Research Department, Technology Department, Ebasco, Grumman, Department of Energy, and, in the last three months, everybody, we were able in the end not only to complete TFTR on our schedule, but also to run all the diagnostics from the final central control room, although at first we thought we wouldn't be able to do that. The actual shots were run in the temporary control room from the point of view of turn-on of the magnet power supply, but the diagnostics, controls, and data acquisition systems were in their final location.

We really did not want to go much beyond 2 a.m. on the day before Christmas with people having worked their butts off for a number of months. And so we said, "One way or another, we're going to stop around 2 o'clock." And I was going to get a bag, pull it over Don Grove's head, and Harold Furth was going to grab his legs, and I was going to grab his arms and we were going to cart him off.

Well, Don figured this out, and we were coming very close. I don't know if he did it, but he had somebody unplug the clock. I swear—maybe we were tired—but it took me and Harold 20 minutes to figure out that somebody had unplugged the clock, and that's the truth. But by that time, everyone was totally absorbed in the effort and nobody wanted to stop.

Finally, we completed what we call the integrated systems test up to the point of actually trying to make the first plasma. With DOE's help, we had defined first plasma as an integrated systems test, not the initial operation of the machine. Don Grove then passed over a formal letter to DOE saying that we had successfully completed the first plasma integrated systems testing up to the point of putting gas in the machine, and J. Nelson Grace from DOE gave him a formal reply, saying, "You are hereby authorized to put gas in the machine." Once again, DOE was able to shorten its review period, which was earlier said to be six weeks, and got it down to be, I think, a total of 10 seconds. This again proves that once a mission is clearly defined and all elements of our structure are behind it, things still can and do get done quickly. It's just getting much, much harder to identify missions and get people solidly behind them.

At 3:05 a.m., the countdown was on. While we were all watching to see that the magnetic fields came up to the correct value, lo and behold, we saw the plasma first shot. It's amazing that the newspapers and TV never picked up the fact that we said 3:06 a.m., when the clock in our photographs said 5 minutes to 2:00.

The TFTR Strategy

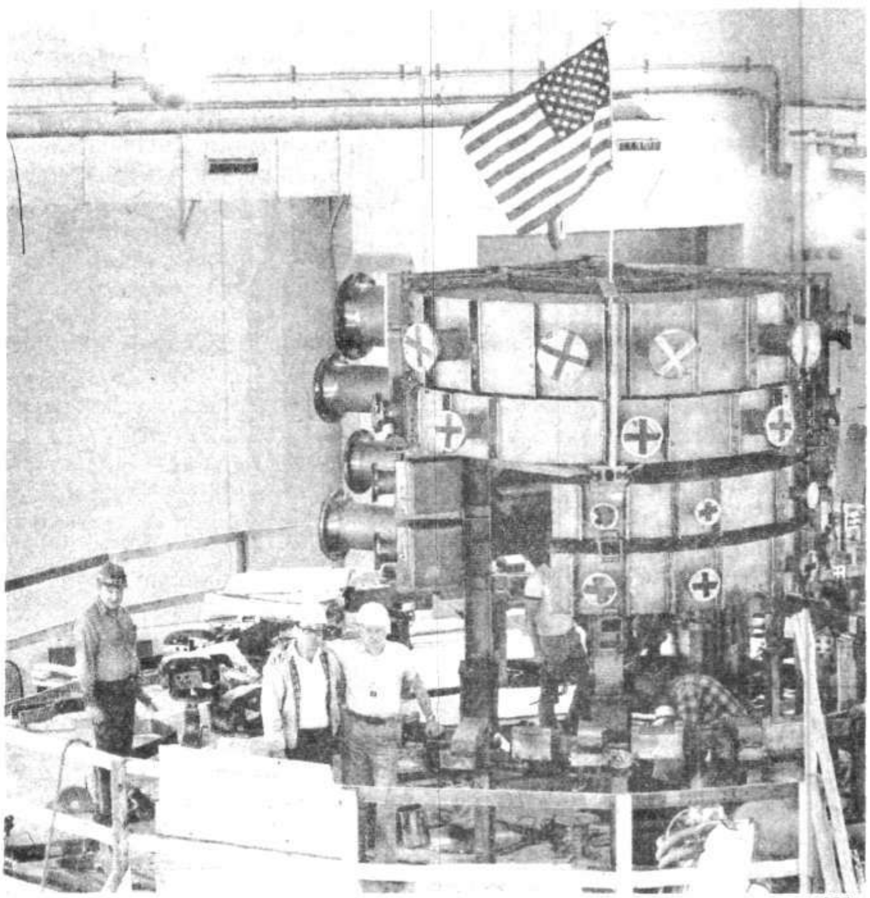
Now that we've built this thing, what are we going to do with it? First of all,

Paul J. Reardon is associate director of the Princeton Plasma Physics Laboratory. This viewpoint is adapted from his talk at the Fusion Power Associates meeting in San Diego, Jan. 6, which he began with a little poem titled "Santa Claus Comes to Fusion."

we did have diagnostics. For first plasma, we had a current of 51 kiloamps with a 50 millisecond pulse. The plasma density was a healthy $7 \times 10^{14} cm^{-3}$. To make sure that this wasn't all some gimmick caused by the magnetic fields, we actually measured the radiation at a wall that was some 200 feet away. So we knew there was indeed a plasma pulse; it wasn't a freak flash.

The basic strategy of the TFTR is that we will spend the next three years getting ready for the earliest practical deuterium-tritium (D-T) demonstration. We do not plan to activate the machine very much, however, and we would limit the scope of the hardware to be installed only to that required for a 10-shot D-T demonstration. In the interim, we will provide the hardware to study, take data, and define the scientific and technical issues associated with high temperature, high current plasmas. Then, following the 10-shot D-T demonstration, we would take a year and a half to get ready—from the point of view of studying hydrogen plasmas—to develop a fusion reactor physics base in a subsequent D-T operation involving thousands of D-T pulses and requiring some remote maintenance because of the high radiation levels associated with this type of D-T operation.

The hardware required through the next five years is either on order or in design and procurement, so that we can do our best to complete this program in the five year period. Beyond that—the bolder D-T operation phase—requires major improvements that have not yet been approved.



PPPL

The TFTR, October 1982. The flag is raised because all the major structural elements are now in place. Shown here is the umbrella structure with the manifold system installed on top.

Over the next two months, we expect to have some 100 shots or so at low magnetic field, 15 to 25 kilogauss, and achieve a plasma current of 250 kiloamps. Beginning in April, we hope to have the facilities available for a 35 kilogauss run so we can achieve a 1 Megamp plasma by summer. In the period April through September, we can do both ohmic heating and compression heating experiments and study transport phenomena in the 1 Megamp regime. Then we will start an intensive effort to bring on the neutral beams, having two neutral beams a year from now, and four neutral beams two years from now.

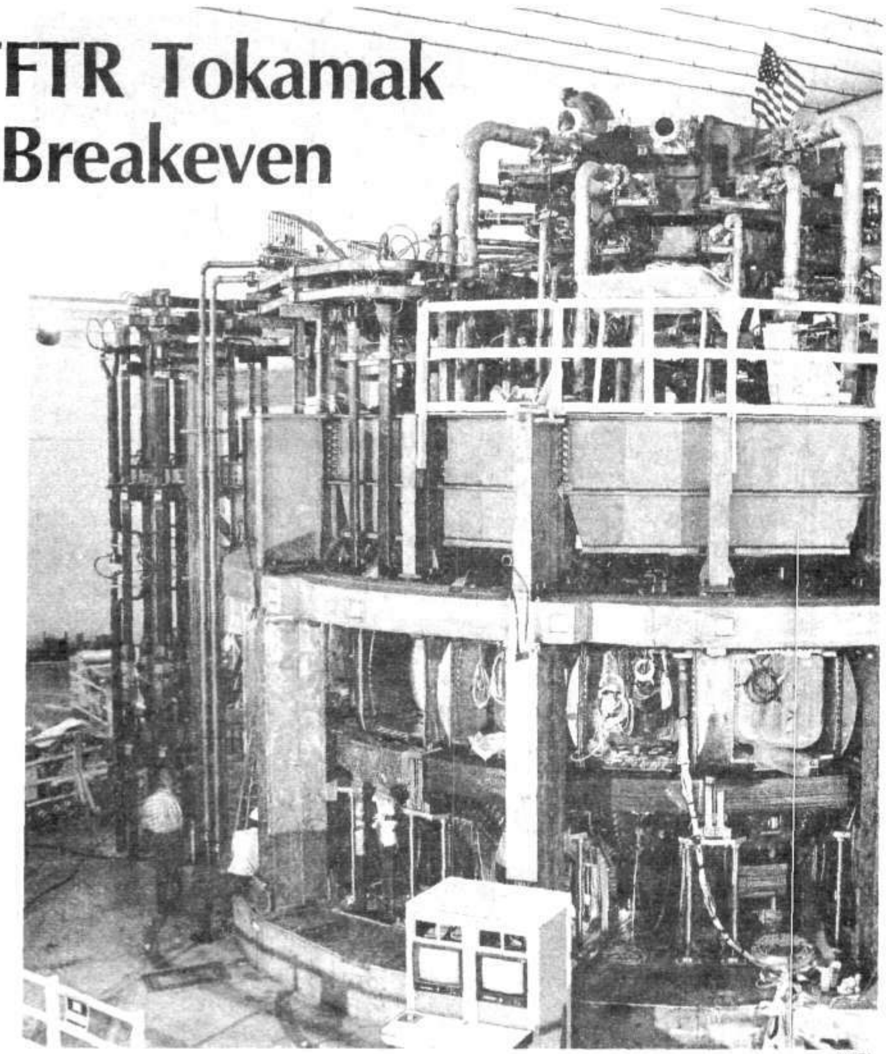
Then we estimate it will take one year to get to a TF magnetic field of 50 kilogauss, a 2.5 Megamp plasma, and 35 MW of deuterium neutral beams. We will then optimize the plasma conditions for D-T operation and spend six months to a year to achieve the 10-shot D-T demonstration. Following that, we will allow the vacuum vessel to cool down and we will use hydrogen plasmas to study optimizing tokamak reactor physics. Then, at the end of 1988 we will be ready to go into a new phase of operations which is yet to be defined and approved.

As I mentioned before, from the hardware point of view, all of the items required for the $Q = 1$ scientific feasibility demonstration[4] are either available or in design or procurement, and we will limit the D-T shots so that the innards of the vacuum vessel will not get higher than 70 millirem per hour and we can then actually do hands-on maintenance if required. Then our tentative plans are to bring on new hardware so that we can be ready to start the $Q = 2$ reactor physics experiment using hundreds of D-T shots.

For $Q = 2$ operations, after two weeks or so we will get to a steady state radiation level at the vacuum vessel wall of about 5×10^4 millirems/hour, so we would have to do fully remote maintenance inside the vacuum vessel if repairs are required. At the moment, we have not defined this well enough to say how much remote

Continued on page 10

Princeton's TFTR Tokamak Prepares for Breakeven



PPPL

The TFTR just a month before it went on line, November 1982.

At 3:06 a.m. on Dec. 24, scientists at the Princeton Plasma Physics Laboratory began operation of the world's largest fusion energy experiment, the Tokamak Fusion Test Reactor, TFTR.

The TFTR will be the first device to control the energy released by the fusion of two hydrogen atoms to generate a net output of usable energy—a condition known as energy breakeven. Although full-scale operation is still many months away, the first test runs of the Princeton device Christmas Eve constitute a technological achievement as significant as the first landing of men on the Moon. The TFTR will provide a proof of feasibility for magnetic fusion energy and go a long way toward making fusion into an economical and practical electricity source.

At a press conference announcing the start-up of TFTR, Anthony De Meo, director of information for the Princeton laboratory, reported that the first shot, or injection of hydrogen test plasma into TFTR, had been more successful than anticipated, achieving plasma containment and energy flux on its first attempt.

More than 400 shots are planned by April in a heavy test schedule of components and behavior of the reactor under many different conditions, before the first compression and full ohmic heating experiments to bring the plasma up to high temperatures. These latter experiments will begin in April.

By September 1983, a neutral beam heating device will be used for the first time to reach plasma temperatures on the order of 100 million degrees Celsius, well in the range for power-producing plasmas. De Meo said that breakeven experiments with deuterium-tritium fuel (D-T) are planned for 1986, although the conditions needed for breakeven will be demonstrated by 1985 with all-deuterium plasmas.

The enormous success of the TFTR already demonstrates that the only constraints to the development of this limitless energy source are political.

As mandated by the Magnetic Fusion Energy Engineering Act of 1980, and proven by scores of government reports, magnetic fusion power plants could be commercially demonstrated before the end of this century, if sufficient resources are devoted to development.

Current administration policy, however, was reflected in the statement of presidential science advisor Dr. George Keyworth: The TFTR start-up "means a tremendous amount of hope for fusion power," Keyworth said, but it "will be well into the 21st century" before any commercial fusion applications are attempted.

What proponents of fusion energy hope is that the TFTR success can provide the spark to reignite the U.S. commitment to fusion development. In any case, the breakthroughs made at Princeton will not be wasted. If not incorporated into a U.S. R&D program, they will nonetheless be used by the nation emerging as the world's leader in fusion energy development—Japan.

Birth of a Reactor

The TFTR was born in 1973 as an idea of Dr. Robert Hirsch, at that time director of the U.S. controlled fusion program. The initial breakthroughs by the Soviets in the late 1960s with their tokamak magnetic confinement concept had been confirmed on a number of U.S. experiments, together with significant advances involving the heating and control of tokamak fusion plasmas. Until that time all existing and planned magnetic fusion experiments used unreactive hydrogen- and deuterium-fueled plasmas. This avoided having to deal with the engineering and technical difficulties of plasmas generating intense fusion energy outputs. Most of the significant scientific questions concerning the problem of generating the condition needed to ignite nuclear fusion could still be addressed while keeping the experimental facilities readily accessible and unencumbered with energy removal and shielding equipment.

Hirsch pointed out at the time that if the goal of practical fusion power plants were to be attained in a timely fashion, the program had to meet and address the problems of fully reactive deuterium-tritium fusion plasmas as soon as scientifically feasible. Hirsch, therefore, took the bold step of mandating that the next major magnetic fusion facility would have to be designed to run with deuterium-tritium fueling.

Hirsch's idea was that the TFTR would mark the beginning of the engineering phase for the development of the first fusion electric power reactor prototypes. At the time, given the many basic scientific questions that remained unresolved, his initiative was viewed as very ambitious.

The Tokamak and Fusion

When Hirsch conceived of the TFTR, the chief problem up to that point in magnetic fusion research had been that of successfully designing a "magnetic bottle" or "trap" that would confine and insulate hydrogen fusion fuel while it was heated up to the enormous temperatures needed to spark significant numbers of fusion reactions.

The easiest fusion reaction to ignite is that between the two heavy isotopes of hydrogen, deuterium and tritium. At temperatures above 50 million degrees Celsius, this D-T reaction becomes sufficiently vigorous such that more fusion energy can be generated than the energy it takes to heat the fuel to these temperatures. But in order to achieve this energy breakeven or net-energy-producing situation, the fusion fuel must be maintained at a sufficient density for significant amounts of reactions to take place. Also, the fuel must be sufficiently insulated that it does not lose its heat content faster than the rate at which fusion energy is being generated. This condition is measured as an energy confinement time.

The conditions of density and energy confinement are combined to form a product that must be greater than 100 trillion seconds-nuclei per cubic centimeter.

When a material is heated to anywhere near fusion temperatures, its atoms become ionized and it forms an "electrified" gas called a plasma. The problem for magnetic confinement fusion is to find a configuration of magnetic fields that stably interacts with the hydrogen plasma to keep its energy confined to the plasma itself. The tokamak magnetic confinement system has the shape of a donut and was the first magnetic configuration to achieve stable confinement of hydrogen plasmas.

In 1978, the Princeton PLT tokamak showed for the first time that temperatures in excess of 80 million degrees Celsius could be stably attained. This was achieved by utilizing neutral beam heaters supplied by Oak Ridge National Laboratory. As pointed out by Dr. Stephen O. Dean, then the director of confinement systems research in the U.S. magnetic fusion program, this meant that there were no scientific barriers to the construction of prototype fusion reactors within the next 10 to 15 years.

To the mind of the Malthusian Carter administration, however, the near-term prospect of abundant, cheap and clean fusion energy was anathema. Robert Hirsch was driven out of government in 1976. Many attempts to cut the fusion research budget, and the TFTR in particular, were mounted by the Carter administration. But even the DOE review panels appointed by Carter were forced to admit the great progress and promise shown by the U.S. magnetic fusion program. And the program was able to at least maintain 1976 funding levels.

As a result of the efforts of the Fusion Energy Foundation and Rep. Mike McCormack, a Washington Democrat, Congress recognized the progress of fusion research by passing the 1980 Magnetic Fusion Energy Engineering Act, which called for the realization of demonstration commercial electric fusion power reactors by the year 2000. The Reagan administration, however, has proved no more willing than its predecessor to move ahead with fusion development. The director of magnetic fusion programs in the Department of Energy, Edwin Kintner, resigned in despair a year ago.

Today, the successful inauguration

Polarized Fusion Research Begins at a Slow Pace

Research on fusion using polarized fuel is proceeding at a slow pace. A proposal from Dr. Bruno Coppi, the initiator of the Alcator tokamak at the Massachusetts Institute of Technology, is still being reviewed by the Department of Energy. Research on polarized fusion has begun at the Princeton Plasma Physics Laboratory, but experiments with fusion plasma are not scheduled for two to three years.

Polarized fusion, if successfully demonstrated, will greatly accelerate the development of commercial fusion energy. Scientists at Princeton and at Brookhaven National Laboratory theoretically determined that spin-polarizing fusion fuels could substantially improve the quantitative and qualitative energy outputs of magnetically confined thermonuclear fusion plasmas. As reported in the September 1982 issue of *Fusion*, using a polarized D-T fuel could shave as much as five years off the estimated experimental time required to reach reactor conditions, because the fuel lowers the temperature and density requirements.

of the TFTR at the Princeton Lab is a powerful reminder of the feasibility and necessity of the nation's still unfulfilled commitment to fusion energy development.

—*Charles B. Stevens*

Depression Hits Administrators

In spite of the heady results from the just completed TFTR, the scientific leaders and administrators of the U.S. fusion program gathered at a Jan. 6 meeting in San Diego agreed that the fusion program is in for hard times because of the Reagan administration's go-slow attitude toward scientific research. The meeting was sponsored by the fusion industry group, Fusion Power Associates.

In a morning panel composed of present and former directors of the U.S. fusion program, as well as representatives of the Department of Energy's Magnetic Fusion Advisory Committee and directors of the U.S. inertial confinement effort, the consensus was that the U.S. fusion program would have to become more "realistic" and "free-market-oriented" if it is to survive the current budget crisis.

The present DOE fusion administrator, Dr. John Clarke, described the new fusion plan, which dictates just such a program: an almost total cut in engineering work under the guise of cost-efficiency; elimination of alternative lines of research, such as the Elmo Bumpy Torus, justified by "concentration of effort"; and a slowdown of the next generation of fusion machine design.

As several industrial representatives present pointed out to the panel, such cutbacks are precisely the policy that the U.S. auto industry implemented in the 1970s, and the U.S. steel industry implemented in the 1960s; and this destruction of long-term investment and aggressive innovation spelled the demise of these industries in the face of Japanese investment policies.

Ironically, as one speaker emphasized, the largest fusion program in the world today is Japan's.

Viewpoint

Continued from page 7

maintenance is required.

For the initial phase of operation over the next year, we will be prepared to study both the compression heating mode required to get the 10-shot D-T demonstration and the bulk-heating mode, which we believe is the best for the Q = 2 and tokamak reactors. In the first case, you build up the plasma on the limiter to 1 Megamp and you compress it to 1.5 Megamps. In the second, case, we would be looking at a 1 Megamp plasma from the point of view of later use of a large plasma that is bulk heated by neutral beams or RF systems, similar to the one (2.5 Megamps) we would use during the Q = 2 demonstration. So we will be prepared at the 1 Megamp level, within a year, to do either one of these experiments, and we'll go into Q = 1 with the system that appears most promising.

The next phase of the program requires installation of complex plasma limiters, which General Atomic is now working on for us. There are some serious engineering problems that must be solved and these limiters are extremely important for they determine the plasma shape. They will be critical for the TFTR physics program of two years from now, and we're watching with great interest the experiments going on at General Atomic with limiters coated with various carbides, not only those with titanium carbide, but also the more recent ones with silicon carbide.

The issues we hope to resolve are related to the confinement and control of large reactor-grade plasmas. We will have an n-τ of at least 10^{13} in the D-T demonstration. The size, current, and temperature of the TFTR plasma will be a factor of 2 over those of Princeton's PLT. Using a zirconium-aluminum gettering system, we hope to keep the impurities down. We expect a beta of about 2 percent.

The Technology Side

On the technology side, we will have 10 times more energy throughput than PLT for the Q = 1 experiment and another factor of 5 to 10 higher for the Q = 2 experiment. We are looking at the PLT and PDX plasma performance and activation and radiation calculations to ensure we know what we're doing when we go into operations with the larger TFTR plasmas.

Earlier, our general plans for TFTR upgrades were primarily concerned with reactor physics and technology associated with D-T operations at Q>2; development of radiofrequency heating and current drive; techniques for long pulse, high power impurity and density control; development of remote handling; some neutron utilization studies with blankets and shields; and development of tritium handling systems with more tritium throughput than we would use with Q = 1. This is not now the case, and the technology issues will not be aggressively pursued in TFTR upgrades.

The Q = 2 experiment will most likely be approved, however, and this is most important, because there's nowhere else in the country that can do alpha particle confinement and heating studies in the 1988 time frame. TFTR is the only U.S. tokamak, that can do D-T plasma bulk heating studies with reactor-like fusion power densities.

In the earlier plans for TFTR upgrades, we did hope to have a broader industrial involvement, even converting some of the operations into an activity managed by industry. This is no longer likely to happen with an upgrade that only involves the physics of Q = 2. The engineering and industrialization phases of fusion are, in fact, being seriously slowed down.

The good news is that we finally seem to have things under control pretty well from the point of view of the Q = 1 scientific feasibility demonstration, which should be occurring roughly three years from now.

The uncertain news—I won't say it's bad news—is how do we get ready for a more ambitious phase of D-T operation that would come in the 1988 time frame without more specific approvals now on TFTR improvements and upgrades?

Notes

1. Harold Furth, director of PPPL.
2. Don Grove is TFTR project manager.
3. Toroidal field coils, ohmic heating coils, and equilibrium field coils.
4. Q is a measure of energy gain. At Q = 1, there is more energy output than energy required to ignite and sustain the fusion reaction.

Developing Nations Want to Go Nuclear!

Earlier this year, King Hassan II of Morocco identified nuclear energy as the key to the development of the Third World. He called on France to sell his nation "several nuclear reactors" to irrigate Morocco's deserts and to raise its population-potential by more than threefold within the next 100 years.

Morocco is one of several Third World countries on the same track—seeking nuclear power as the most affordable, surest path to development. This trend was evident at the early-March summit of the Non-Aligned nations in New Delhi, whose final communiqué affirmed the "inalienable right" of all nations to "full or unrestricted access to nuclear technologies for peaceful purposes under nondiscriminatory conditions" and abhorred "the pressure and threats directed against the developing countries to prevent them from accomplishing their program for developing nuclear energy."

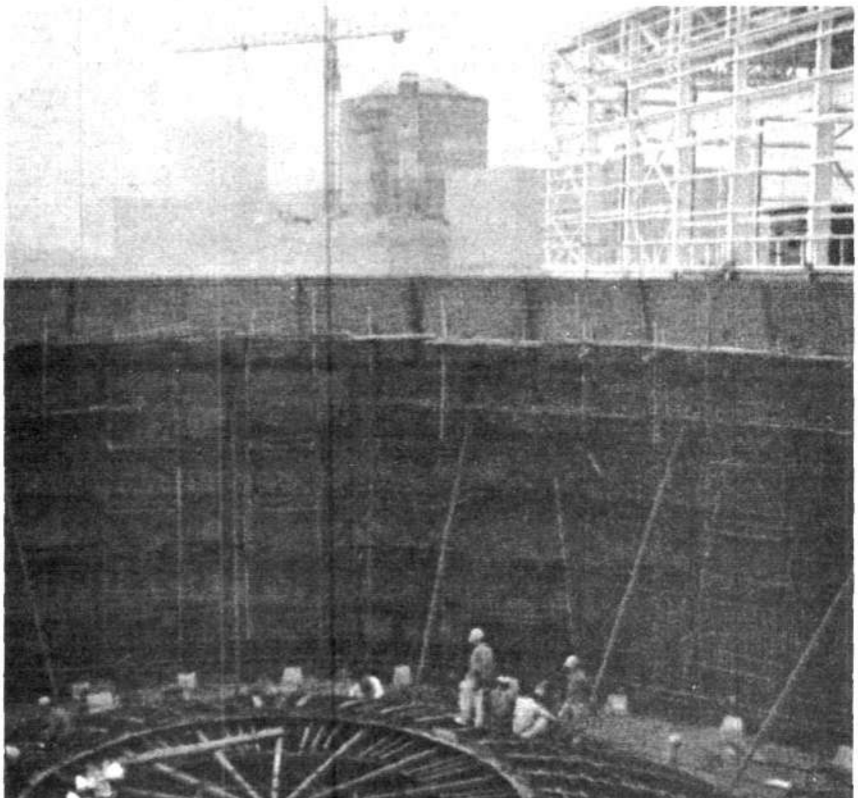
The pronuclear group within the Non-Aligned movement hopes to move up the timetable for a United Nations conference on the peaceful uses of nuclear energy to August. The advanced countries have thus far refused to agree on an agenda, after three preparatory committee meetings in Vienna over the past year and a half. A fourth meeting is to be held at the United Nations in early April, in a final effort to reach agreement on an agenda.

Why Nuclear Energy?

Since December 1953, when President Eisenhower gave his famous "Atoms for Peace" speech at the United Nations stating that nuclear power must be developed and made available to the entire world, it has been known that this energy source would be the cheapest and most abundant known to mankind. Although this fact has been challenged and debated over the past 30 years, and especially during the last 10 years, the original claims continue to be proven correct year after year, as actual nuclear power plant operating experience accumulates.

France's recently published record of its last nine years of electrical power generating costs now shows nuclear electricity at one-half the cost of electricity generated from conventional fossil fuels—in 1981 francs, 14.8 centimes per kilowatt-hour (about 2.7 cents) compared to 28.2 c/kwhr (about 5.2 cents). See Table 1. Coal-fired stations provide most of France's fossil fuel-generated power, with oil accounting for only about 20 percent of its generating capacity. If oil were the basis of all France's conventional generating capacity, the cost of this electricity would be anywhere from four to seven times greater than nuclear-generated electricity. Similar statistics are readily available from electrical power generating stations in the United States and elsewhere.

It is facts such as these that answer the nuclear energy question for the developing nations. Most of these nations have neither coal nor oil as a



Ministry of Science and Technology, Republic of Korea

Korea is going nuclear. By 1986, the Republic of Korea expects to produce 4,766 MWe in nuclear plants—27.1 of all the nation's electricity. By 1991, the figures will jump to 11,216 MWe and 41.5 percent of the nation's electricity. Shown here is the containment vessel for nuclear unit number 5, now under construction; in the background are nuclear units 1 and 2.

Table 1
GENERATING COSTS OF FRENCH POWER STATIONS*

Year	Conventional stations Cost (c/kwhr)	Conventional stations Operating hours	Nuclear stations Cost (c/kwhr)	Nuclear stations Operating hours
1973	12.1	4,980	18.7	4,993
1974	19.0	4,398	17.0	4,832
1975	19.7	3,985	12.7	6,004
1976	17.0	5,107	15.6	5,594
1977	19.0	3,793	14.3	4,679
1978	17.4	4,071	11.6	5,798
1979	18.1	4,222	12.0	5,221
1980	21.7	4,015	12.4	5,958
1981	28.2	2,943	14.8	5,470

* *Costs in constant 1981 francs (centimes per kilowatt-hour).*
Source: Electricité de France.

natural resource and therefore must import them. In most cases, they import oil because it is much easier to transport and distribute in nations with poor transportation infrastructure.

Hence, the developing countries pay extremely high costs for electricity. In fact, the costs are so high today, and economic conditions in the developing countries so depressed, that they are in most instances forced to go without additional generating capacity. The decision facing developing countries, therefore, is straightforward. They must have nuclear energy to get the electricity they need to expand and raise the living standards of their populations, or no development will occur.

The conclusion is the same for developing nations with reserves of fossil fuel, in particular the oil countries of the Middle East. These countries have large but finite resources of oil; they must use their oil income to put in place the infrastructure necessary to generate electricity after their oil runs out, perhaps 20 years from now. The only solution to their future energy needs is nuclear power, and they know it.

Finally, any developing nation that hopes to progress over the next decades must invest in the education of its population, preparing it to assimilate current and future technologies. National nuclear development programs address this objective—the training of a core group of skilled workers and engineers—at the same time that they are solving the energy problem.

Some History

In 1973, the International Atomic Energy Agency (IAEA) completed a study of the future nuclear power plant requirements of the developing nations during the period from 1981 to 1990. This study, "A Marketing Survey for Nuclear Power in Developing Countries," presented a country by country list of the amount of nuclear power that would be needed, and forecast a total of 355 nuclear units with a combined capacity of 220.7 gigawatts-electric (GWe) in operation by that period.

Dennis Small/NSIPS

Brazil's Angara 1 nuclear plant near Rio. Construction on two companion plants has come to a halt because of IMF restrictions.

Because of the international economic crisis of the mid-1970s and the environmentalist attacks on nuclear power that followed, nothing near this goal is now expected to be achieved. Instead, official estimates are now forecasting 35 GWe by 1990 in approximately 20 units, less than 16 percent of what is needed.

However, in recent months, several developing nations have begun to try to turn this situation around, making requests for combined economic aid and nuclear power plant trade deals in order to get the ball rolling again. Because France has been particularly receptive to such deals, many of these nations are approaching French officials.

The most recent such request was that of King Hassan II of Morocco. French President Mitterrand said in response that France would sell Morocco the reactors needed to meet the needs outlined by Hassan. The exact number of reactors is not yet known; however, Morocco's current long-range plans call for one 600-megawatt-electric unit within 10 years and another four 600-MWe units by 2000.

Much of the recent interest in nuclear energy has come from the Middle East—a development that has not gone unnoticed by political forces with a vested interest in keeping the area undeveloped and in turmoil. Recently the antinuclear *Middle East* magazine, published in London, railed that prestige-hungry Third World countries are being duped by "Western salesmen" into buying nuclear power plants just at the point that nuclear energy is being rejected as too costly and unsafe by the Western countries ("A Brave New Nuclear World?" Feb. 1983, p. 15).

A comprehensive table that accompanied the article, showing near-term and long-range plans of the Mideast countries, shows why the antinuclear lobby is complaining (see Table 2). In just 14 developing nations of the Middle East (excluding Israel), more than 10 GWe of nuclear power is now planned for the next 8 to 10 years. If the other developing nations begin to revive their nuclear growth plans again with similar vigor, as many of them are now doing, the total nuclear generating capacity in 1990-1992 will be 65 to 70 GWe. This is double the maximum 35 GWe now forecast for the developing nations by that time.

Middle East magazine laments that many Arab leaders have come out strongly for nuclear energy. Syria's Dr. Adnan Mustafa, assistant secretary general of the Organization of Arab Petroleum Exporting Countries, "believes nuclear power is likely to grow fourfold before the end of the century." Dr. Munir Ahmad Khan, chairman of Pakistan's Atomic Energy Commission, is quoted as saying, "nuclear power represents both a well-developed and proven technology. . . .

"[It] remains the only viable alternative for meeting the future electric power needs of the world for the coming decades."

Other Programs

The desire to go nuclear is also present in developing nations outside the Middle East. In Asia, for example, Indonesia's nuclear energy development program took a major step forward last October with the signing of a final contract with West Germany's KWU subsidiary Interatom for the construction of a 30-MWt research rector. (Because research reactors do not produce electricity, they are rated according to their thermal output, megawatts-thermal—MWt.) This reactor will be the centerpiece of a major new nuclear research center being built at Batan for the Indonesian Atomic Energy Organization.

Indonesia, furthermore, is already planning for its first nuclear power generating plant and has picked two possible sites for a 200- to 400-MWe

Table 2
NUCLEAR POWER IN THE MIDDLE EAST

Country	Nuclear power plans		Installed electrical capacity—all types (MW)	
	Immediate	Long-Term	Present	Planned
Algeria*	Feasibility study under way (France)	1 × 600 MW by 1990	2,230 1,280 (under construction)	
Egypt	1 × 1,000 MW at Al-Daaba (France or W. Germany?)	8 × 1,000 MW by 2000 (2 each from U.S., Canada, France, and W. Germany)	4,500	22,000 by 2000
Iraq*	600 MW under discussion (France)		3,790	6,400 by 1985
Jordan			300	600 by 1990
Kuwait*		3,600 MW by 2000 (plans frozen)	2,650	4,500 by 1985 12,000 by 2000
Libya*	440 MW (possibly 2) (USSR)			
Morocco		1 × 600 MW by 1983 4 × 600 MW by 2000		
Saudi Arabia*		Under consideration	4,185	16,250 by 1985
Syria		600 MW by 1991 6 × 600 MW by 2000		
UAE*		1 plant by 1991	1,208	2,772 by 1985
Turkey	600 MW 1986 (Switzerland or W. Germany)	1 × 600 MW by 1982 10 × 600 MW by 2000	6,000	30,000 by 1990
Iran*	1 × 1,200 MW at Bushehr (W. Germany/Pakistan)	(Plans for 23,000 MW by 2000 dropped)	12,000	75,000 by 1994
Israel	To build own plant (after talks with U.S. stalled)	Still under discussion	2,200	3,500 by 1985
Pakistan	137 MW operating at Karachi; 600 MW to be built at Chasma	8 × 900 MW planned for Chasma	4,064	21,800 by 2000

* OPEC countries
Source: "A Brave New Nuclear World," *Middle East*, Feb. 1983

unit that will be ordered some time in 1984. The plant will be located on Java, some 200 to 300 miles east of Jakarta.

Late last year, Bangladesh requested that the IAEA sponsor the construction of a small- to medium-size demonstration nuclear power plant of 200 to 400 MWe. The site has already been chosen, and some clearing activities are already under way. When the agreement is finally signed, hopefully later this year, it will be a joint effort between Bangladesh and other IAEA member nations, both developing and reactor-manufacturing nations, with the goal of demonstrating the economics and performance of advanced technology small- to medium-sized nuclear power plants.

India, which for several years now has had the capability to build its own nuclear power plants, has just announced its decision to design and build a dozen 500-MWe nuclear power plants before the end of the century. This reactor design represents an increase in size of two and one-half times over India's standard 200-MWe Candu reactor, which it has been building for the past eight years. India's electricity grid will have the capability of supporting larger plants in the future; moreover, the cost of electricity will be lower with these larger plants because of the economies of scale. India's current plans are to have an installed nuclear capacity of 10,000 MWe by the year 2000, entirely manufactured with Indian technology and fueled with Indian uranium.

In South America, Colombia is the newest member of the nuclear energy camp. Argentina will build a 3-MWt research reactor for the Colombian Nuclear Affairs Institute as the centerpiece of its planned nuclear center. Argentina previously negotiated a similar deal with Peru; and negotiations for similar centers in Montevideo, Uruguay, and in Guatemala are taking place. As a follow-up to establishing their own nuclear expertise, many of these same nations are already probing reactor suppliers for small- to medium-size power plants of 200 to 400 MWe each, with orders expected over the next two years.

In addition to those shown in Table 2, the nations of Gabon and Nigeria in Africa have each let France know of their interest in constructing at least one nuclear power station over the next six to eight years. Other African nations have expressed their desire to establish nuclear energy research centers.

The Future

According to official IAEA statistics, at the end of 1981 there were nine developing nations with 34 nuclear power reactors in operation or under construction, with a total capacity of 21 GWe. The IAEA expects that the number of developing countries with nuclear power programs will increase to about 20 by the turn of the century. This represents only about 20 percent of the nations that are considered developing nations, a rather small portion compared to total Third World electricity needs presented in the IAEA's own 1973 forecasts.

The assessment of the actual potential and desire for nuclear power in the developing nations is certainly not reflected accurately in these latest IAEA projections. An estimate of a 65 to 70 GWe in operation by the 1990-1992 period is more representative of the actual potential. And this rate would translate into 140 to 150 GWe operational by the turn of the century.

Making this happen depends on a solution to the current economic depression, a solution that features extension of low cost credit to the developing countries to enable them to buy nuclear and other advanced technology from the advanced countries. This will require the implementation of a New World Economic Order, following a renegotiation of the now unpayable Third World debt, both items that are under intense discussion within the Non-Aligned movement.

—Jon Gilbertson
Director of Nuclear Engineering, Fusion Energy Foundation

The Price of Not Going Nuclear— 115 Million Third World Deaths

At least 115 million people have died over the last 15 years—most of them in the Third World—as a result of the obstruction of nuclear power development worldwide, according to a demographic study undertaken by the Fusion Energy Foundation.

The study estimates that at least that many people have died unnecessarily as a result of the slower economic growth, poorer health care, and impeded urbanization caused by antinuclear policies, in particular, those of the United States—potentially the greatest supplier of nuclear exports to the developing sector.

The relationship between nuclear power and life expectancy is mediated by the higher economic growth rates attainable with nuclear power. The FEF researchers estimated that economic growth worldwide could have been at least 3 percent higher a year between 1965 and 1980 if the 200 or more plants scheduled had in fact been built. Instead of investing in nuclear power, most nations diverted capital into less efficient modes of energy production—oil and coal-based electricity—resulting in lower economic growth and lower productivity increases.

Based on historical trends, the researchers assumed that balanced economic growth can, in most developing countries, increase life expectancy by 1.2 years for each 10 percent growth in per capita gross national product, up to the point that life expectancies reach approximately 70 years. Under the high nuclear investment strategy projected by the U.S. Atomic Energy Commission in the 1960s—3,500 full-size plants by 1990—world population would have been 115 million larger than it is today.

If current trends continue, the study projects that by 1990 slower economic growth attributable to slow nuclear energy development will result in a world population 250 million smaller than if nuclear energy had been developed at the rate foreseen by the AEC.

The Nuclear Freeze: For Fascism and War

A majority of the Americans supporting the nuclear freeze movement, *who sincerely want to prevent war and* bring about world development, would be shocked to find out who else is in the international "peace" movement—the proterrorist Green Party of West Germany, Libyan dictator Muammar Qaddafi, leaders of the neo-Nazi movement, one worlders whose goal is to eliminate the nation state, and Aquarian cultists for whom nuclear holocaust is the punishment for presumptuous scientific inquiry.

What unites these groups, who are the real controllers of the freeze, is a shared hatred of technological progress and democratic forms of government. A mass-based anti-nuclear-weapons movement is for them a vehicle to insinuate their own policies, including the suppression of peaceful nuclear energy and the elimination of sovereign nation states committed to industrial development.

Philip Ulanowsky/NSIPS

"'Our goal is to make the Western democracies ungovernable," said Green Party member of Parliament in West Germany Roland Vogt. Shown here are nuclear freeze demonstrators in New York City.

The Greens

"Our goal is to make the Western democracies ungovernable," said Roland Vogt, an executive committee member of West Germany's Green Party (Die Grünen), which seeks to replace the industrialized nations of Europe with a feudal "Europe of the regions" free from the blight of modern technology. Vogt, who was formerly a member of the Brussels-based Ecoropa organization, is one of the 27-member ecologist fraction elected to the West German parliament in March 1983. (Like another political movement in Germany's history, the Greens capitalized on the spreading unemployment and discontent with the government's austerity policies.)

Leaders of the Green Party are in constant communication with the U.S. freeze movement and helped to plan International Disarmament Day in New York City June 12, 1982. The Greens are also in contact with Libya's Qaddafi, who has sent hit teams against the U.S. President and who said in a January 1983 interview with French and American journals that he thought "Hitler was right" in fighting a "Zionist subversive plot" against Germany in the 1930s. In March 1982, several leaders of the Green Party, including Vogt, met with the Libyan dictator in Vienna under the sponsorship of the Austrian Society for North-South Relations to plan the targeting of NATO missile installations in Sicily and elsewhere in Europe by the Greens.

Following the West German elections, Petra Kelly, founder of the party, told a press conference, "We cannot be less militant than other members of the movement just because we have been elected." She added that there would be "training programs in nonviolence for all of the peace movement"—nonviolence presumably like the bloody attacks on police at the Brokdorf nuclear site and Frankfurt airport demonstrations. Kelly also predicted a wave of "spectacular actions such as hunger strikes and sit-ins," ostensibly to protest the stationing of the Pershing II missiles on West German soil.

(Despite her radical pronouncements, the former aide to freeze-supporter Sen. Edward Kennedy has a standing invitation to address the New York Council on Foreign Relations.)

Another new Green Party Bundestag member, Juergen Reents, is former publisher of the leftist weekly *Arbeiterkampf* in Hamburg and an adherent of the "direct action" current inside the Green Party. Still another, Otto Schily, is a West Berlin lawyer who gained notoriety for defending the Baader-Meinhof terrorist gang. At a press conference after the elections, Schily assured his followers that the Green representatives in parliament—who sit on defense, domestic security, and other sensitive committees—would broadcast any secret information they hear to the general public.

Nazi Roots

Several Israeli military and intelligence officials have characterized the Greens as fascists "reminiscent of the precursors to the Nazis in the late 1920s and early 1930s." On Feb. 14, the mass-circulation Israeli daily *Ha'aretz* carried a prominent news item from its Bonn correspondent on the theme that the Greens are the "new anti-Semites of Germany." The same day, in a statement to the *Executive Intelligence Review*'s Middle East correspondent, Israeli member of parliament Ehud Olmert denounced recent Green Party propaganda as containing "positions and views which are traditionally anti-Semitic."

In fact, there is a straight line between the antitechnology Greens and the Nazi *wandervogel* movement, through a little-known organization called the World Alliance for the Protection of Life (Weltbund zum Schutz des Lebens). The Weltbund was founded in the early 1950s, shortly after the fascist networks that put Hitler in power reconstituted themselves in the Neo-Nazi International, run out of Malmö, Sweden and Lausanne, Switzerland. The founding document of the Weltbund was written by Austrian writer Guenther Schwab, a close friend of former Swiss Nazi Party banker François Genoud. Schwab's book, *Dance with the Devil*, predicts a conspiracy by the devil to destroy the world through industrial pollution.

At a time when most of today's Greens were not even born, the Weltbund was whipping up the "ban the bomb" movement in West Germany in the early 1950s, in collaboration with the Bertrand Russell-led British side of the movement. The actual aim was to prevent the spread of peaceful nuclear energy for development. A Weltbund brochure of the time stated: "The so-called mastery of space-flight technology and the uncontrollable effects of nuclear fission both prove to mankind the doubtfulness of his technological progress, and point him back to his confined globe, to the limits, boundaries, and laws of life."

The Weltbund subsequently organized the first protest against a West German nuclear power station in the late 1960s and was the transmission belt for the *wandervogel* ideology of the antinuclear protestors at Wyhl and Brokdorf, the birthplace of the Green Party.

The Cults

The international "peace" movement has still another side to it—religious cults whose prominent members include former secretary of defense Robert McNamara, now a supporter of the freeze. At the center is the Lucis Trust—formerly the Lucifer Trust—which was founded in the 1920s by Alice Bailey, the head of the New York Theosophical Society, and her husband, Foster, head of Scottish Rite Freemasonry in the United States. The cult doctrines of the moon-worshipping Lucis Trust include the belief that nuclear energy is too powerful a living energy source to be in the hands of individual nations; it should be controlled by a world government such as the United Nations.

Today, the Lucis Trust has an office in the U.N. and runs the Temple of Understanding, which purports to be an interdenominational meditation center, at the U.N. and in the U.S. Capitol Building. McNamara is publicly affiliated with the U.N. Temple of Understanding and other offshoots of Lucis Trust.

Adherents of the Tara Center, one of the Lucis Trust spinoffs, believe that the final conflagration is coming in the form of nuclear war, but that Lucifer, god of light, will step in in the nick of time to prevent the holocaust. The New York-, Amsterdam-, and Geneva-based Tara cult is now directing its members to join the ranks of the nuclear freeze movement.

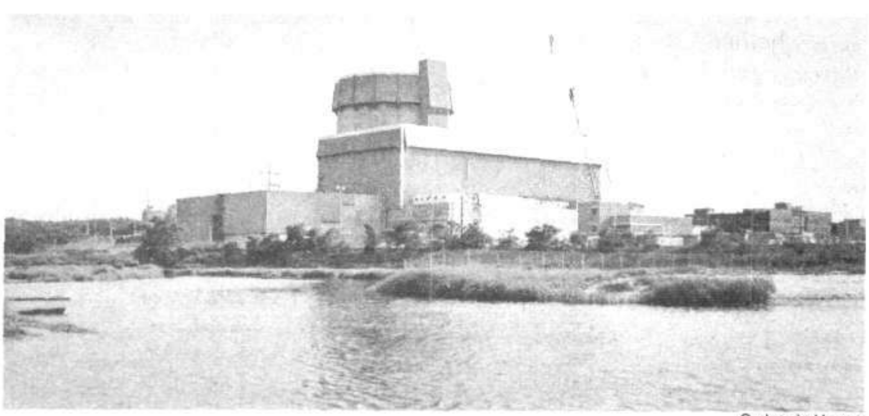
The Lucifer and one worldist cults are not to be dismissed as the extremist fringe of the freeze movement—they are directing its day-to-day policy interventions, as the case of Robert Strange McNamara illustrates.

McNamara has as much as stated that his motive for supporting the freeze is to shift military spending away from advanced R&D to a conventional arms buildup for more Vietnams. In a letter to the chairmen of the Senate and House budget committees dated March 2, McNamara cited "ballistic missile defense" (for example, space-based beam weapons) under the heading "setting unrealistic objectives." The letter, which was also signed by former defense officials Cyrus Vance, McGeorge Bundy, and Elmo Zumwalt, commented, "It makes no sense to spend very large sums on things we do not know how to do."

Largely unreported and unnoticed at the time, the nuclear freeze resolution passed by the House Foreign Affairs Committee March 8 contained an amendment, sponsored by the World Federalist Society, calling for the abrogation of U.S. sovereignty over the nation's military capabilities. The amendment, introduced by Iowa congressman James Leach, would place U.S.-Soviet arms negotiations in the context of the McCloy-Zorin agreement of 1961, a crusade of the World Federalists for decades. This never-implemented procedural agreement between John J. McCloy and Valentin Zorin, U.S. and Soviet arms negotiators, respectively, advocates the establishment of an international military force under the control of the U.N. and staged, total disarmament overseen by the U.N.

In the context of the deepening world economic crisis, the revival of McCloy-Zorin coheres with the attacks on national sovereignty by the U.N., International Monetary Fund, and other supranational agencies, and their efforts to police debt collection and austerity policies in the Third World and advanced sector.

—Lydia Schulman



Carlos de Hoyos

The just completed Shoreham nuclear plant in New York is idle because New York Governor Mario Cuomo decided to boost the antinuclear freeze movement by maneuvering to keep the plant from starting up.

Helen Caldicott's Lethal Comedy of Errors

by Howard C. Hayden


UPI
Caldicott: If you think your doctor doesn't know what he's doing, call the plumber.

Editor's Note

This new column will provide readers with vital information about the so-called scientists who oppose technological progress.

Helen Caldicott, the subject of this month's Profile, has for the last decade made a career out of writing and lecturing on the mythical dangers of radiation. In the early 1970s, she instigated a national movement against nuclear power in her native Australia around the issue of French nuclear weapons testing in the Pacific. Caldicott, a pediatrician, moved to the United States in the mid-1970s, joining the staff of the Children's Hospital in Boston.

The author, Dr. Howard C. Hayden, is associate professor of physics at the University of Connecticut.

Contrary to popular opinion, Helen Caldicott, the antinuclear crusader, doesn't get everything wrong. Most notably, the title of her book *Nuclear Madness*[1] tells exactly what's in it: madness.

Finding herself in disagreement with all of the experts on nuclear power and on the health effects of ionizing radiation, she simply says, *"Don't entrust your life to 'experts.' "* One wonders whether she would have her house wired by the local, friendly milkman instead of the electrician. She apparently believes quite seriously that the generation of electricity should not be done by experts and that the health effects associated with various means of electrical generation are better understood by laymen. In any case, hers is a simple way of avoiding intellectual conflict: Just declare the experts misfits.

If you think your doctor doesn't know what he's doing, call the plumber. This, in fact, is the approach Caldicott takes, and it is an attitude that makes it all the easier for her to obtain so-called information. By declaring the experts "dumb, stupid, or highly compromised,"[2] she automatically elevates to the status of real experts the infamous few who have been repeatedly rebuffed in the scientific literature for faulty arguments, faulty statistical methods, and meaningless data: Gofman, Sternglass, and Mancuso.[3]

Presumably the American Medical Association has been added to her list of dolts as well, because it has compared the safety aspects of various methods of generating electricity and found nuclear generation the safest.

That many other scientific societies, not the least of which is the American Nuclear Society, have also come to the same conclusion is also ignored by Caldicott. It would indeed be damning to her case to admit that, say, the Professional Engineering Society is on record as favoring nuclear power, and perhaps even more so to admit that numerous Nobel Prize winners—indeed all of them with expertise in nuclear physics—support nuclear power, so she doesn't even bring the subject up. It is somehow easier to trot out a few disgruntled ex-employees of the nuclear industry.

The Half-Life Argument

It is worthwhile considering a few false arguments used repeatedly by Caldicott that require only a trifling amount of technical background to understand. Two of them relate to half-life. She correctly defines half-life as the length of time required for the quantity of a radioactive substance to be diminshed by half—and then fails to understand the implications.

First, a long half-life implies a low radioactivity. That is, if there are two radioactive samples with an identical number of atoms, the one with the longer half-life will eventually give off the same number of emissions, but it will take a longer time doing it. It decays less rapidly; consequently, it is less radioactive. Caldicott makes the benign sound truly awful, and the extremely dangerous sound moderately safe.

This is a very important point and bears repetition another way. If the reader were given the choice of sitting in the same room with either of two radioactive samples—identical in number of atoms and mode of decay—and the half-lives were two days and two million days, respectively, the reader would be wise to choose the one with the longer half-life, because it is a million times safer!

Caldicott misses this point *every time* she mentions the topic. (On this point she is consistent.) In making the case against nuclear power on the basis of some long half-lives, in fact, she presents a good case for the affirmative!

Her case gets even worse, again because of her inability to understand half-life. Nuclear power is not without some competition, of course. Coal, for example, is relatively abundant and easy to use. It does produce some chemical wastes; they have a half-life of forever and will be on Earth with us always, with no diminution whatsoever in their toxicity. Nuclear wastes are radioactive, but they are not chemical toxins. When they are gone, they are gone forever; but the wastes from coal remain.

Mythical Hazards

Another point that requires but little knowledge to understand pertains to scenarios. The number of people who meet their demise through caffeine poisoning is quite small, if there are indeed any, despite the hundreds of millions of cups of coffee and cola drunk daily, and despite the fact that they can cause death. What is *potentially* hazardous need not present any hazard at all. What matters is *actual* exposure.

Typical of Caldicott's logic is her concern with krypton, which, she says, "has been found to concentrate in the upper layers of the abdomen." Most Superman fans will recognize that whereas *kryptonite*, a mythical solid substance, makes Superman weak, *krypton* is an inert gas that makes no chemical compounds at all. Krypton entering the atmosphere remains there, diluting itself in the entire atmosphere. By the time any of it is inhaled, it is thoroughly decayed because of its short half-life.

Caldicott would have us worry about krypton, quite as if chemists wouldn't laugh until their sides hurt. Baldly put, she seems unable to distinguish between a poison in the body and one that is neither in the body nor capable of getting into the body. Nor, for that matter, does she distinguish between chemically active and inert species.

No discussion of Caldicott would be complete without reference to her thoughts on plutonium. That nobody has ever had a health problem caused by plutonium poisoning doesn't seem to be relevant to her, as she continues to press the claim that "one pound, if uniformly distributed, could hypothetically induce lung cancer in every person on earth."[4]

Plutonium is toxic, to be sure, about one fortieth as toxic as radium, but it's not as bad as Caldicott pretends. In the lung, a milligram is a toxic dose; a pound is 450,000 milligrams; therefore, a pound of plutonium, if distributed uniformly, could hypothetically induce 450,000 lung cancers. She is off only by a factor of 10,000, even given the ridiculous scenario.

Energy Equals War

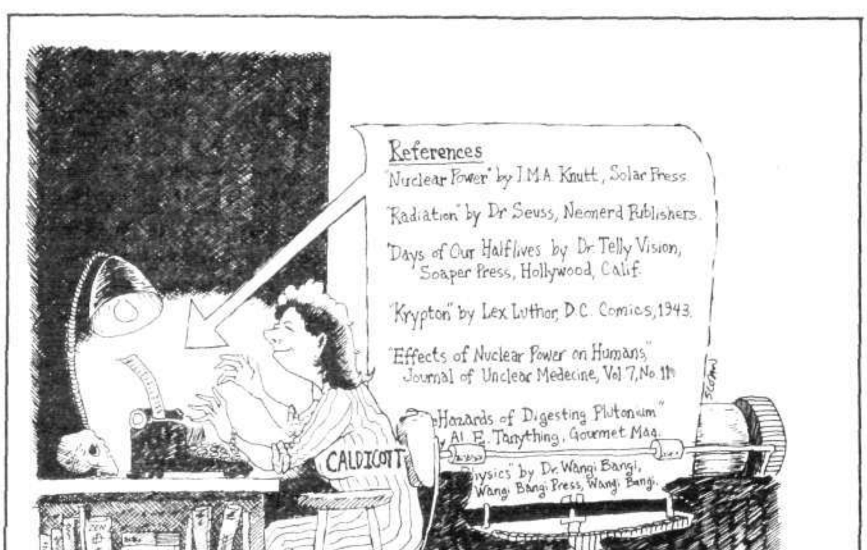
Now, we might ask, why has Caldicott shifted her focus to nuclear warfare? It is, of course, a reasonable change of direction from at least three points of view. First, all would agree that nuclear warfare is worse than nuclear power. Second, the antiwarfare talks draw larger crowds and pay better. Third, the case against nuclear power was, albeit unwittingly, a case for nuclear warfare.

It is evident from the first paragraph in *Nuclear Madness* how Caldicott discovered that it is even better to be opposed to nuclear warfare than to be opposed to nuclear power. In fact, she links them in the same way that electricity and electric chairs are linked, or in the way gasoline and molotov cocktails are: *Any source of energy can kill.* Molotov cocktails are bad; therefore, gasoline is bad. Nuclear weapons are bad; therefore, nuclear power is bad.

There is considerable irony in her recent fervent opposition to warfare, because she has spent years doing things that are likely to bring us to the brink. It is hard to imagine a more likely cause of a nuclear confrontation than an acute shortage of energy: Recall that Japan attacked Pearl Harbor just after President Roosevelt embargoed oil headed for Japan. Recall also the militant hostility of many Americans toward the Arabs because of their oil embargo against us, even though the actual energy shortfall was only about 1 percent.

Energy independence may not guarantee that we never become involved in nuclear confrontation, but a life-threatening energy shortage could indeed make an otherwise rational country desperate enough to take drastic action. Caldicott has stridently resisted efforts to strengthen our energy position through nuclear generation; indeed, she has worked long and hard to weaken it.

If perchance the reader believes that Caldicott is simply an errant scholar at least on the side of health and safety, there is reason to pause. Her Physicians for Social Responsibility group is adamantly opposed to (1) having civilian hospital facilities for tending the wounded in case of large-scale disaster (including, but not necessarily limited to war) and (2) procedures for evacuation in case of military attack.



Notes

1. *Nuclear Madness: What You Can Do* (Brookline, Mass.: Autumn Press, 1979).
2. The *Boston Globe*, May 5 and May 28, 1978.
3. Dr. John Gofman, nuclear biochemist at the University of California at Berkeley; Dr. Ernest Sternglass, Department of Radiology at the University of Pittsburgh; and Thomas F. Mancuso, a researcher at the University of Pittsburgh.
4. Since plutonium isn't easily made airborne, there seems to be no way of creating this scenario short of asking Caldicott's Physicians of Social Responsibility to stuff plutonium into everybody's lungs.

The Beam Weapons Debate

The Issue Is 'Technological Optimism'

"There is one fundamental difference which I have with you. I don't believe in technological optimism."

The remark was made by Dr. Bernard Feld, a Massachusetts Institute of Technology physicist who advises the nuclear freeze movement, in a debate with *Fusion* editor-in-chief Dr. Steven Bardwell before a packed audience at MIT in January. But it is the same point that was made by all of the freeze leaders whom Bardwell and other FEF spokesmen debated this winter, whose chief objection to defensive antimissile beam weapons is that their development would let the genie of "uncontrolled" technological growth out of the bottle.

Feld, MIT's George Rathjens, and Bill Ramsey, a coordinator of the St. Louis-based Nuclear Weapons Freeze Campaign, all said in response to Bardwell: We have to stop the arms race. The arms race forces the continual development of new technologies.

This association of technological progress with a destructive "arms race" identifies the actual aims of the nuclear freeze movement. Before hundreds of college students, on campuses from Cambridge to Seattle, Bardwell exposed the freeze as a cover for zero-technological growth and a conventional arms buildup, policies that will mean genocide in the Third World and a heightening of the tensions leading to war.

The model for the freeze-supported reorientation of U.S. military policy, to prepare the United States to fight "limited" wars over resources in the Third World, was Robert McNamara's war in Vietnam, Bardwell said.

Many of the freeze leaders admitted that they support a conventional buildup, claiming that this will not raise the "nuclear threshold." Regarding the now public endorsement of the freeze by McNamara, former CIA director William Colby, and other Vietnam War

Stuart Lewis/NSIPS

Steven Bardwell (right) and WMCA talk show host Barry Farber.

Keegan, Bardwell Counter Freeze Advocate on WMCA

Major General George Keegan, the first American military figure to identify the Soviet lead in the development of beam weapons in 1977, and *Fusion* editor-in-chief Dr. Steven Bardwell debated freeze spokesman Dr. Michio Kaku on the Barry Farber show on WMCA radio in New York March 9. Kaku is a professor of nuclear physics at City University of New York.

While both Bardwell and Keegan documented that a two-phase beam weapon development program could provide complete area defense against all-out nuclear attack within 10 years, Kaku kept repeating that beam weapons are impossible—"The laws of physics say it can't be done." When Bardwell cited the technical references that prove the opposite, Kaku replied, "Those references don't exist." "You're five years behind the times," Bardwell told him.

Kaku ridiculously maintained that there is no solid proof of Soviet ABM capabilities, and that "80 to 90 percent of nuclear physicists in the United States" would agree with him that beam technologies were not yet understood, although General Keegan and Bardwell presented various solid proofs of such beam technologies. Keegan noted that there is now near unanimous agreement that he was right in his assessment that the Soviet Union had a three- to five-year lead in 1977 in the development of beam technologies and is still ahead of the United States. The phase down in U.S. military capabilities initiated by former Secretary of Defense Robert McNamara, he said, had by 1971 left the United States with only a 1 percent capability of inflicting serious damage to Soviet military targets.

architects, they "have changed their minds," say the freeze leaders. According to freeze coordinator Ramsey, "You can't doubt the sincerity of Robert McNamara."

Strange Allies

The same antitechnology arguments made by the freeze appeared in the *Agenda '83* document issued by the Washington, D.C.-based Heritage Foundation Jan. 11. In its analysis of U.S. defense policy, the austerity-minded foundation explicitly attacked "long-shot" advanced R&D, emphasizing a conventional military buildup and the cost-accounting approach to military strategy made notorious by McNamara.

In response to this document and related events, the FEF escalated its campaign for directed energy beam weapons development with a press conference in late January exposing the efforts afoot in Washington to kill all advanced R&D items in the Defense Department budget.

Lyndon H. LaRouche, Jr., a member of the board of directors of the FEF and a noted economist, charged the Heritage Foundation with leading such efforts, acting on behalf of British policy circles, who have an "understanding" with Soviet head of state Yuri Andropov, to sabotage the Reagan administration's commitment to advanced military R&D (this would be the first step in an agreement between the superpowers to halt the "technology race").

LaRouche also warned against the nomination of Kenneth Adelman as head of the U.S. Arms Control and Disarmament Agency, noting that Adelman enthusiastically endorsed the Carter administration's PD-59 memorandum on flexible response, a policy that entails a conventional arms buildup and deployment of tactical nuclear weapons for "limited" conflicts, in the Heritage Foundation journal, *Policy Review*, in summer 1981.

The Economics of Technology

A major thrust of the FEF's beam weapons campaign has been to demonstrate the positive relationship between advanced technology military programs and generalized technological progress. Directed energy beam weapons not only would make nuclear

Continued on page 62

Washington

Reagan Budget Retrenches On Energy, Space Programs

The administration's fiscal year 1984 budget request for the advanced energy and space programs continues a two-year trend of ending federal support for promising medium-term energy technologies and prohibiting the initiation of major new projects in space and fusion energy research that would bring about longer-term capabilities.

The "free market" economic ideology of the Reagan administration—which posits that if something is promising, industry should pay to develop it—plus the overall cutbacks in

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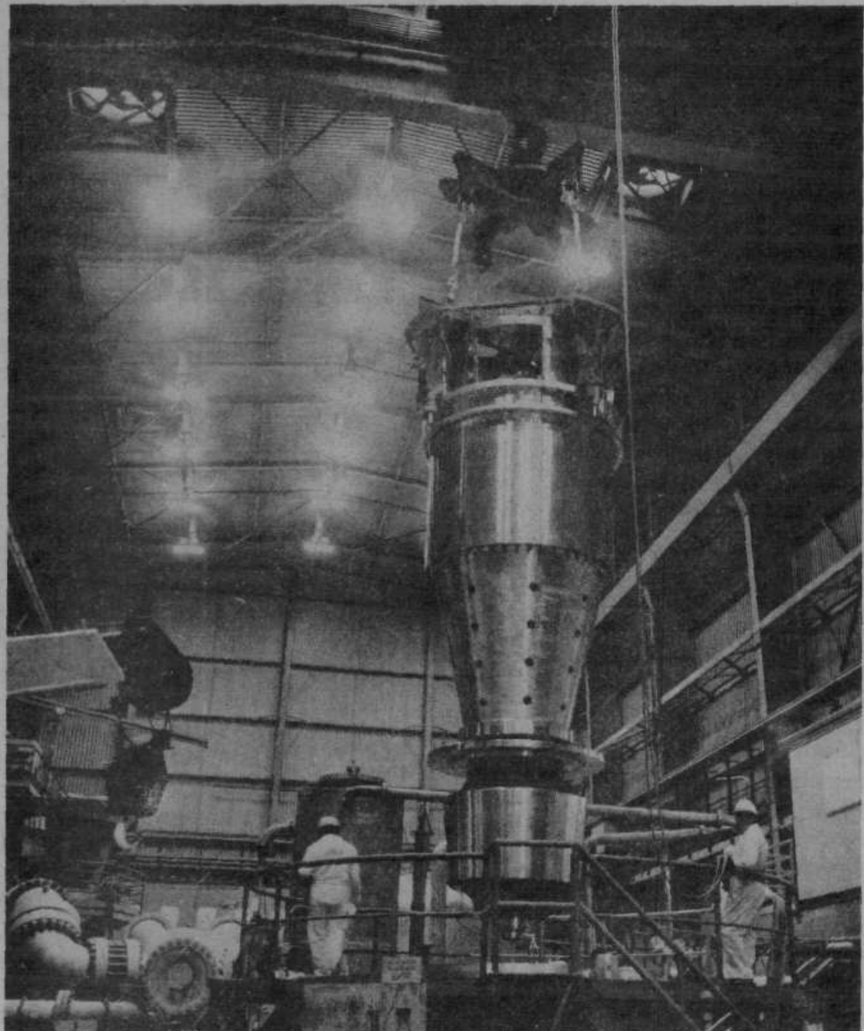
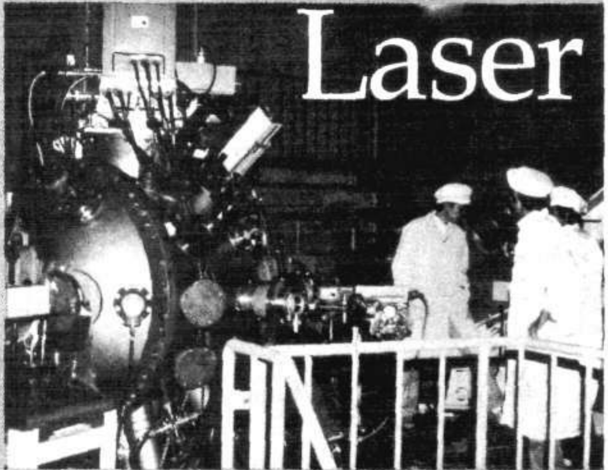


Clinch River Breeder Reactor Project

Because the Clinch River Breeder reactor is viewed by the administration as a promising near-term technology, its budget has been cut and it is left to "industry" to fund the completion of the project. Shown here is the testing of Clinch River's prototype sodium pump in June 1982. The six sodium pumps in the breeder reactor will each be capable of pumping 33,700 gallons of sodium per minute.

The X-Ray Laser



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A Revolution in Defense, Medicine, and Industry

by Charles B. Stevens

At the U.S. national laboratories today, scientists are perfecting a technology—the X-ray laser—that will revolutionize our lives. First, as the basis for a second-generation defensive beam-weapon system, the X-ray laser will provide America with near invulnerability against an all-out nuclear attack, thus ending the threat of nuclear holocaust. Second, and perhaps even more momentous, X-ray lasers will give scientists the ability to see what goes on within living cells on the subatomic level, without killing the tissues, thus bringing biology and medicine a quantum leap forward. With X-ray lasers, researchers can make three-dimensional motion pictures of important biological processes such as the replication of DNA or the synthesis of proteins. In addition, the same technology has broad-based potential applications for technology and industry, from the diagnosis of fusion shock waves as they propagate, to new methods of mining and processing, as well as the generation of entirely new materials.

Some of these important applications, discussed below, include X-ray lithography for the fabrication of microelectronic components, electron spectroscopy for chemical analysis, surface and radiographic nondestructive testing of metals, microradiography, radiochemistry, X-ray crystallography, and photonuclear processes.

X-ray lasers for civilian applications use high power infrared lasers as an energy source. Shown here is the Gekko 12 laser at Japan's Institute for Laser Engineering.

How Lasers Work

Light amplification through the stimulated emission of radiation—or the *laser*, as the process is abbreviated—has existed only since 1960. However, the scientific principles upon which it is based emerged in the early part of this century as specific applications of the fundamental advances made possible by Bernhard Riemann's relativistic physics, set forth in a series of groundbreaking papers in the mid-19th century.

Specifically, there was the work of Max Planck, the early work of Albert Einstein on the interaction of matter with electromagnetic radiation or light, and the wave mechanics of Erwin Schrödinger, which he noted was inspired by Riemann's *concept of the shock wave. Schrödinger's work* permitted scientists for the first time to begin to comprehend the coherent structures found on a subatomic scale.

In the simplest terms, the laser is a machine that converts *incoherent energy* (light or heat or other electromagnetic radiation) into *coherent energy*, where the wavelengths are the same and the wave patterns are all traveling in step (in phase).

The first systems to generate coherent electromagnetic radiation (see Figure 1) consisted of alternating current generators and electronic devices like vacuum tubes, which produced radiation at very long wavelengths. To generate the shorter-wavelength, high-frequency electromagnetic radiation, scientists have to manipulate electron motions on an atomic scale. In other words, they have to be able to access electron energy transitions within the atom itself.

Since 1960, when the first laser was created using a ruby rod, there have been many advances in laser technology. The next step, which is under way today in the national laboratories, generating X-ray radiation, involves extremely high-energy electron atomic transitions. And the next region of radiation frequencies, gamma rays, will involve energy transitions on a nuclear scale.

All lasers consist of three elements: an *energy pump,* a *lasing medium* that the energy pump excites into activity, and a *host* material that maintains the lasing medium in a desired configuration during the lasing process.

Energy pumps can be flash lamps, electron beams, neutron beams, or even a laser beam itself—that are all external to the lasing medium. Or the energy pump can be a chemical or nuclear reaction that takes place within the medium itself. These pumps direct their energy into the lasing medium, which can be a gas, a liquid, or a solid, such as a special kind of glass. In a gas laser, the host can simply be a bottle to hold the lasing gas, and in a solid laser, the host can be a slab of glass in which the atoms or ions (charged particles) of the lasing medium are embedded.

Once a significant portion of the atoms or electrons in the lasing medium are excited by the energy pump, they will begin spontaneously to emit electromagnetic radiation of a specific frequency. When this initial emission of light is continuously reflected back through the lasing medium

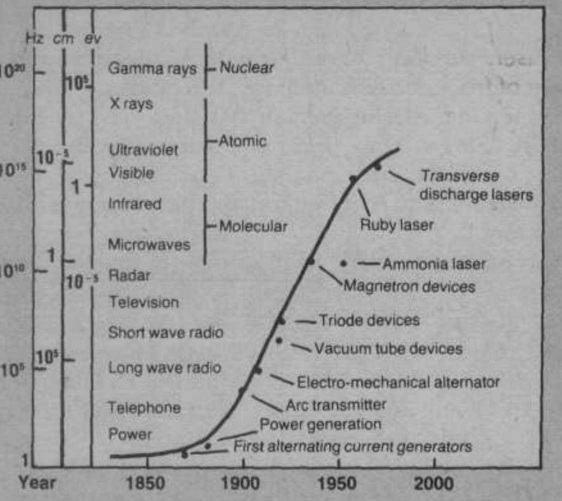


Figure 1
CHRONOLOGY OF DEVELOPMENT OF SOURCES OF COHERENT ELECTROMAGNETIC RADIATION
The points on the graph show the date of the first development of devices for generating coherent radiation in the range described in the list to the left of the graph line. The vertical axis, in three columns, shows the frequency (in hertz), the wavelength (in centimeters), and the photon energy (in electron volts). The development of infrared, visible light, and ultraviolet lasers increased the range of available frequencies of coherent radiation exponentially, a trend that will be continued with the development of X-ray and gamma-ray lasers.

Adapted from Baldwin, et al., *Review of Modern Physics*, Oct. 1981.

using mirrors, it stimulates the remaining excited atoms to emit radiation coherently at the same frequency. This reflecting chamber is called the resonant cavity.

The initial laser beam can be extracted from the resonant cavity and amplified by passing the beam once through other excited lasing mediums.

The Next Laser Generation

The next stage in the generation of coherent electromagnetic radiation is the X-ray laser, which will require a qualitatively new science and engineering. The shorter wavelength, higher-energy radiation of X-rays is harder to generate in a coherent form, but it provides much more penetrating power and better resolution.

The X-ray laser, in fact, makes possible the complete mastery of atomic and molecular processes. This is not only because X-rays have wavelengths comparable to the dimensions of the atom—wavelengths larger than the atom are not capable of "seeing" it—it is also because X-rays have a high microscopic energy density that gives them an inherent capability of penetrating matter. As a result, biological specimens can be viewed *in situ* and *in vivo* without disrupting the ongoing life processes, which is not the case in ordinary optical and electrical beam microscopy. The X-ray laser will also revolutionize chemistry, allowing chemists to observe the interaction of atoms.

To give you a sense of how miniscule these X-rays are: conventional lasers operate in wavelengths ranging from 100,000 angstroms down to several thousand angstroms, while X-ray lasers operate in the range of hundreds of angstroms, down to 1 angstrom. An angstrom is one ten-billionth of a meter.

The next stage after the X-ray laser, the *gamma ray laser*, or *graser*, will extend this capability to the subatomic or nuclear scale, providing the key for unlocking the secrets of nuclear structure and its interactions with atomic and electronic structures. The graser will also provide the unique means for directly or indirectly catalyzing nuclear energy transitions, which could lead to the creation of entirely new forms of generating nuclear energy. Theoretically, at least, the graser is projected as a direct energy source, because the nuclear transitions produced in the graser can generate more energy than the input pump energy used to catalyze them.

New Physical Principles

The X-ray laser, because of its very high energy density, has required completely different technological approaches to its realization. In the areas of pumping and focusing, the X-ray laser operates on physical principles different from any existing laser.

The first problem in the design of an X-ray laser is the identification of suitable energy transitions in the prospective lasing medium. These energy transitions simultaneously must have the required high energy in the X-ray region, must be unstable enough to be pumped, and yet must be stable enough so that the required large number of these transitions can be excited to make stimulated emission possible.

The pioneering work in the identification of suitable energy transitions was done by researchers in the Soviet Union, who, along with Western scientists in the past 15 years, have identified two general classes of energy transitions: The first is a set of high energy electron transitions in the cores of medium weight elements. The most promising of these involves the use of gaseous neon in its electronic state, which resembles sodium (that is, it has one electron missing). These electronic transitions can be used only in a gaseous medium because of the tendency for collisions between neon atoms to remove energy from the potential lasing transition. However, the second approach would overcome the inherent low energy density of a gaseous lasing medium by using electronic transitions in highly doped (or impure) heavy metals, which offer the possibility of much higher energy density in a solid host.

In each case, a multi-step process is required to pump the medium. First, a pulse of very high intensity, broadband (that is, disorganized and incoherent) X-rays must be generated; this step is the X-ray laser equivalent of a flashlamp in a conventional optical frequency laser. For the gaseous X-ray laser, this pulse is generated by the irradiation of a metal foil with the high intensity infrared radiation from a conventional optical laser or with a burst from a high-current electron beam machine. In either case, a combination of physical processes occurs—similar to those responsible for the generation of X-rays by the electron gun in a color TV screen—which generates a pulse of X-rays with an energy about 10 times that of the ultimate X-ray laser. However, these X-rays are spread over a wide range of frequencies, directions, and phases. If the energy transition in the lasing medium has been correctly chosen, this incoherent X-ray pulse will selectively energize the lasing transition and generate a "population inversion," the unstable state required for amplification by stimulated emission.

The pumping for the solid-state X-ray laser is achieved by a totally different mechanism; a small (by nuclear standards) neutron bomb, exploded in an underground test facility or in outer space, is used to generate a pulse of X-rays, which in turn vaporizes one end of the solid state lasing medium. As the surface of the lasing medium is blown off, or ablated, in this explosion, it drives a shock wave into the lasing medium. The next step is to take this X-ray burst and use it to excite the lasing medium. If the original solid and the impurities with which it is doped have been correctly chosen, the shock wave will also produce a population inversion.

Once the lasing medium has been excited, the laser will release a large pulse of concentrated, single-frequency X-radiation. Figure 2 shows a physical set up for a current series of experiments being done at Lawrence Livermore National Laboratory using this technique of directing a flow of neon gas through a chamber whose outer surface is irradiated with optical laser light. These experiments have been recently declassified and a large amount of data concerning the transitions, power levels, and efficiencies is now available. Many scientists expect to see the same spectacular advances in gas X-ray lasers in the next five years that occurred in optical lasers in the first five years of their development.

The hypothesized construction of an X-ray laser experiment conducted at the Nevada Test Site using a solid state laser medium is shown in Figure 3. This experiment remains highly classified in the West, although there is no doubt about the existence of a series of such tests that have been conducted with increasing success. The most detailed information available about the Nevada Test Site X-ray laser design has come from a Soviet publication, *Soviet Journal of Quantum Electronics* July 1981, p. 971. In an article published shortly after the first public mention of the experiment in *Aviation Week and Space Technology* (Feb. 1981, p. 25), three Soviet experts on plasma lasers from the Lebedev Institute provide a detailed description of a possible configuration for such a laser (as summarized in this artist's depiction). At the present time, however, no Western scientist involved in X-ray laser research can comment on the Soviet research!

Where X-ray Laser Research Stands

The details of the status of X-ray laser development are being kept top secret at this time because of the military applications. However, it is possible from references made in the open scientific literature and published news stories in *Aviation Week* and *Laser Focus* magazines to establish the essential outlines of what is going on, as follows:

In December 1980, scientists from Lawrence Livermore National Laboratory in California used the intense incoherent X-ray output of a small nuclear explosion to demonstrate the scientific principles of an X-ray laser design. Although this highly expensive method of using a small nuclear explosion as the energy pump for an X-ray laser precludes its widespread application as a scientific diagnostic and industrial tool in the near term, many significant scientific investigations for civilian applications can be carried out as secondary experiments along with the military development tests.

Furthermore, advances in inertial confinement fusion, high-power lasers, particle beams, and magnetic fusion can provide alternative X-ray energy pump sources for the X-ray laser within the next five years, and these alternatives could make the X-ray laser sufficiently accessible and economical for general laboratory and factory use.

In fact, Livermore scientists are now carrying out experiments with the recently constructed Novette laser to generate a laboratory-scale X-ray laser, using experiments based on the concepts of Dr. Peter L. Hagelstein. The high power Novette laser is focused on a target and generates an intense burst of incoherent X-rays. This X-ray burst then hits a second target material that undergoes X-ray lasing.

The most immediate and far-ranging impact of X-ray laser diagnostics will probably occur in the microholography of living organisms. At present, the physical limitations of both optical and electron microscopy prevent observation of the most significant details of biochemical processes. Lasers permit recording of three-dimensional pictures of objects, which are called holograms. The resolution of these pictures is determined by the wavelength of the laser used. Since X-ray lasers operate with wavelengths down to 1 angstrom, the typical dimension of an atom, theoretically X-ray lasers will be able to make atomic-scale holograms.

X-ray microholograms will provide biological and medical researchers with their first atomic-scale pictures of what goes on within living cells. For the first time, man will be able to directly observe the structures and chemistry responsible for life itself. In order of magnitude, one can compare the potential of this to the development of the eye in biological evolution. Cancer and aging research, together with all aspects of disease and health care, will be revolutionized overnight. Genetic bioengineering will be catapulted from a hit-and-miss empirical field of research into a fully elaborated science.

These developments could emerge in the very near future, for, as noted above, many crucial experiments could be carried out in conjunction with existing weapons tests. X-ray microholography will also revolutionize ordinary chemistry, both directly through the observation for the first time on an atomic scale of the phenomena involved, and indirectly through the application of the chemical principles learned by such minute observation of living processes.

Unleashing Fusion Energy

The X-ray laser can provide scientists working on the problem of fusion energy development with a crucial diagnostic tool. One of the principal avenues of experiment in fusion energy research is the method known as inertial confinement fusion. In this process, a small pellet of hydrogen fusion fuel is heated and compressed by bombardment from laser or particle beams, until the temperature and pressure are reached at which the atomic nuclei of the fuel pellet fuse together. This creates a new element, helium, and an enormous release of energy.

Inertial confinement fusion is what occurs, in an uncontrolled fashion, in a hydrogen bomb. In that case, a small atomic explosion is used to set off the fusion process. The problem scientists have been grappling with is how to release this enormous energy in a controlled way, so it can be used to generate electricity and heat for industrial processes and residential users. The hope is that the X-ray laser will allow them to look inside the fuel pellet to see what is going on.

It is known that in the H-bomb, the fusion process is driven by a shock-wave compression of the fusion fuel. A portion of the radiation output of the trigger fission explosion is absorbed within a solid or plasma, a superhot gas. At the same time, another portion of the radiation output irradiates the surface of this substance and generates a shock compression of the substance. As a result, the initial trapped radiation is compressed to an extremely high energy density.

This compressed radiation then irradiates an assembly of fusion fuel, resulting in high-intensity, ablation-driven compression of the fusion fuel. The shock wave acts to increase the density of the fusion fuel and generate a thermal spike in the center of the fusion fuel at the final stages of compression. This shock-created thermal spike is of sufficient intensity to ignite thermonuclear fusion. Most of these phenomena can be observed indirectly, or, at best, seen with a resolution far short of that needed to capture the actual dynamics. The discrimination and penetrating capabilities of X-ray lasers will radically change this.

A Revolution in Mining

The use of the X-ray laser to study shock-wave propagation could have an immediate revolutionary impact on raw materials gathering, processing, and finishing. This potential application of X-ray laser diagnostics, however, is among the most highly classified ones.

As weapons scientists in particular have come to appreciate, the propagation of shock waves is not theoretically understood. One senior researcher has described the situation this way: "We know what's going on in front of the shock and what's going on behind it. We don't know what's going on within the shock front itself. If you take the simple-minded Newtonian billiard ball model of molecules bouncing around in the shock front, you can't begin to explain the observed dynamics and effects of the shocks."

One example these researchers point to is the ability of a shock to generate entirely new materials. For example, when carbon is exposed to a shock wave generated by an H-bomb, a new substance, never before seen, is created. The substance has the crystalline structure of carbide tools in one direction and that of diamond in another. Because of the hardness of diamond and the thermal dissipation properties of carbide, this substance could be extremely useful for micromachining metals and other materials.

X-ray laser diagnostics will permit researchers to observe shock-wave propagation on an atomic scale and with sufficient time resolution to capture all of the important dynamics. There are currently indications that new types of coherent matter-energy interactions are taking place within shock fronts, particularly those of high amplitude and frequency. With X-ray laser diagnostics, scientists could, for the first time, understand how to tailor shock waves to generate specific chemical transformations. A subsidiary aspect would be the forming and shaping of finished materials such as metals and metal shock welding.

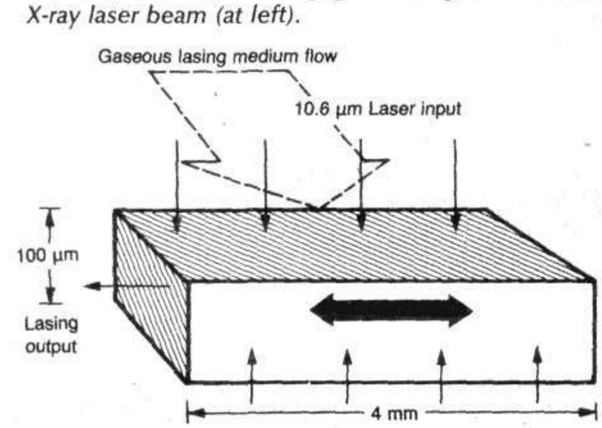
The overall effect could be the rapid realization of entirely new, extremely efficient and cheap industrial processes; a sort of near-term *fusion shock torch*. First of all, such a shock torch with its high energy density will make possible the generation of entirely new families of materials. Second, raw materials could be directly processed with the minimum number of stages and facilities needed to obtain the finished material. For example, one could develop shock techniques for processing raw ores *in situ* right in the ground. Or one could mix the raw ore ingredients needed for some finished material and "shock process" them *in situ*. Alternatively, one could envision shock processing *in situ* to make desired elements more readily accessible to other processing technologies such as chemical leaching of ores.

Because shock processing does not appear to have any limits of scale, interplanetary mining and processing on a gigantic level would also be quite practical.

Although the full projection of the new miracle materials that could be generated with shock processing must await further analysis and declassification of existing capabilities, the projections made for metallic hydrogen give us some indications. It is currently projected that stable hydrogen metal can be formed only at extremely high pressures. Once understood, shock-wave processing could provide the unique means of generating metallic hydrogen. Cur-

Figure 2
X-RAY LASER LABORATORY CONFIGURATION

This configuration was used in recent laboratory experiments for X-ray laser generation with the Lawrence Livermore National Laboratory's Novette laser. The top and bottom of the box are irradiated by the two laser beams of the Novette system. Metal waffers at both top and bottom absorb these beams and generate specific lines of X-rays. This X-ray "'flash lamp" output then irradiates the flowing gas within the box, and the flowing gas then generates the X-ray laser beam (at left).



rent theory predicts that hydrogen metal will have stupendous physical properties, compared to existing metals: Hydrogen metal could be a superconductor at room temperatures, and it could provide an extremely lightweight, strong metal capable of withstanding both high and low temperatures.

Applied to chemistry, the X-ray laser will permit highly accurate electron spectroscopy, a technique used for chemical analysis. It will revolutionize research on chemical catalysis, metallurgy, and organic compounds. A further advantage of great significance is the possibility of exploiting the X-ray laser beam's small diameter in microprobe analysis. Such selected area electron spectroscopy could be applied to the analysis of fracture surfaces of high-strength alloys as two-phase composite materials.

Electron spectroscopy with X-ray lasers will affect all areas of materials research and production, including microelectronics, composite materials, ceramics, and alloys.

One of the most promising applications is in the production of printed circuits, a component of all modern electronic devices. Applied to the technique known as laser lithography, the X-ray laser would improve production rates and miniaturization by orders of magnitude. X-ray laser lithography will permit the scale of microcircuit elements to be reduced from 1 micron to 0.1 microns. This closer element spacing—reduced line widths—allows for the incorporation of new physical processes, such as the Josephson junction. In the Josephson junction, self-organized quantum effects are utilized to mimic the function of transistors, vastly increasing the speed and the number of operations per unit energy used. The incorporation of other, new microprocesses along with the Josephson junction means that the 10-fold decrease in scale made possible by X-ray laser lithography can actually generate an exponential increase in the power of modern microchips.

In terms of production rates and quality assurance, the coherent and monochromatic nature of the X-ray laser radiation vastly improves microlithography as well. The general method of microlithography is to have a mask that incorporates the microcircuit design placed over a photosensitive material that is activated when a light source is shined on it. Using long wavelength and incoherent "light" sources causes penumbral blurring that makes it necessary to keep the mask in close contact with the photosensitive resist material. This means that the functional lifetime of the mask for multi-chip production is limited. Also, physical contact between the mask and resist leads to the introduction of defects in the finished printed circuit due to mask-resist sticking.

X-ray laser lithography would permit the use of a physical gap between the resist and mask, and would significantly increase the production lifetimes of masks and vastly decrease the introduction of defects. In combination, these effects will add up to a new computer revolution over the course of the next decade, producing computer chips thousands of times more powerful and cheaper than existing units.

The gamma-ray laser, or graser, the next generation of laser after the X-ray, presents even greater possibilities for a defensive weapons system as well as for industrial processing. The X-ray laser could provide the unique means of pumping such a gamma-ray laser, as pointed out by both U.S. and Soviet scientists. If realized in a practical form, the graser would be an ideal directed energy weapon. Its short wavelength and extremely high penetrating capabilities would make it an efficient disabler of nuclear warheads over million-mile ranges.

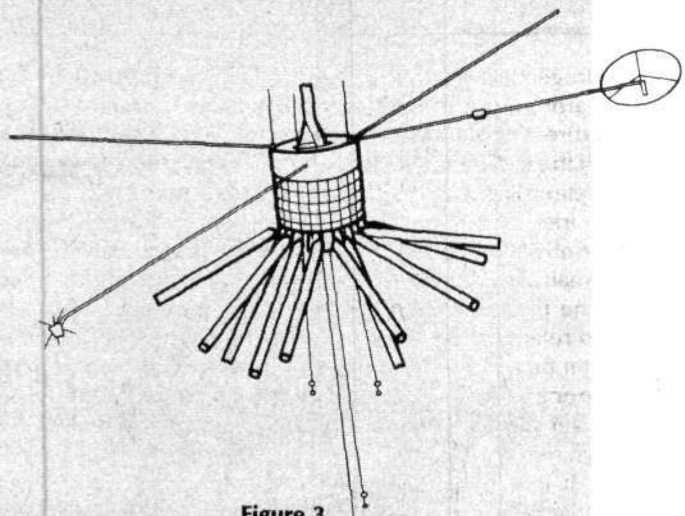


Figure 3
ORBITING X-RAY LASER SYSTEM
In an orbiting X-ray laser system, the detonation of a nuclear device would generate an intense pulse of X-rays that ablatively implodes the lasing rods. The shock wave generated by the implosion process causes the inner portions of the metal rods to undergo X-ray lasing. This artist's depiction is based on a 1981 Soviet description of tests of X-ray lasers by the Lawrence Livermore National Laboratory in 1980. More recent analysis indicates that a relatively large hydrogen bomb is used to pump 20-meter long X-ray lasing metal rods in such a satellite system. It is likely that the metal rods are formed into zeta pinch (reversed field) plasmas just before they are pumped by the X-rays from the explosion. Each zeta-pinch metal plasma would be pointed at a separate target.

The orbiting X-ray laser system would also include an independent targeting and tracking system, a communications center for linkup to more sophisticated targeting and tracking satellites, the nuclear explosive, and 20 or so lasing rods.

Scientifically, the graser will provide man with the unique means to observe the structure of the nucleus. As a result, entirely new forms of nuclear energy could be discovered, such as the possibility of catalyzing latent nuclear processes, or speeding up radiation decay. To quote a leading U.S. laser scientist, Dr. John Rather: "While serving as major deterrents to total war . . . such lasers can also provide mankind with major nonfossil energy options, a quantum leap ahead in opening space for massive human endeavors, and enormous new defense and commercial opportunities in remote sensing, communications, and photochemistry."

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

Mathematics instruction properly begins with geometry, not abstract algebra. In this article for adult readers and teenagers, the editor of the German-language Fusion *maps out a program for reversing the mind-destroying effects of the new math and all abstract-algebra approaches to teaching math to children.*

Abstract Algebra Banned

A Mathematics Curriculum For Creating Citizens

by Dr. Jonathan Tennenbaum

Civilization cannot survive another generation of youth brought up on so-called modern mathematics (set theory) and related horrors of the last decades' educational reforms—not to speak of the worse horrors, including the replacement of teachers by computer terminals, now under advanced preparation in the United States and elsewhere.

At stake is not only the urgent requirement for training the next generation of scientists and engineers, without whom critical technological breakthroughs will not be made, but also the fundamental identity of succeeding generations. Today's youth counterculture, with its hatred of school and indeed of all learning, its embrace of cultism and consumption of drugs, its immorality and arrogant indifference to the future, is directly the product of those so-called reforms, of which the virtual elimination of geometry in favor of meaningless set-theoretical jargon has been one of the most destructive features. Without a dramatic intervention to reverse the destruction, tomorrow's teenagers may no longer even resemble human beings. Whether future generations have the mentality of slaves or of thinking citizens, creators "in the image of God," depends to a great extent on the success of the speedy, forced implementation of programs along the lines proposed here.

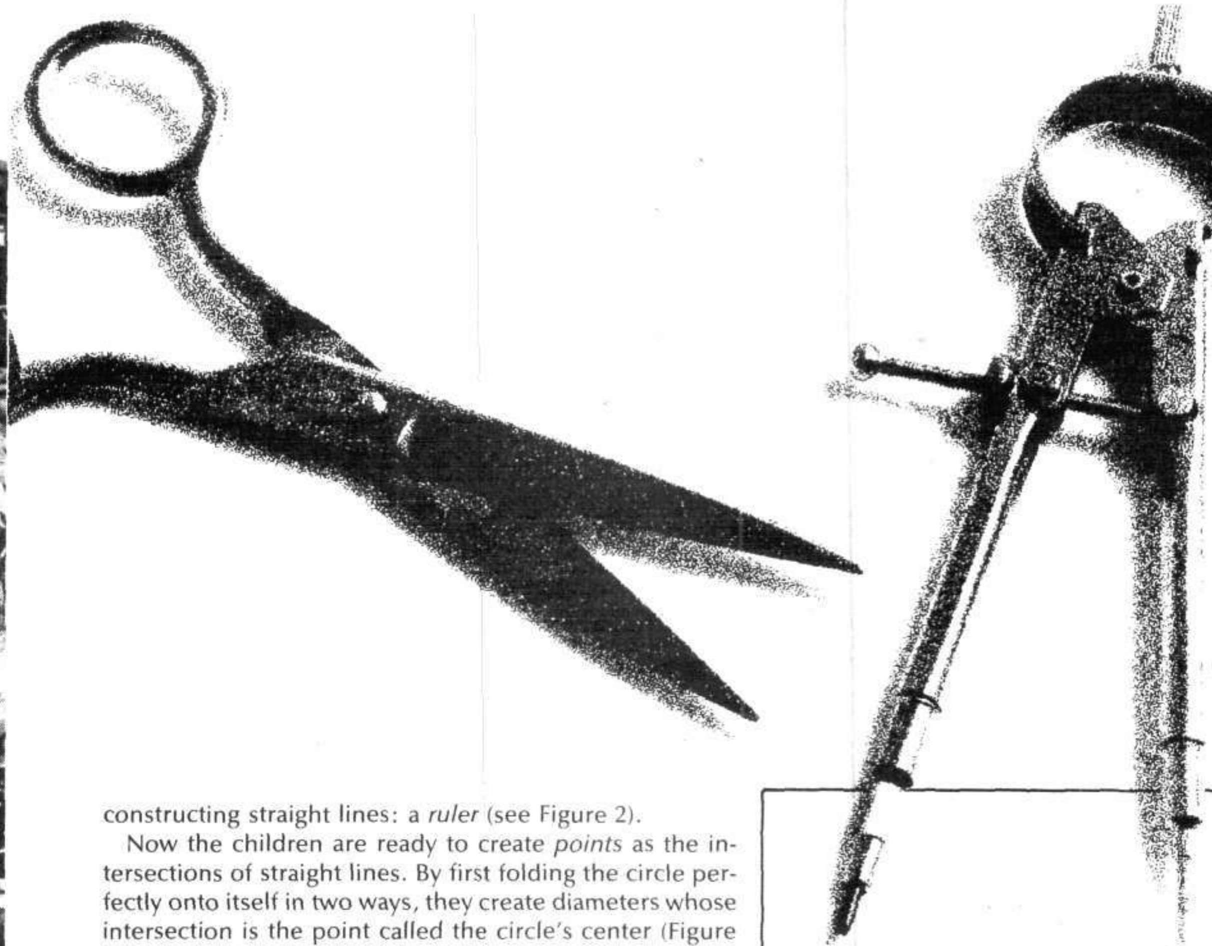
The key to the proposed mathematics program is *geometrical construction*. All abstract algebra, as well as the formal definition-axiom-proof routine customary in both traditional and set-theory-oriented teaching, will be banned from the start. Arithmetic will be introduced as an advanced branch of geometry. Proofs will be proofs by construction. Properties of geometrical figures will be derived not from formulas, but from the manner in which the figures are generated in the process of construction.

As a by-product of the emphasis on rigorous geometrical thinking, 13 to 15-year old children will routinely be able to master areas of mathematical physics generally thought accessible only to doctoral-level university students. Indeed, by clearing away the mass of extraneous algebraic formalism that today mystifies much of mathematics and physics, the ideas and methods that have brought about progress in science will be revealed as "childishly simple." This demystification of science will have profound benefits not only for school education, but also for the frontiers of science, for example, in opening the way for a new geometrical attack on the problems of plasma and relativistic beam physics.

Geometry Begins with the Circle

The first phase of the planned curriculum, already successfully tested with kindergarten-age classes in the United States and Mexico, begins with the construction of circles—circles of all sizes, created in a variety of ways. For example, the children draw circles using a length of string attached at one end to a thumb tack and at the other to a pencil or, on a larger scale, using a rope attached to a post in the school yard. They find that the same figure is traced by any rigid body rotating about a fixed point. The circle is likewise created by bending a thin band of spring-steel upon itself, or by letting a toy wind-up car run with its front wheels turned at a fixed angle. By cutting out circles they have drawn on paper or cardboard, the children can discover the remarkable orderings of circles—concentric circles, tangent circles, and so forth—and investigate what happens when circles intersect (see Figure 1).

Next, the children focus on the figures that can be created out of a single circle, beginning with the straight line. (Straight lines and points are treated throughout as derived from the circle, not as the "elements" or building blocks of geometry.) The straight line is created simply by folding the circle exactly onto itself, and—behold—the child has created not only a straight line, but also an *instrument* for



constructing straight lines: a *ruler* (see Figure 2).

Now the children are ready to create *points* as the intersections of straight lines. By first folding the circle perfectly onto itself in two ways, they create diameters whose intersection is the point called the circle's center (Figure 3a). Then, by using the just-constructed ruler to connect the end points of two diameters, the children construct a *rectangle* (Figure 3b). As a by-product of this construction, the children are in a position to see immediately why the angle formed in a semicircle by the chord from any point on the circumference to the end points of the diameter is always a right angle—that is, the same angle as the corner of a rectangle (Figure 3c). By folding the circle upon itself twice, perpendicular diameters, and from these a *perfect square,* are created (Figure 4).

Helping Figures

Soon the children are in a position to discover how each newly built figure may "change the rules" of the construction game, by becoming a "helping figure," or instrument for further constructions. This idea is already implicit in the use of a once-folded circle as a straight line, or a twice-folded (quarter) circle as a right angle. Another example to be taken up in the curriculum is the "1 – 2" triangle, the right triangle whose base is twice the length of its shortest side. Four copies of this triangle can be generated by folding a square in half and then dividing each rectangle so formed along a diagonal into two right triangles, whose sides are in the the ratio 1:2. By rearranging the four triangles into squares in two different ways, the children can generate Pythagoras' theorem (Figure 4). Through another rearrangement of the triangles, the children can easily construct the *golden rectangle,* whose remarkable proportions are found throughout nature and in great art (Figure 5). Then, using the golden rectangle as a helping figure, a simple construction produces the *regular pentagon.*

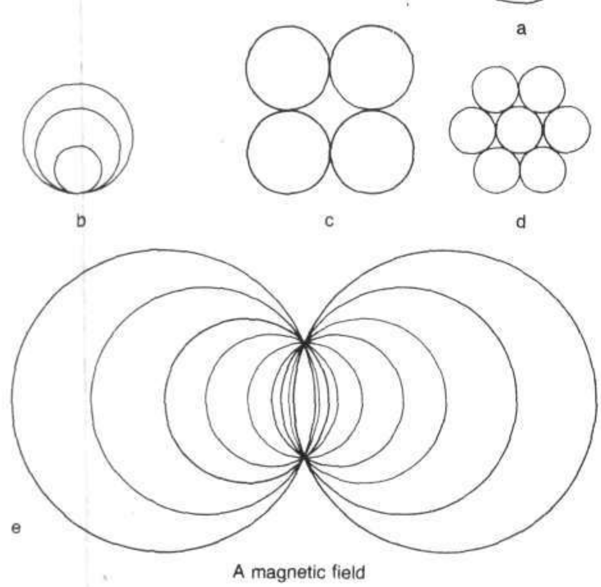


Figure 1
VARIOUS CIRCLES
*The children explore the remarkable orderings of circles—concentric circles (**a**), circles tangent to each other at a single point (**b**), a square lattice of circles (**c**), a hexagonal lattice of circles (**d**), and a family of circles with two common points (**e**). The family of circles represents a magnetic field; the two common points correspond to north and south poles.*

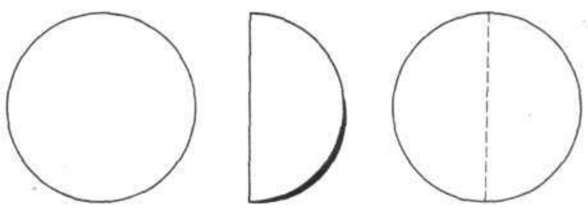


Figure 2
THE CONSTRUCTION OF A STRAIGHT EDGE
A straight edge, used in all subsequent constructions, is created simply by folding a circle onto itself.

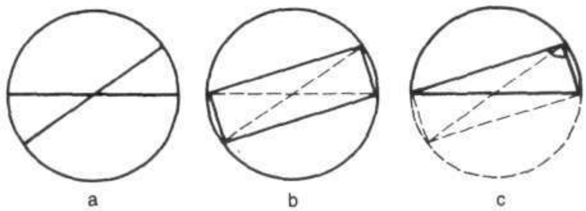


Figure 3
CONSTRUCTIONS WITH A CIRCLE AND STRAIGHT EDGE
*Once the children have created a circle and, by folding the circle onto itself, a straight edge, they are in a position to construct other derived figures: a point (**a**), a rectangle (**b**), and a right angle, the angle defined by two sides of the rectangle and its diameter (**c**).*

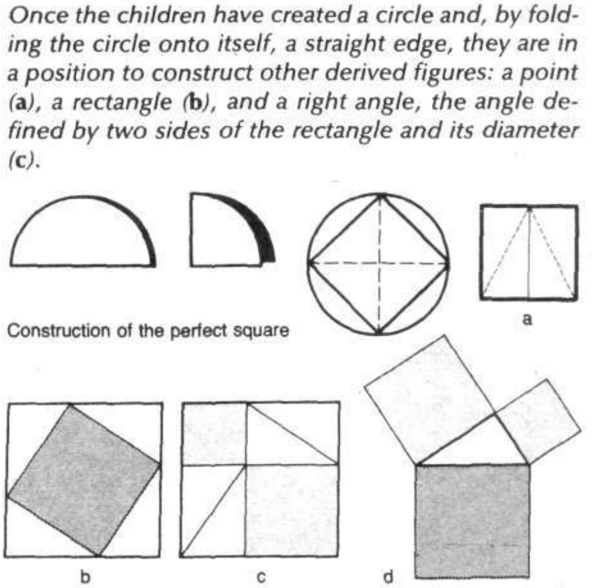


Figure 4
THE PYTHAGOREAN THEOREM
*To generate Pythagoras' theorem, the children begin by constructing four 1-2 triangles: They fold a square (itself made from a circle) twice, once to get two rectangles, and again to form the diagonal triangles of those rectangles (**a**). They then arrange the triangles to form the large square in **b**. The large square is outlined and the triangles are rearranged within it, in the configuration shown in **c**. It is immediately evident that the area of the large square that remains after the triangles are subtracted is the same in **b** and **c**—and that the square of the long side of a right triangle is equal to the sum of the squares of the other two sides.*

Later on, more powerful helping figures are found, which subsume the constructions made possible by earlier helping figures and open the door to new families of constructions. Thus, for example, the children can construct a *cylindrical helix* by drawing in the diagonal of a square and bending the square into a cylinder (see Figure 6). The cylindrical helix makes it possible to construct regular polygons of any desired number of sides. For example, to construct a pentagon, the child marks off five equal parts along the height of the cylinder. Finding next the points on the helix corresponding to the five equally spaced height-points on the line, and projecting those points vertically down onto the base circle of the cylinder, the children obtain five equally spaced points on the circle—the corners of a pentagon! After the helix, *conical logarithmic spirals* are constructed (see below). These not only subsume the helical constructions, but also solve a vast array of other construction problems, such as doubling a cube (that is, constructing a cube whose volume is twice that of a given cube).

The Platonic Method Embodied in the Curriculum

Watching kindergarten-age children having fun playing with circles, a casual observer might not realize that those children were on their way toward acquiring an understanding of science superior to that of all but a handful of the most privileged scientists of the last two centuries. The choice of the circle as the fundamental construction, and the ordering of the later constructions, implicitly embody

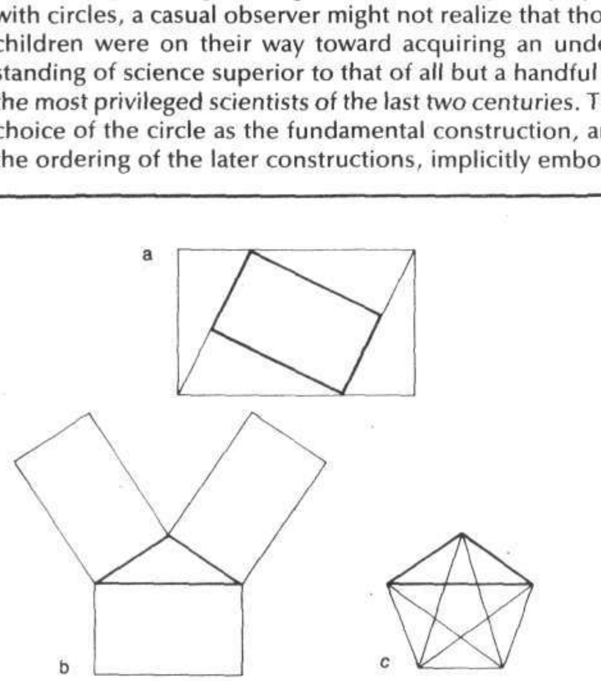


Figure 5
THE GOLDEN RATIO AND THE CONSTRUCTION OF A PENTAGON
*In this construction, the children rearrange the 1-2 triangles to form two golden rectangles (**a**). The ratio of the shorter to the longer side of both the inner and outer rectangles forms the golden mean. This is the unique ratio satisfying the condition that the ratio of the smaller segment to the longer segment is equal to that of the longer segment to the whole (**a**). Three golden rectangles form a golden triangle (**b**), and five golden triangles form a regular pentagon (**c**).*

the essentials of Platonic scientific method—a method that becomes ever more explicit as the children move forward through the curriculum, up to the reading of Plato's *Timaeus* and other writings.

The essential subject of the course is not primarily knowledge of specific theorems of geometry, nor of the properties of specific geometrical figures, but rather the mastery of *geometry as a rigorous language for describing and transforming the universe*, and of a *notion of negentropic development coherent with that of the physical universe*. Above all, the curriculum's emphasis on construction develops the child's sense of himself or herself as a productive human being, as a *creator* "in the image of God," not a mere passive learner. Thus the child triumphantly can declare, "Let there be a circle!" and call the circle into existence with his or her own hands; then the child can say, "And now I shall create a point!" and so on.

This conception of geometry as a language, not primarily an assemblage of theorems, follows from the method embodied in the parable of the cave in Plato's *Republic*. The physical universe is not directly accessible to our senses, nor even to scientific instruments. Rather what we "see" (even in the extended sense of investigating with scientific instruments) are only "shadows": images projected from the unseen but actually real manifold of universal physical process "onto" visible space, the space normally identified with three-dimensional Euclidean space. That, in turn, is a construction based on the spherical image immediately given by sight, that is, the spherical image obtained by looking in all directions from a fixed point (see Figure 7). But, although we cannot "see" real physical space, we can nevertheless describe the use of visual geometry to represent it.

The circle and sphere are prime examples of this. Platonic science has been governed from the start by the hypothesis that the *universe* (the real physical universe) *is a closed, continuously self-developing whole*, which is a *continuum* in the sense that it posesses no part cut off or insulated from the whole, and which furthermore is *finite in the very special sense that it is conceivable as a whole rather than a mere infinite assemblage of parts* (this Georg Cantor called an *actual infinity*). The figure from visual geometry that uniquely corresponds to those requirements for the universe is the *circle*. The self-developing character of the physical universe finds its image in the *process of construction starting from the circle*, a process made rigorous by the requirement that only such instruments are to be used in a given phase of construction that have themselves been constructed at earlier phases of the construction process. The helping figures *mediate* this process as forms of the circle "acting upon itself"; thus, the 1−2 right triangle, itself created out of the square, which in turn was created from the circle, provides the means for dividing the circle into five equal parts (that is, inscribing a pentagon in the circle).

Elementary projective geometry provides the essential language in visual geometry for describing the manner in which the cone is analogous to the real physical universe and the spirals on the surface of the cone, which projectively cover its base, are analogous to physical *fields*. The

Carlos de Hoyos

Figure 6
A CYLINDRICAL HELIX
The cylindrical helix, formed by drawing in the diagonal of a square and bending the square into a cylinder, is a powerful helping figure. The author, Dr. Tennenbaum, gives a lecture-demonstration.

Figure 7
PROJECTION ONTO VISIBLE SPACE
We see the universe as if it were projected onto a sphere surrounding us.

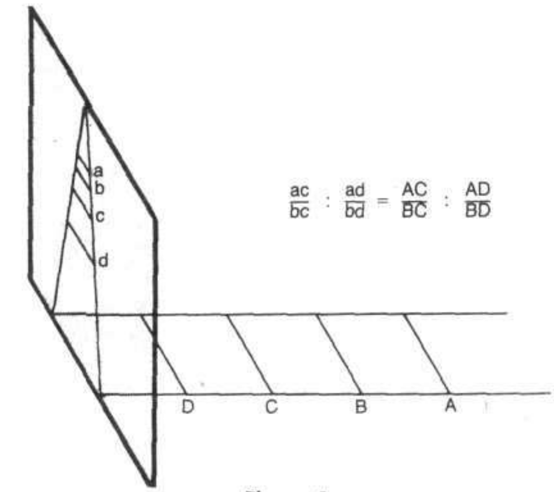


Figure 8
PROJECTIVE INVARIANCE
Even though the shapes of the figures differ (here, for example, railway tracks and their projected image), the value of the cross ratio remains the same.

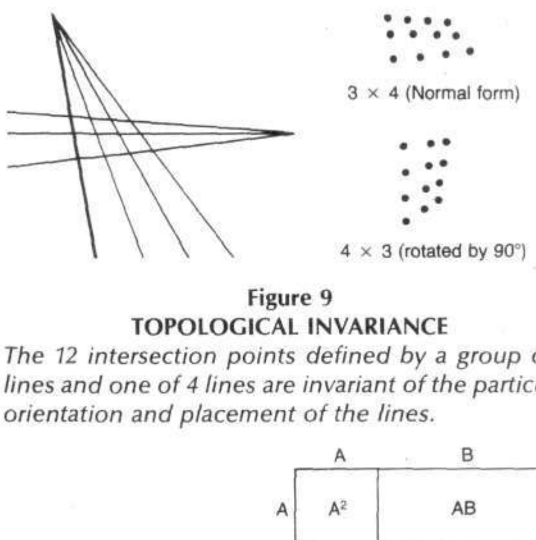


Figure 9
TOPOLOGICAL INVARIANCE
The 12 intersection points defined by a group of 3 lines and one of 4 lines are invariant of the particular orientation and placement of the lines.

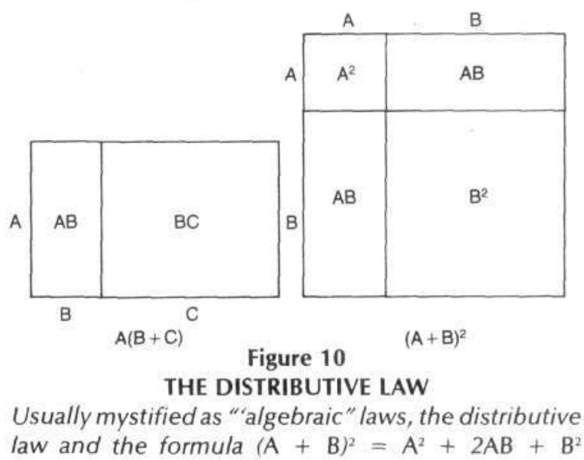


Figure 10
THE DISTRIBUTIVE LAW
Usually mystified as "'algebraic" laws, the distributive law and the formula $(A + B)^2 = A^2 + 2AB + B^2$ correspond to the simplest division of a rectangle and square.

cross-ratio from elementary projective geometry (see Figure 8) becomes a paradigm for the general notion of *projective invariance*: Which aspects are merely artifacts of a particular projection and which remain the same from one projection to another?

Such a geometrical language has far more than a merely metaphorical relationship to the real universe, as overwhelming empirical evidence of the geometrical ordering of physical processes demonstrates. Even at the most elementary level, circles and spheres define the shapes of the Sun and planets, as well as the propagation of light and sound; ellipses define the trajectories of the planets; and the golden mean proportion, derived from the pentagon, predominates in the geometrical proportions of plants and animals. Moreover, the farthest point reached by mathematical physics today, attained by Bernhard Riemann in the 19th century, is in its essence *geometrical*, however much modern algebraic formalism has tended to obscure that fact. In addition, the notion of using geometry as a language belongs in the tradition of Gottfried Wilhelm Leibniz's great (but unfortunately unrealized) project for a *Characteristica Universalis*: a universal scientific language in which the symbols for concepts were to reflect, in their geometrical relationships, the relations among concepts.

Contrast with Existing Mathematical Education

The approach to mathematics sketched above diverges radically from traditional practice. Characteristic of the differences is the rejection of the traditional emphasis on *arithmetic as pedagogically prior to geometry* and on the teaching of algebra on at least equal footing with geometry. With the advent of "modern" set-theory-oriented school mathematics, geometry has been almost entirely banished from existing curricula, leaving mostly empty symbolism and a proliferation of useless and confusing terminology.

The case of arithmetic is exemplary. The first and primary use of the whole numbers, 1, 2, 3, . . ., is to *count*; but to count—at least in the real world—there must first be *discrete objects* to be counted. Now, as Platonic method as well as the evidence of modern science attest, discrete objects (matter) do not exist self-evidently, disconnectedly in the universe; they are *created*. Their creation and continued existence involve, directly and indirectly, the entire universe. That is, the universe does not consist of discrete objects, but rather the opposite is true: Discrete objects, or what appear to us to be discrete objects, are created out of the preexisting continuum.

This situation is well mirrored in visual geometry, where we insist that *points are first created by the intersection of lines*, lines by the intersection of planes, and so forth. Thus, by folding the circle we can construct the four vertices of a square; having created those points, we can now count them: 1, 2, 3, 4. The modern mathematics definition of a line as a set of points is both conceptually confused and mathematically faulty; such definitions have no place in the instruction of children.

Since geometry immediately furnishes the paradigm of processes by which discrete, countable objects are created as singularities out of continuous wholes, geometry must be primary; since, moreover, geometry is also simple, there is no question that it should precede arithmetic in elementary education. This hardly means that children should be forbidden to count, but rather that *arithmetic should be taught as a branch of geometry.*

Consider, for example, the arithmetical relationship $3\times4=12$. This relationship corresponds to a very simple geometric configuration. If I have two groups of lines, with 3 lines in one group and 4 in the other, then these groups of lines in general define 12 intersection points (see Figure 9). The student observes that the existence of exactly 12 intersection points is *invariant,* regardless of the particular choice of orientation and placement of the lines; hence, the equation $3\times4=12$ reflects a topological invariant—a general property deriving from the manner in which geometrical singularities (in this case points) are generated. In particular, we can represent the general case by an especially simple *normal form,* where the intersection points are aligned in rows and columns, the familiar rectangular array (the horizontal and vertical lines that generated the points can be omitted as implicitly understood). Now, the fact that $3\times4=4\times3$, the so-called *commutative law* often taught as an *axiom,* emerges immediately by rotating the rectangular array by 90°. Similarly, such "algebraic" laws as the distributive law, $A\times(B+C)=(A\times B)+(A\times C)$, or the formula $(A+B)^2=A^2+2AB+B^2$ correspond to the simplest division of a rectangle and square (see Figure 10).

Arithmetic, viewed in this way, leads directly to such considerations of topology as *Euler's theorem,* which can then be easily understood by elementary-school children. Euler's theorem states that in a closed polyhedron (a solid body bounded by a finite number of plane surfaces, such as a pyramid or oblong box), the number of faces, *F,* of edges, *E,* and of vertices, *V,* are always related by $F-E+V=2$. If we look at the faces, edges, and vertices of the polyhedron as singularities generated by the planes that bound the body, then the analogy with the previous arithmetic example becomes evident. In both cases we are dealing with the lawful relations among numbers of singularities, which are derived from the manner in which those singularities are geometrically determined.

Once the primacy of geometry and the simple geometrical principles underlying arithmetic have been mastered, the necessary facility in calculating can be attained very quickly. Meanwhile, a major source of the mind-crippling obsession with discrete objects as primary reality rampant today in our culture will have been eliminated.

The Logarithmic Spiral and Complex Numbers

The construction of the logarithmic, or self-similar, spiral and the related treatment of the complex numbers should serve as a final, striking example at a more advanced level of the efficacy of the geometric method employed in the proposed curriculum.

A first approximation of the logarithmic spiral belongs already to the kindergarten-level beginning class. By dividing the radius of a circle successively in half, the child draws a succession of concentric circles with the radii ½, ¼, ⅛, and so forth of the original circle. Next, the child cuts out an approximately ⅕ sector out of the original circle, draws in "diagonal" lines connecting the arcs of the

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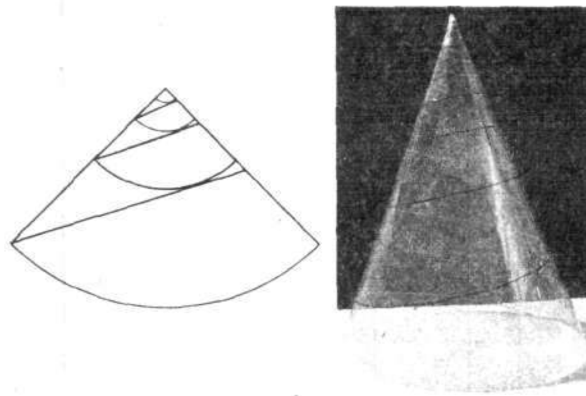

Carlos de Hoyos

Figure 11
CONSTRUCTION OF A SPIRAL ON A CONE
A first approximation of the logarithmic spiral can be constructed out of concentric circles with the radii 1/2, 1/4, 1/8, and so forth of the original circle. The conic spiral thus constructed travels half the remaining distance to the apex with each winding around the cone.

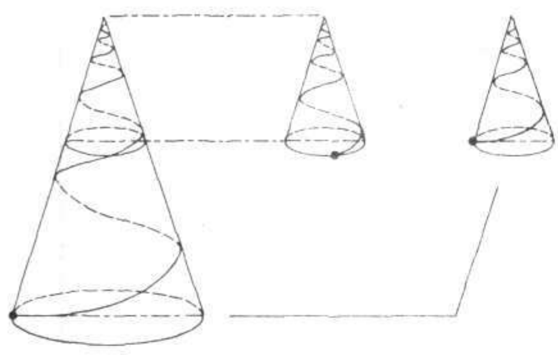

Figure 12
THE SELF-SIMILARITY OF THE LOGARITHMIC SPIRAL
The characteristic property of the logarithmic spiral is its self-similarity: A cut made anywhere parallel to the base produces a smaller cone, which is identical to the larger cone except for its scale and rotation.

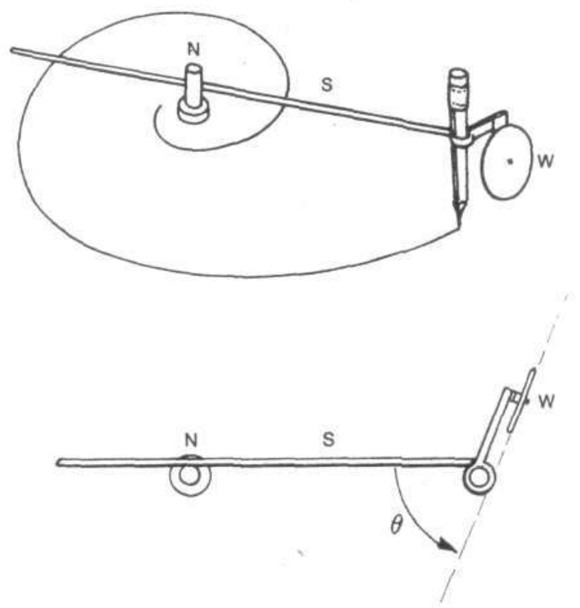

Figure 13
THE SPIRAL MAKER

A wheel W is fastened to a stick S, so that the wheel's direction of rotation forms a constant angle to S. While the wheel moves forward, the stick glides along a fixed pin N. The path of the wheel then describes a logarithmic spiral, which is drawn by the pencil attached to the stick near the wheel.

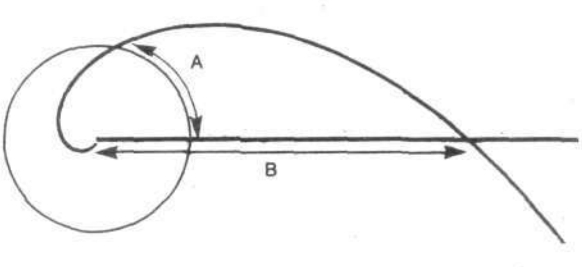

Figure 14
THE NATURAL LOGARITHM AND EXPONENTIAL FUNCTION

As the 45° spiral is rotated over a paper on which is drawn a circle and a radial ray, the intersection point of the spiral and the ray moves outward at an exponential rate. In fact, the relationship between circular arc, A, and the radial distance determined by the spiral, B, is given by $B = e^A$ and $A = \ln B$.

concentric circles, and bends the sector around to form a cone. The diagonal lines match up to form an approximation of the logarithmic spiral (Figure 11).

Later, the exact version of the spiral is developed rigorously. We start with the cone as the unique simplest representation of the projection of a higher-order space (the surface of the cone) onto a closed space (the base of the cone, representing visual space). We ask: What are the characteristic curves and characteristic transformations peculiar to the geometry of the cone?

The answer to the first part of the question is near at hand: Besides radial lines down from the apex and circular sections parallel to the base, the characteristic curves of the cone are defined by the trajectories of moving points winding up (or down) the cone at a constant angle of ascent (or descent). These curves are called (conical) *logarithmic spirals*. The projection of such a spiral from the cone perpendicularly down onto the plane of the base circle yields the plane curve normally known as the logarithmic spiral. This curve has the property that the tangent to any point makes a constant angle with the radial line through the central point (the projection of the cone's apex). The characteristic property of the conical logarithmic spiral, its *self-similarity*, is readily observed using a good model (Figure 12): If I truncate the cone by slicing it anywhere by a plane parallel to the base, then the resulting smaller cone and spiral are identical to the original whole, except for changes in scale (magnification and contraction) and rotation.

Here we have the geometrical representation of the complex numbers. Thus, the complex number denoted i corresponds to a rotation of the cone counterclockwise through 90°. Two i means rotate through 90° and stretch everything by a factor of 2. Rotating everything through 180° yields -1. Performing two or more transformations in succession is known as *multiplication*. Thus, for example, $2i \times 3i = -6$, since two rotations through 90°, plus the combination of a stretch by factor 2 and one by factor 3, have the effect of a rotation by 180° and stretch by factor 6. Similarly, $i \times i = -1$. This is the simple geometrical meaning of the so-called imaginary equation $i^2 = -1$. Indeed, the complex numbers do not deserve the customary names *imaginary* and *complex*, for they are both very concrete—rotations and changes of scale on a cone—and simple, deriving directly from the nature of conical geometry.

An easily constructed instrument allows the student to draw precise conical and plane spirals, as helping figures of remarkable power (Figure 13). The student soon learns how the spiral subsumes the exponential, logarithmic, and trigonometric functions as "projected" aspects. In fact, the study of the logarithmic spiral, along purely geometrical lines, is the best introduction to the study of these transcendental functions.

So, for example, the student generates a 45° spiral (that is, one that makes the constant angle of 45° with the radial line) on a sheet of transparent plastic. Placing this spiral over a paper sheet on which a circle with a radial ray from its center has been drawn, in such a way that the spiral's and circle's centers coincide, and fixing a nail through the two centers, the student can observe how the intersection point of the spiral and the ray moves outward at an exponential rate, as the spiral is rotated over the paper. In fact, the relationship between the circular arc and radial distance determined by the spiral is exactly that given by the so-called natural logarithm ln x and exponential e^x. In particular, the student obtains a purely geometrical determination of the famous mathematical constant e (Figure 14).

On the other hand, if a logarithmic spiral is traced on a transparent cone, and the cone is viewed from the side, then we see a sinusoidal curve. For the special case of an "infinitely" long cone, that is, a cylinder, the spiral becomes a *helix* and the side view yields the exact forms of the sine and cosine functions.

Taking these conical constructions as a whole, the close relation between the exponential, logarithmic, and trigonometric functions and the complex numbers, a subject normally reserved for advanced university mathematics courses, becomes accessible to a mere child!

Once in possession of the logarithmic spiral, the student can explore the vast expanse of physical and other applications of this construction. The spiral form is found directly in nature on such widely separated scales as sea shells and spiral galaxies. Furthermore, the logarithmic spiral defines the most important singularity in hydrodynamics and electrodynamics: the vortex, whose flow lines are congruent spirals emerging from a common center. The student can easily model the vortical flow by tracing spirals inward from equally spaced points on a circle. By superimposing the clockwise and counterclockwise-winding vortices obtained from 45° spirals, the student obtains the striking pattern illustrated in Figure 15, which in turn defines the so-called *complex exponential* and *logarithmic functions*. This same mapping has been shown to determine the correspondence of nerve cells on the visual cortex of the brain with the retina of the eye. The student will be able to identify and prove the remarkable geometrical properties of the complex logarithm that enable us to recognize the form of objects independent of their size and orientation. The analogous property of *hearing*, namely that we can recognize a melody independent of its starting pitch (that is, its key), leads the student to suspect that the logarithmic spiral might play an equally important role in hearing and in music. In fact this is the case. It is easy to show that both our subjective perception of tone, and the determination of pitch in the well-tempered (equal-tempered) musical system, are governed by the logarithmic spiral (see Figure 16).

The Pedagogical Museum

In addition to the constructions made by pupils—of which only a few characteristic examples have been discussed here—every school must have a *pedagogical museum*: a permanent collection of sturdy, precision-built geometrical models and instruments, together with physical specimens, models, and photographs illustrating geometrical principles in nature, art, and technology. The core of the museum should include:

1) A section on the golden mean, showing its construction and properties, and on related figures (golden rectangle, pentagon, golden mean spiral, and so forth); in

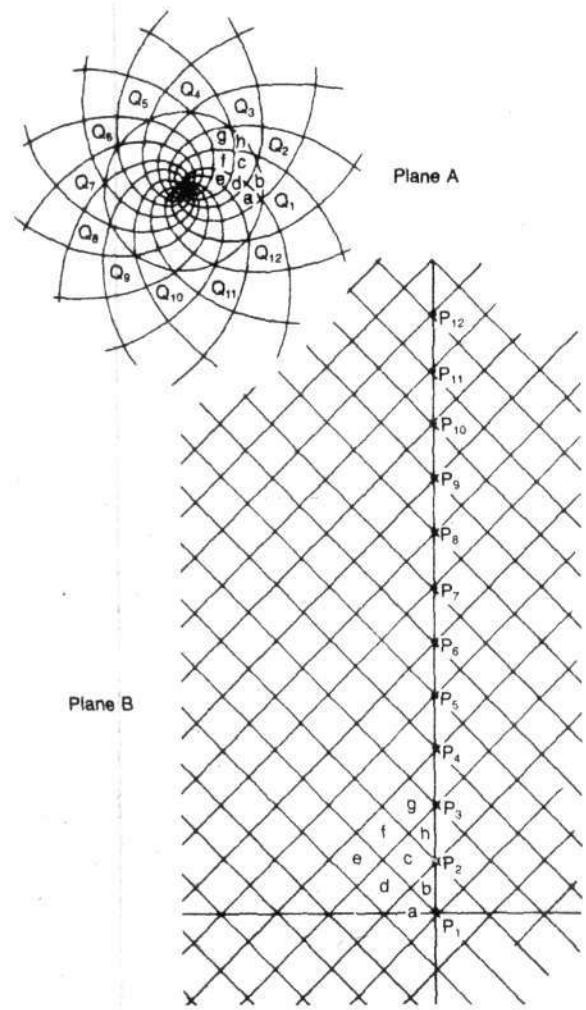

Figure 15
THE LOGARITHMIC PRINCIPLE AND VISION
The families of spirals and diagonals define a mapping between planes A and B above. Point Q_1, Q_2, . . . on the circle in plane A correspond to P_1, P_2, . . . on the vertical in plane B, and the regions labeled a, b, c, . . . in each plane correspond to each other. We call mapping of plane B onto plane A a complex exponential function and that of plane A onto plane B a complex logarithm. In first approximation, the complex logarithm corresponds to the mapping of the retina of the eye (plane A) onto the superior surface of the visual cortex of the brain (plane B) via the optic nerve. The geometrical characteristics of the complex logarithm bring it about that—in accordance with the equation $\ln(A \times B) = \ln(A) + \ln(B)$ for all complex numbers A and B—with enlargement, diminution, or rotation of the image, the image on the visual cortex simply shifts left or right, up or down, without changing in other respects. In this way, we recognize form independent of the size and position of objects.

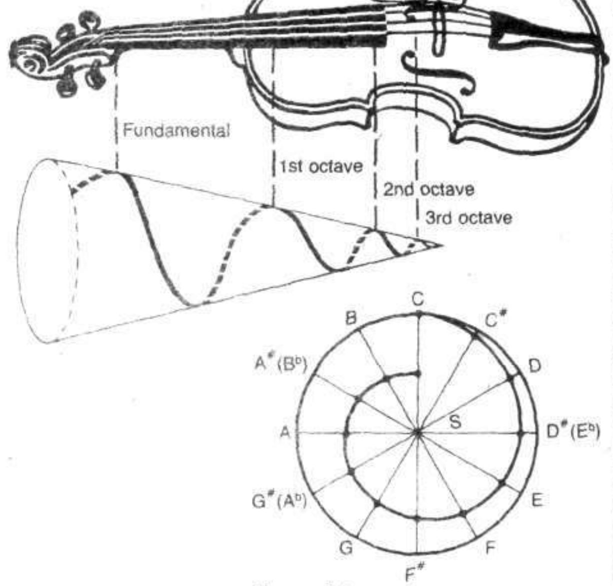

Figure 16
THE LOGARITHMIC PRINCIPLE AND MUSIC

With stringed instruments we obtain successive octaves by successively halving the vibrating part of the string (thus producing a doubling of the frequency of vibration of the string). The intervals between successive octaves on the string thus become progressively shorter; were the keyboard of a piano constructed in this manner, the keys would be concentrated in the upper register. Subjectively, however, we hear all octaves as musical intervals of equal size. This illustrates that the sense of hearing functions according to a logarithmic principle. This becomes clear when we mark off the string lengths at vertical distances on a cone on which is drawn a "base 2" spiral, a spiral that with each winding around the cone moves up half the remaining distance toward the apex. Each octave corresponds to a 360° rotation of the spiral, so that our subjective perception corresponds to equal angles of the circle at the base, while the physical string length corresponds to the height of the spiral on the cone.

In the well-tempered system, the octave is divided into 12 equal intervals, or semitones. We construct the corresponding string lengths by dividing the circle at the base of the cone into 12 equal sections and then connect each of these cuts along the circumference with the apex of the cone. The height of the intersection with the spiral determines the position of well-tempered intervals along the string, for example, the spacing of the frets on a guitar.

The distance between the origin S and the intersection with the spiral corresponds to the length of the strings with equal tension. This results in the 12 tones of the well-tempered system, and the determination of the well-tempered system by means of a logarithmic spiral.

addition, a large collection of examples from organic nature, painting, and architecture demonstrating the predominance of golden-mean proportions.

2) A complete set of models of Platonic and Archimedean solids with their various nested combinations, including Johannes Kepler's model of successively inscribed and circumscribed spheres giving the spacing of the planetary orbits; examples of regular and related polyhedra and polygons in nature, including mineral crystals, snowflakes, single-celled organisms (for example, plankton and honeycombs).

3) A section on projective geometry, with models of the Rappus, Pascal, Desargues, and other important theorems and configurations; examples illustrating the use of perspective (including spherical perspective painting as well as descriptive geometry techniques in engineering and architectural drawing); optical devices for demonstrating projections of planes, spheres, and other surfaces; applications of stereographic and other projections in map making.

4) A complete collection of models dealing with the conic sections; clay and wood models of cones cut at various angles, optical projections between conic sections, string and rod models showing the projective constructions of the conics as envelopes, focus-point constructions of conics using strings and mechanical linkages; model of the Dandelin spheres for determining the focal points of conic sections; circular, elliptic, and parabolic mirrors showing the optical properties of these curves; models illustrating Kepler's three laws for the planetary orbits.

5) A section on the helix and Archimedean and logarithmic spirals, including such examples and applications as a model of the DNA molecule, the periodic table of the elements in helical form, spiral growth in the sunflower and other plants and animals, spiral nebulae, hydrodynamic vortices (including photographs of hurricanes taken from space), and a model illustrating the nerve mapping from the retina to the visual cortex; logarithmic charts showing the hierarchy of scales (orders of magnitude) in the organization of the universe.

6) A section on the geometry of music, featuring Kepler's derivation of the consonant musical intervals from the construction of regular polygons, a monochord for showing the relationship between musical intervals and geometric proportions, the construction of diatonic major and minor scales, transposition as a projection, and helical and spiral models of the well-tempered system.

7) A large selection of models of the higher curves and surfaces and their modes of generation, illustrating radii of curvature, pedal-point and envelope constructions (involute and evolute), torsion of space curves, surfaces of revolution, ruled and developable surfaces, Gaussian curvature, geodesics, and families of surfaces and singular points; generation of higher curves by linkages and systems of gears.

8) A section on the least action principle and related extremal problems, including proof of the isoperimetric property of the circle (the fact that the circle is the unique closed curve with maximum contained area for a given perimeter), demonstrations of minimal surfaces using soap

bubbles, models of the brachistochrone, and other classical examples of curves defined by minimal properties; demonstration models of least action in physics, including the bending of light rays in an inhomogeneous medium (Fermat's principle of least time) and the motion of masses constrained to surfaces.

9) A section illustrating Riemann's theory of functions, using the geometric-hydrodynamic analogy developed by Felix Klein in which complex functions are viewed as hydrodynamic flows on surfaces with given singularities. This section should include models of flows on spheres and tori with one or more holes, the construction of orthogonal nets of curves corresponding to various analytic functions, deformable orthogonal nets made of wire demonstrating conformal mapping of regions (Riemann's mapping theorem), plaster models of Riemann's surfaces, reliefs of elliptic and modular functions, and photographs and possibly actual demonstrations of flow arising in electrodynamics and aerodynamics.

This rough sketch of the most essential features of a pedagogical museum for geometry clearly points to the unity of geometry and physics. Indeed, although there is not space to elaborate the point here, it should be evident that the teaching of mathematics and physics must be combined, once a thorough basing in geometrical thinking has been laid through the first several years of the geometry curriculum. The child who has been through a course in geometrical construction along the lines proposed here, and who has explored the pedagogical museum, will find most of physics an open book.

The Role of Scientific Classics

Alongside the program of geometrical construction and the pedagogical museum, the reading of classics of science, particularly works of Plato, Archimedes, Kepler, and Leibniz, will form an indispensable part of the complete curriculum. Typical of the writings to be studied are Archimedes' *Sand Calculation* (in which he estimated the number of grains of sand that might fill the sphere containing the solar system), Kepler's *Six-Pointed Snowflake* (a pioneering work on crystallography and the least action principle), and his *Harmonies of the World* (the basis in geometry for music and the organization of the solar system, based on the method of Plato's *Timaeus*)—three beautiful applications of geometrical method to fundamental questions about the universe.

The purpose of young students' reading such classics is not only for the sake of the particular detailed content of the individual works. Rather, children must have the chance to become intimate, "personal friends" with historical figures who have made decisive contributions to science—seeing them not as superhuman geniuses, but as inspiring models with whom the student can measure and develop his or her originality and powers of scientific judgment. To joyfully note when one's own thinking parallels that of the masters, to admire the courage and rigorous use of the Platonic principle of hypothesis that enabled them to advance beyond their predecessors, to begin thinking how one might oneself contribute to the progress of human knowledge—these are priceless moments in the growth of young human beings, which no textbook can provide.

Many people might agree with the general approach outlined here but object that it is impractical in view of the entrenched position of existing curricula. The problem is political. Although the proposed geometry program incorporates some significant features of novelty, the role of geometry and geometrical construction in the education of children has been well understood for thousands of years. It was discussed extensively by Plato. It was cultivated during the Arab and Italian renaissances. It was the chief element in the program for universal public scientific education established by the French republicans under Gaspard Monge at the end of the 16th century. More recently, in this century, Monge's ideas, which had been greatly developed on the level of advanced mathematics by Gauss and Riemann, were taken up by Felix Klein as the basis for a far-reaching reform of science education in Germany. Not accidentally, the establishment in schools and universities of large collections of geometrical models, similar to the pedagogical museum proposed here, was stressed by Klein as an indispensable element of his program. Klein's reforms were without question one of the pillars of German scientific and industrial greatness from the turn of the century until World War II.

Implementation

More generally, it has been known, at least since the time of Plato, how to raise children to become productive, responsible citizens, and even how to willfully cultivate scientific genius in an increasing portion of such children. The *political* problem, however, is that such knowledge is not being practiced today. The oligarchical faction in world affairs, represented by such institutions as Aurelio Peccei's Club of Rome, has successfully imposed its program of *education of slaves* at the expense of the Platonic republican notion of *education of citizens*. It can be documented that the educational reforms of the 1950s and 1960s, including the new math, were conciously imposed by agencies linked today to the Club of Rome: specifically the International Monetary Fund, UNESCO, and the World Bank. These agencies have been instrumental in the destruction of the nation-state and the very concept of an educated citizenry, in favor of a new, feudalist "world system," in which all education will be "relevant"—that is, limited to indocrination in zero-growth ideology. The Club of Rome's Peccei has in his recent writings explicitly attacked the idea of man as creator, in the image of God—an idea he and his associates correctly observe spreads in populations whose education has been influenced by republican principles.

So, by beginning with the circle and the child as the creator of the circle and the whole universe of later constructions, the proposed geometry program goes to the very heart of the battle between the education of citizens and the education of slaves. That political battle must now be won, and it defines the urgent practicality of the proposal outlined in this article.

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The American System:

by Dr. Steven Bardwell

That decapitalization, slavery, depopulation, and death travel always together, is a fact whose proof is to be found in every page of history; but none is the proof more thorough and complete than in that which records the story of Ireland, from the day when she ceased to have a Parliament, and became a mere appendage to the crown of England. . . . The people of Ireland were, in fact, selling their soil to pay for cotton and woolen goods that they should have manufactured themselves; for coal which abounded among themselves; for iron, all the material of which existed at home in great profusion; and for a small quantity of tea, sugar, and other foreign commodities; while the amount required to pay rent to absentees, and interest to mortgagees, was estimated at more than thirty millions of dollars. Here was a drain that no nation could bear, however great its productive power, and its existence was due to the system which—by forbidding the application of labor, talent, or capital to any thing but agriculture—forbade advance in civilization. By degrees was the unfortunate country depleted of every thing that could render it a home in which to remain, while those who could not fly were "starving by millions. Throughout the west and south of Ireland, the traveller is haunted by the face of popular starvation. It is not the exception—it is the condition of the people. In this fairest and richest of countries, men are suffering and starving by millions." Happy was the full-grown man who could find employment at sixpence a day without clothing, lodging, or even food.

The existence of such a state of things was, said the advocates of the system which looks to converting all the world, outside of England, into one great farm, to be accounted for by the fact, that the population was too numerous for the land; and yet a third of the surface, including the richest lands in the kingdom, was lying unoccupied and wasted.

A contemporary newspaper illustration of German immigrants arriving in New York City in the mid-1800s.

'People Are Wealth'

From that date famine and pestilence, levelings and evictions, have been the order of the day. Their effect having everywhere been to drive the poor people from the land, its consequences are seen in the fact that the population numbered, in 1850, one million six hundred and fifty-nine thousand less than it did in 1840; while the starving population of the towns largely increased. . . . It is usual to ascribe the state of things now existing in Ireland to the rapid growth of population—that in its turn being charged to the account of the potato, the excessive use of which, as Mr. McCulloch [the British economist] informs his readers, has lowered the standard of living, and tended to the multiplication of men, women, and children. "The peasantry of Ireland live," as he says, "in miserable mud cabins, without either a window or a chimney, or any thing that can be called furniture," and are distinguished from their fellow-laborers across the Channel, by their "filth and misery"; and hence, in his opinion, it is that they work for low wages. . . . "The unexampled misery of the Irish people is directly owing to the excessive augmentation of their numbers; nothing can be more perfectly futile than to expect any real or lasting amendment of their situation until an effectual check has been given to the progress of population. It is obvious, too," he continues, "that the low and degraded condition into which the people of Ireland are now sunk is the condition to which every people must be reduced whose numbers continue, for any considerable period, to increase faster than the means of providing for their confort and decent subsistence."

Such is the erroneous view to which men of high ability are led by the Malthusian doctrine, that man—the being of highest development—tends to increase more rapidly than potatoes, turnips, fish, and oysters. . . .

—Henry Carey,
The Principles of Social Science, 1858

The devastation foreseen for Ireland by Henry Carey, one of the greatest American System economists, has continued to this day: Ireland's population is today one third of its population in 1840! The policies that he describes so eloquently have been the policies of colonial economic relations for at least 200 years in modern times, replicating in many details the characteristic relations between Persia and its colonies in the fourth century B.C. and between Imperial Rome and its colonies for 500 years.

This policy of labor-intensive investment, prevention of industrial development, and population control is precisely that outlined in the *Global 2000 Report to the President*, which was commissioned by President James Carter and is still receiving a hearing in the Reagan administration as the basis for American foreign policy.[1] Contrary to appearances, this document does not describe *projections* for the ecological consequences of continued population growth, but rather existing *consequences* of zero-growth policies already in operation in the Third World.

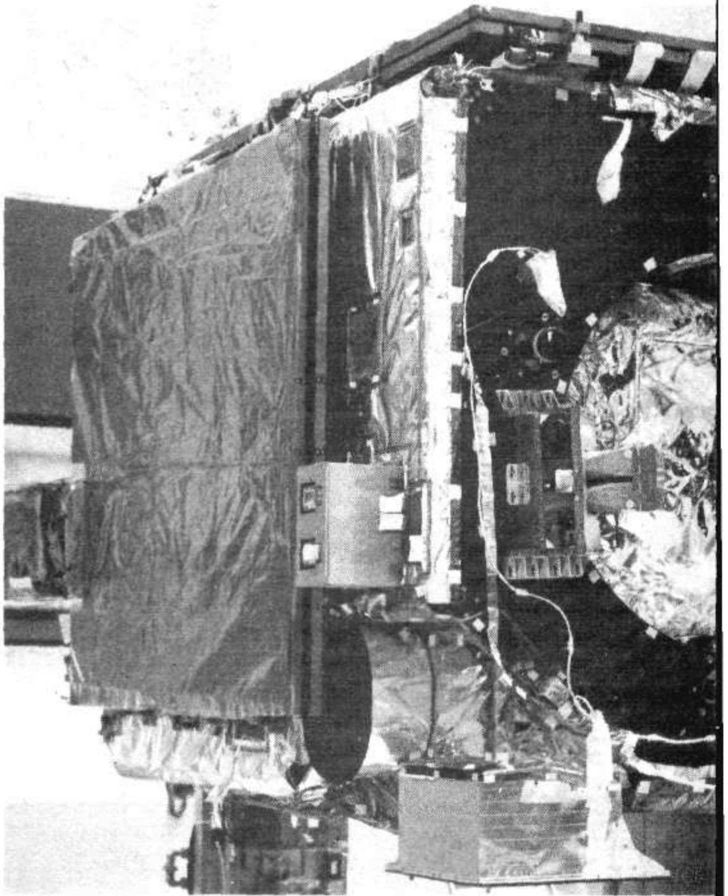
A recently completed case study of the demographic impact of these policies in Colombia presents data as shocking as the description Carey gives of Ireland's depopulation in the 19th century.[2] Colombia has been for 20 years the showcase of the World Bank, the most successful application of the bank's investment policies, and the country that has experienced the most dramatic drop in population growth rate of any nation in Latin America.

A few highlights from this study show that the population control program imposed by the World Bank has dramatically different import from that advertised by the World Bank. To take a few examples:

(1) The initial declines in population growth rate were caused by declining birth rates, which more than compensate for increasing longevity. Colombia's 65 percent urbanization made the aggressive birth control program funded by the World Bank relatively easy. In the past two years, however, the cause for the continued decline in Colombia's population growth rate has changed: An increasing infant mortality rate and declining life expectancy have been the primary causes of population decline!

(2) Infant mortality, according to official figures, is the highest in Latin America—80 per 1,000 births. The government reports that 65 percent of the school-aged population suffers from malnutrition. More than 150 children die every day in Colombia from gastroenteric diseases—52,000 deaths per year. In Bogota alone, according to government statistics, there are 400,000 *gamines*, homeless and parentless children who live in the streets, supporting themselves by begging and thieving. This is the situation for 1 out of every 5 children.

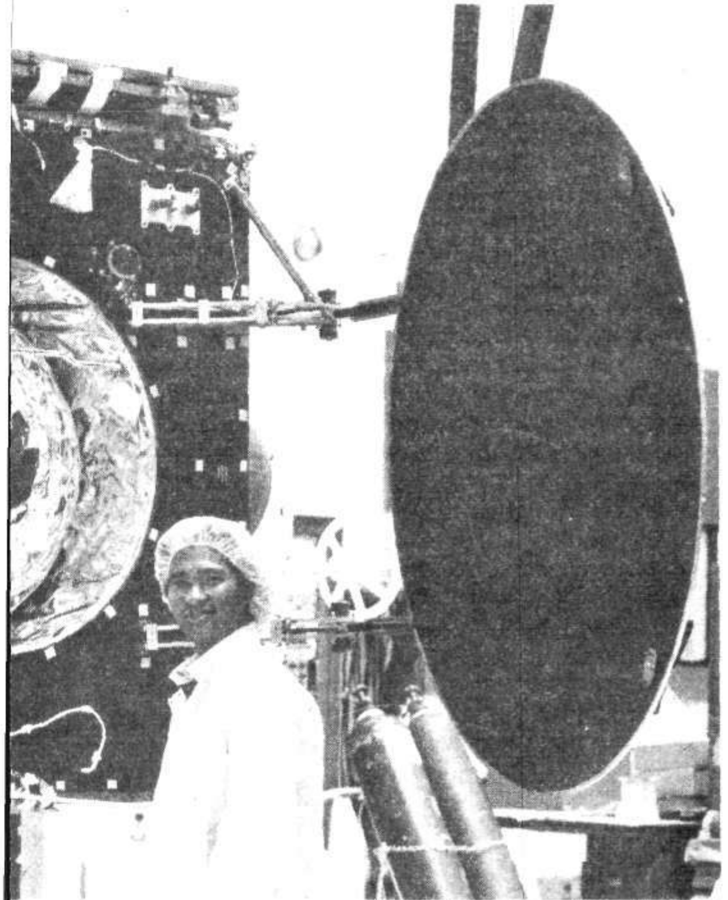
(3) Accurate estimates for the decline in life expectancy are difficult to obtain. However, all the causal factors influencing life expectancy have turned for the worse. The rate of urbanization has decreased; the available health care has dramatically worsened; and the infrastructure of the large cities is decaying. In Bogota, for example, the number of hospital beds stands at two per 1,000 inhabitants.[3] The electrical system in Bogota experiences nightly blackouts, caused by insufficient maintenance. In 1980, for example, the amount of World Bank investment in the electrical grid was smaller than the debt service payments made by Colombia to that institution for the electrical grid.



India, like Ireland, was devastated by British colonial rule. Since then, India has pursued a path of high technology

It is clear even from this brief profile that the population growth of Colombia has begun decreasing because of "death control"—increasing infant mortality and decreasing life span. Indeed, this result was "projected" in the *Global 2000 Report*, which notes that the traditional ideas of demographic transition to lower growth rates with higher living standards, will be replaced—under a regime of forced underdevelopment—by a drop in population growth rates caused by extreme poverty:

> [There is] new data suggesting that fertility rates in some areas have declined a little more rapidly than earlier estimates indicated. The new data indicate that fertility declines have occurred in some places even in the absence of overall socioeconomic progress. Between 1970 and 1976, for example, in the presence of extreme poverty and malnutrition, fertility declines of 10-15 percent occurred in Indonesia and 15-20 percent in the poorest income classes of Brazil.[4]



Courtesy of Ford Aerospace and Communications Corp.

and scientific development. Here, a technician with India's INSAT satellite.

The extent of the corresponding decline in expected life spans, projected by *Global 2000* over the next 20 years, is equally gruesome. The figure shows the evolution over time of the projected life expectancies for Mexico and India as derived by the U.S. Census Bureau demographers, who prepared the demographic data for the *Global 2000* report. In 1963, in a climate of larger investment in health care and infrastructure expected over the decades before 2000, these demographers had expected an average Indian to live 63 years, and an average Mexican 71 years. However, by 1980, actual investment figures had dropped so much that these demographers cut 6.6 years from the life expectancy of an Indian, and 7.75 years from that of a Mexican in the year 2000.

This policy—it is not a projection as the case of Colombia shows, but rather actual, currently implemented policy—was accurately called "preventative genocide" by Julio Silvacomenares, the Colombian economist, in his 1974 study of the World Bank's population policy, *No Mas Hijos* (*No More Children*).[5] Interestingly, for *his* refutation of the scientific veneer given to this policy, Silvacomenares refers to one of the greatest exponent of the American System, the German economist Friedrich List: "List notes that it is only necessary 'to look at the actual potential of the productive forces to support a given number of people in a given area' to refute Malthus," Silvacomenares writes.

The American System: The Economics of Population

The central idea that unites the American System school of economics is what economist Lyndon H. LaRouche, Jr., who has brought this school to its highest point, has called the "potential relative population-density," and what List describes in the quotation above.[6] In its simplest form, given by the first American System economists like Alexander Everett, it is the maxim that "population is wealth."[7] This idea was elaborated by the American System school of economists from List, Henry Carey, and Erasmus Peshine Smith, through LaRouche, who most precisely defines it:

> How can we measure in advance what will in fact be a contribution to mankind? Second, how can we predetermine some efficient causal connection between our choices of personal action and the desired quantity of consequence?
>
> The answer to those two questions is to be found in the following steps.
>
> The general consequence of human activity is the production of human existence. The question of the consequences of our actions is the way in which those actions increase or diminish the power of our species to produce human existence. This power is expressed in first approximation in terms of the number of individuals who can be self-sustained on an average square mile of habitable land. . . . We must measure the power to effect a *relative population-density of self-sustaining populations*.[8]

This concept and its precursors provide the only rigorous refutation of Malthus and his pseudoscientific rationalization of the policies of "decapitalization, slavery, depopulation, and death," which Carey decried and which are the basis of World Bank policy today.

In the 17th century, Leibniz and his associates had formulated in general terms the interconnected concepts of energy as artificial labor and population as wealth in a series of economic essays. However, it was not in Europe that these concepts were elaborated, but rather in the North American continent where Leibniz's republican vision came to fruition. After initial work on the economics of energy and population by Alexander Hamilton, Henry Carey and Erasmus Peshine Smith provided the "American System" of economics with a rigorous theoretical foundation.[9]

Smith identified the central importance of these concepts for economics:

> The disagreement in relation to the truth of the proposition [that food production must always lag behind population], and the consequences therefrom, makes the whole difference—a sufficiently wide one—between the American System, the final issue of which, made axiomatic by the native sense of the people, is rendered in the national aphorism, "pop-

ulation is wealth," and the Economical system of the Old World.[10]

From the time in 1824 that Henry Clay coined the term "the American System," these economists realized that their fight was not merely with the idea of Malthusian population doctrine, but rather over the control of political policy in the United States, in which fight they were charged with providing an American school of economic thought to counter the British school used by the various anglophile factions in the United States. Carey, List, and Smith all identified the question of population and economics as central. From their population doctrine flowed a three part program that formed the core of the American System as an economic policy:

(1) Protective tariffs to establish manufacturing. The trade war used by British industry had repeatedly aborted early American attempts to build a domestic industrial capacity, and protective tariffs had been successfully used during the war of 1812 to circumvent these attacks. The success of the protection policy forced by the war deeply impressed Carey and his associates, and a protective tariff policy became the backbone of the measures they proposed.

(2) Internal improvements. Hamilton had pointed out forcefully in his reports to Congress that the future progress of the United States depended on the construction of "internal improvements," canals, roads, and the like. The American System economists included in this category the great 19th-century infrastructural projects of continental rail systems and telegraph networks. The aggressive encouragement of federal government financing of infrastructure development was a consistent policy of the Whigs during the first half of the 19th century under the influence of the American System economists.

(3) A nationally guaranteed source of cheap credit for industry and agriculture. As both Carey and E.P. Smith point out, high interest rates are causally and correlatively connected to economic stagnation, and low interest rates to active commerce and growing industry. One hundred and fifty years ago, these economists provided the essential arguments against a policy of high interest rates under any circumstances. Hamilton's national bank was the model for an institution capable of implementing their investment policies, although the commitment to low interest rates was logically independent of the existence of such a centralized credit-granting institution.[11]

Although these ideas had existed in various forms of specificity before, most importantly in Hamilton's several reports to Congress, it was Henry Clay's 1824 speech that defined the ideas as a body of economic policy. The first major attempt to provide a theoretical justification for these policies, however, did not occur until 1848, with Henry Carey's book *The Past, the Present, and the Future.* Carey undertook to provide a rigorous intellectual foundation for the Whig policies, and, as he says, to challenge the unquestioned intellectual hegemony of Adam Smith, Malthus, and Ricardo in all American universities. The Whigs saw this British dominance of economic science as a great danger and continuing source of internal subversion, and this is what Carey set out to change.

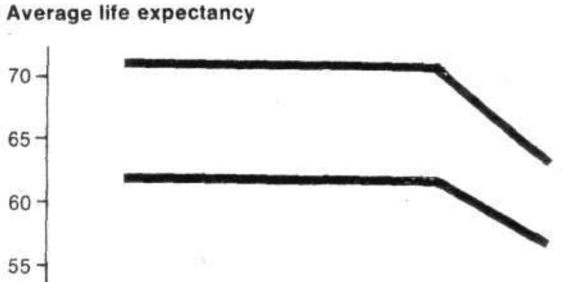
Drawing on the vast amount of agricultural chemistry research by the German chemist Justus Liebig and his collaborators (research, which in its own right, had a tremendous impact on American farmers and farming methods), Carey struck a daring and brilliant blow against the Malthusian-Ricardian system. Malthus and Ricardo argued that population grows faster than food production, and hence progressively drives men to cultivate less and less fertile land in search of food, an ultimately futile endeavor since land is finite. This doctrine pictures mankind's agricultural history as the progression from the most fertile first-cultivated land, to successively poorer land, the cultivation of which is forced by a demand for food that grows more rapidly than the farmers' ability to produce it.

Carey, inspired by Liebig's finding that the major part of the fertility of land is the result of man-created improvements in drainage, fertilizer, irrigation, and land management, pointed out that land functions only as the means for converting fertilizer, water, and air into food. Land is neither consumed nor exhausted, nor is its food-producing capability a "natural" property. Land is fertile, he said, to the extent that man alters its natural tendency to revert to forests; therefore, man must continually recreate the fertility of the land.

Carey's arguments against Malthus and Ricardo are

PROJECTED LIFE EXPECTANCIES FOR THE YEAR 2000 IN MEXICO AND INDIA, 1960-1980

Over the course of the past 20 years, there has been a remarkable change in the life expectancy projected for the year 2000 for the Third World. Life expectancies are projected based on the known consequences of health expenditures, infrastructural development, and the like. The drop in life expectancies shown here results from the drastic drop in the levels of investment in the past five years. The Global 2000 Report *outlines—and recommends—the policies that will cause such a drop.*



The discredited policies of Adam Smith (left) and Thomas Malthus (right) are alive today at the World Bank, the United Nations, and the U.S. State Department.

strikingly modern; in fact, they suffice to destroy the scientific basis of the *Global 2000 Report*.

Carey illustrated his argument with an historical refutation of Ricardo and Malthus's law of decreasing returns in agriculture. Carey showed that, contrary to common sense, all societies that are growing progress from cultivation of the *poorest* lands first to richer and richer lands! The richest lands, he argued, because of their fertility, will be wet, swampy, or heavily forested. In any case, such lands are unavailable for cultivation by a small population. Indeed, the history of the American colonies provided striking proof of this statement, since the first successful colonies were in the poorest agricultural areas, like Massachusetts, while very fertile areas in the South remained virtually uninhabited because of malaria, dense forests, and the like.

Carey takes this argument one step further by showing that the fertility of the cultivatable land increases with increasing population density. It is only with more people that the surplus labor becomes available for clearing forests or draining swamps. If the first settlers in America had tried clearing the forests of Pennsylvania, they would have starved to death, for example; but with the growth of cities and more intense cultivation of farmland, water control and the recycling of organic waste became feasible, resulting in a rise in the average fertility of land *in direct proportion to the density of the population supported by the food from that land.* It is important to note that this one argument suffices to completely destroy the whole system of Malthus's overpopulation and Ricardo's rent theories. Both these theories depend on the combined assumptions of a "natural fertility" of land and of the progression from the first, most fertile land to poorer and poorer land for farming.

Carey's masterful insight provoked almost no reaction from the continental economists, who by that time were totally dominated by the Malthusian school. However, in the United States, it led to the writing of one of the towering economic works of the 19th century, Erasmus Peshine Smith's *Manual of Political Economy,* published in 1853. This little book, drawing on Carnot and Joule's work on heat, List's work on productivity, and Carey's economic interpretation of Liebig, contains a profound formulation of a theory of "thermodynamic efficiency" for economic systems, and, from this, a rigorous basis for an economic theory of population.

E. P. Smith's Energy Theory of Value

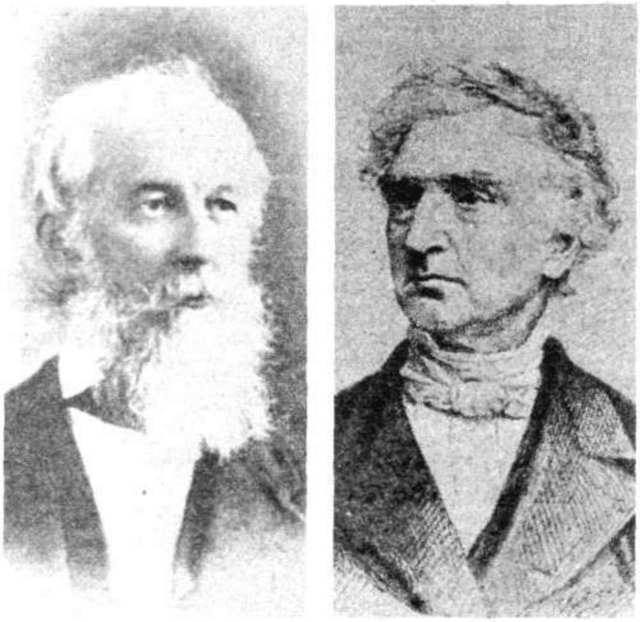
Beginning with a restatement of Carey's arguments on the fertility of land and its dependence on population density, Smith proposed a twofold generalization of Carey's observation, what Smith called the "law of endless circulation in matter and force."[12] Smith concluded, first, that the essence of Liebig's agricultural science is that land used for the production of food is actually only the means for transforming matter and energy into an economically useful form. That is to say, land is not used up in producing food; rather, land is surface through which water, fertilizer, and sunlight are forced to generate food. Smith then took a remarkable step: He said that all capital was distinguished by its function of mediating the transformation of energy into useful output. Thus, 100 years before any other economist, Smith concluded that land was not essentially different from any other aspect of man-improved nature—it was a converter of energy.

From this extraordinary standpoint, Smith made three critical conclusions:

First, the importance of capital (in either industry or agriculture) lies in its giving man the ability to appropriate the "gratuitous forces of nature," which man uses to amplify his own power. "Machinery is the appropriation of power existing in Nature, and only waiting for human intellect to discover its existence and laws, and to devise the means, in accordance with those laws, of converting it to use."[13] Smith took Hamilton's idea of artificial labor and discovered that it owed this remarkable property of amplification to the additional energy made accessible by capital.

Second, Smith immediately saw the thermodynamic implications of this idea and defined a free energy ratio for an economic system, which he saw as equivalent to a productivity function. That he saw the equivalence of the two notions is astounding; that he quantified a free energy-productivity function as the ratio of "gratuitous energy" to manpower is even more amazing. In a letter to Henry Carey written shortly after the publication of the *Manual,* Smith explained this idea in detail:

> Wealth consists in the power of man to command the always gratuitous forces existing in Nature. This is equivalent to the proposition that wealth consists in the low value [that is, input labor costs] of products, in the dimunition not the increase of value. If we represent the mass of quantity of commodities in a



The agricultural chemistry of Justus Liebig (right) and the economics of American System thinkers like Erasmus Peshine Smith (left) thoroughly refuted the Malthusian lies about population outpacing man's ability to grow food.

community by Q, Value and Wealth by V and W, you may express it mathematically $Q/V = W$; that is, to say when Value is stationary Wealth increases in proportion to Mass or Quantity; when Quantity is stationary Wealth increases only by the decline of value and any accession is then represented by *leisure*. The formula avoids the materialism of the old systems, and the only objection which now occurs to me is that it clashes with the material signification that modern usage has given to the word wealth, bringing it back to the old sense of weal, well-being. When this is done we must cease to speak of Wealth in any of the relations of quantity which apply to physical objects only. You can no longer say the United States have twice the Wealth of France, any more than you can say they are twice as happy. To express it viz the relative Wealth, in the modern sense, you would have to say that they have twice the quantity of products, or they have the same quantity of products and work but half as long and as hard.[14]

Third, amplifying Carey's observation, Smith stated emphatically that the causal element in the whole production process was the manpower required. As Smith stressed in the quotation above, his energy theory demands a nonscalar concept of energy, a concept whose qualitative aspect is required first, because the result of the energy consumption must be useful economic output, and second, because the available energy in any process is defined relative to the transformations in technology required for the consumption of that energy. Man enters as the causal agent first because it is his muscle-power that must be minimized if wealth (or productivity, or relative potential population-density) is to increase. For Smith, this was accomplished by a skilled, highly paid work force:

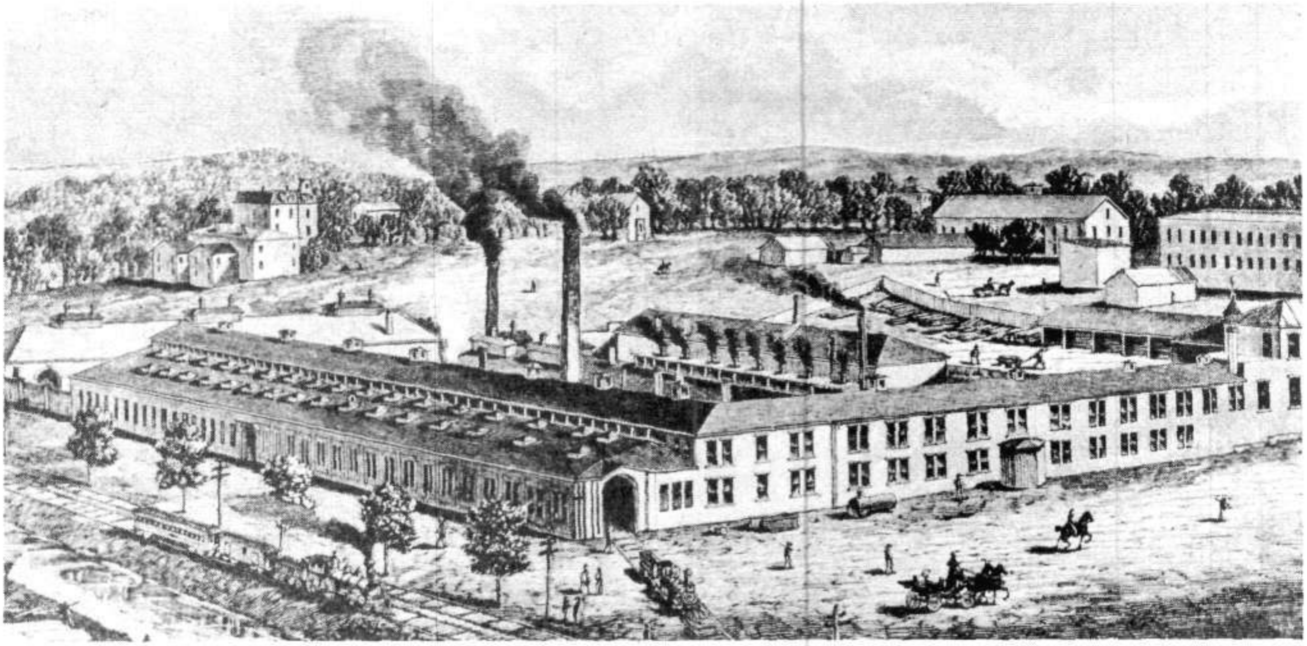
> *Looking upon a human labourer, then, just as we would upon a steam-engine, we see that the amount of force which he is capable of exerting, depends upon the amount of food supplied to him—a part of it answering to the water that is converted into steam and generates motion. A sheet-iron jacket put around the boiler prevents the waste of heat in one case, just as a woolen jacket about the body of the labourer does in the other.*
>
> But food, clothing, and shelter are supplied to the human machine in the shape of wages. To stint them, and to keep the labourer down to the lowest quantity that will induce him to live, without deterring him from propagation, is precisely the same kind of economy which would keep the steam-engines of a nation at half their working power, to save wood, and water, and sheet-iron.[15]

Smith then pointed out, that man is a very inefficient converter of food into heat or force, and that his real genius is as creator of the technologies that amplify his own puny power:

> real power is mental. *It is a waste of power for him to take that upon himself, which can be better and more* cheaply accomplished by brute matter. He ceases to do so just in proportion as, by studying the laws which his Creator has imposed upon the material world, he rises to his Creator's design and becomes its Master.[16]

This power of invention is the causal element in economic progress, as Smith described in an eloquent passage:

> It is manifest, too, that there is a law of constant progress in man's appropriation of natural forces, independent of the discovery of any new motive powers. Every machine facilitates the construction of new ones, for utilizing those already known. It cheapens them; it enables us to undertake those previously impossible (without regard to cost), for want of the necessary quantity and duration of force; and it liberates men from physical toil, to study and experiment. Each new truth discovered is the key to a whole magazine, and each new art the parent of a thousand. The motive forces of Nature first brought into use were the most gross, material, and, therefore, obvious. The weight of running water, the wind that rustled every tree—these forced themselves upon the observation of the earliest men. Steam, caloric, atmospheric pressure, are more subtle and more useful, because they can be developed on the spot where their action is required. The machinery for their use can be carried where it is wanted—can drive itself on its way. Electricity surpasses them in subtlety and power, in rap-



Asher & Adams, *Pictorial Archive of American Industry*, 1876

"Every machine facilitates the construction of new ones . . . and liberates men from physical toil, to study and experiment." With the American System economics as a guide, U.S. heavy industry grew rapidly in the last quarter of the 19th century. Here the Manchester, New Hampshire Locomotive Works, one of many illustrations in an 1876 centennial album of American industry.

idity and intensity of action. Invisible, imponderable, of immeasurable velocity, it seems like the link between matter and spirit. So volatile is it, that it has thus far eluded the endeavors of science to make it do the work of which it is undoubtingly believed capable. It separates metals from their ores, it gilds them, it runs errands on the telegraph wires, and finds its way back through land and water, annihilating space. But of an agent that can work such marvels what are we not authorized to expect? And once having fully mastered it, what yet more tricksy and potent spirit may we not evoke by its aid?[17]

Human Nature and Population

Smith's formulation of a thermodynamic theory of economics is successful because he identifies the driving force in economic progress as man's ability to generate new technologies—not the static efficiency of a given technology, nor the living standard of a given population. Rather Smith defines this as the way new inventions create the economic and demographic environment for their own succession by technologies that make higher living standards and greater energy intensities possible. This quality of man and his interaction with the material world was elaborated by LaRouche in a recent series of papers into a modern theory of relative potential population-density.[18]

The same theme was taken up from a theological standpoint in the September 1981 encyclical by Pope John Paul II, "On Human Labor." In this document, the Pope defines work as the *differentia specifica* of man. Man's having been created in the image of God, the Pope says, refers precisely to his being endowed with a spark of his Creator's creative spirit.

The American System economists understood this point in a very precise way, and they used it to provide the most powerful argument against the Malthusian doctrine and on behalf of the American System. This debate has reappeared in a modern garb in what is probably the most vicious argument of the Malthusians—that man is limited, that his wants and needs are limited, and that mankind must, at this point, give up its quest for material well-being and pursue instead a higher "quality of life." Behind this euphemism is the Malthusians' demand that man become an animal. In a passage that should be writ large over every school of economics Smith wrote:

> It is the characteristic of man, in his higher nature, that his desires are illimitable, always propagated in widening circles, of larger extent—as the ring made by a stone cast in the water creates another beyond it. The animal nature has no such quality, because its functions are carried on in a mechanical way, by the prompting of instinct, which is neither progressive nor improvable. It can find out no new pleasure; for all pleasure resulting from the activity of functions, where these are actuated by an unvarying force, their activity has a fixed limit, and the capacity for pleasure is equally constant. The round of its wants is small and unchanging; once satisfied, the stimulus to action is gone, and the animal nature reposes contented. Its constitution is adapted to a stationary condition, which it never seeks to improve. The foxes that

Nimrod hunted had the same fleetness and cunning, and no less greed for poultry, or other vulpine luxuries, than those trapped by David Crockett. Crockett, on the other hand, desired a thousand things, to the wish for which, Ulysses, after all his wanderings and sightseeing, was a perfect stranger; and the men of the year 1900 will have as many new motives for exertion as they will have comforts and conveniences of which we have no conception. . . . Social progress consists in the growth of population and capital. Both begin at zero together, and go on continually increasing. As labour becomes continually more effective, each unit of population in one generation makes a larger contribution to the stock of capital than a unit in the preceding generation. It follows that capital increases in a more rapid ratio than population. It certainly follows, unless the increasing power of man is attended with a decreasing disposition to exercise it. Such would be the case if his wants and desires were constant. But it is the characteristic of his nature, that which distinguishes him from the brute, that his desires are insatiable. The satisfaction of one creates another; and he is thus goaded by his intellectual and moral nature—the angel element in the human constitution—to ceaseless activity. The lower animals, from generation to generation, have the same uniform powers and the same wants. Nature gives them an early maturity of frame, and an instinct which makes no progress. They win from her no further powers. They are contented, and devise no machine, no art. With all the imitative faculty of the monkey, and his opportunities of seeing its great convenience to man, it is said that he has never yet learned to make a fire.[19]

Economic development and growth are not, of course, ends in themselves; but the realization of man's human potential is. It is historically and causally obvious that the opportunity for every human being to realize his human potential requires a high standard of living. However, Peshine Smith's contention—that the standard of living required for continued human progress is rising and that man's needs are never satisfied—is not so obvious. In modern terms, Smith would be describing the necessity for the development of unlimited energy sources, like fusion, and the necessity for man's colonization of the solar system. These are the challenges of the American System today.

Dr. Steven Bardwell, editor-in-chief of Fusion, has written a number of articles on the necessity for population growth and has directed the FEF work with the LaRouche-Riemann economic model on the U.S. and world economies.

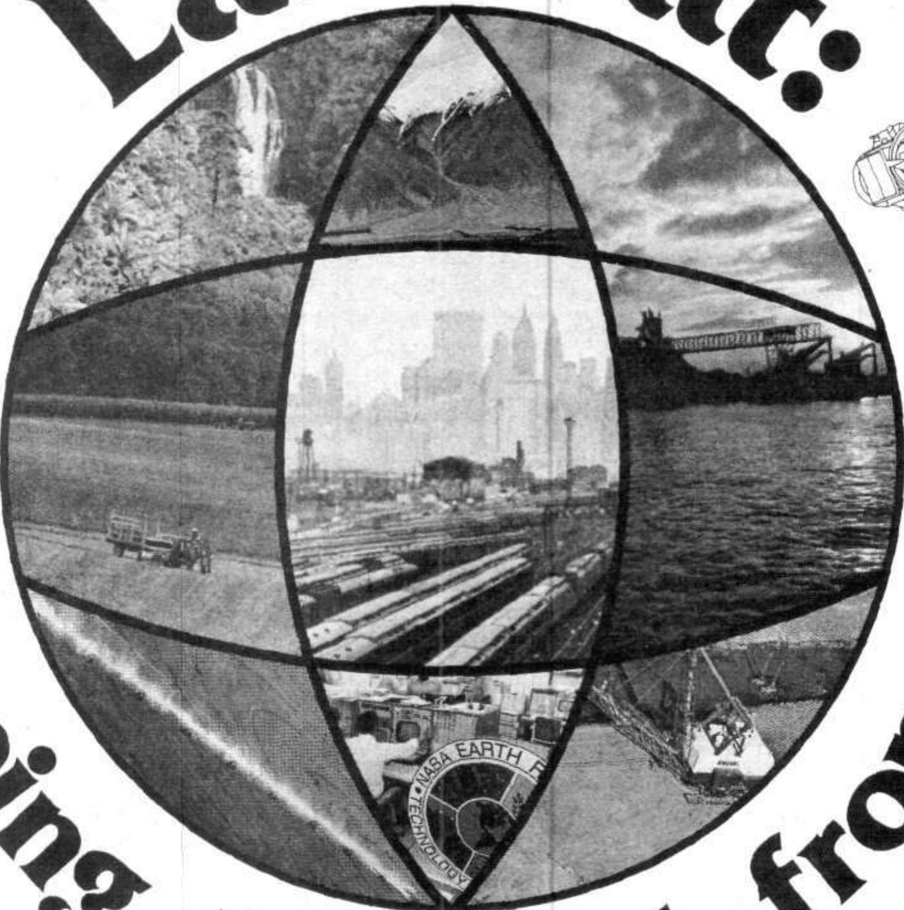
Notes

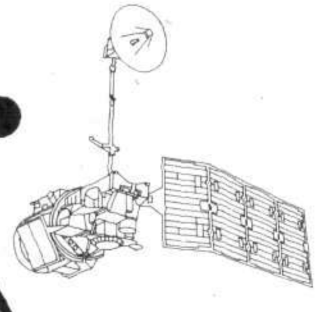
1. *The Global 2000 Report to the President,* along with its policy recommendations, *Global Futures,* was commissioned by President Carter in 1977 and published in January 1981, just before Carter left office. The reports have generated much literature attacking their scientific incompetency (see, for example, "The World Needs 10 Billion People: A Scientific Refutation of Global 2000" *Fusion,* Sept. 1981, p. 24). However, *Global 2000* is still under active study by the Reagan State Department as the basis for American foreign policy.
2. See "The Global 2000 Attack on Colombia" and "How the Colombian Population Was Cut" by Cynthia Rush, *Executive Intelligence Review,* Dec. 1, 1981, p. 37.
3. The passage of Medicaid in 1965 resulted in a dramatic drop in infant mortality rates in the United States. Infant mortality had leveled off at approximately 27 per 1,000 births between 1960 and 1965, having slowly declined from a level of 29 in 1955. In the first 10 years of Medicaid, however, the infant mortality rate dropped to about 14 per 1,000. In other words, prior to Medicaid, American babies were dying for lack of medical care.
4. *Global 2000 Report,* Vol. 1 (Washington D.C.: Government Printing Office, 1981), p. 12.
5. Julio Silvacomenares, *No Mas Hijos* (Bogota, Colombia: Ediciones Paulinas, 1974).
6. The American System was the name given by Henry Clay to his Hamiltonian, protectionist economic policy. It was first used in a speech before Congress in 1824.
7. Alexander Everett, *New Ideas on Population* (Boston: Cummings, Hilliard and Company, 1826). This was reprinted in 1970 by A.M. Kelley Publishers, New York, (with an introduction by M. Hudson).
8. Lyndon H. La Rouche, Jr., "The Economics of Population," *Campaigner,* Oct. 1980, p. 8.
9. Henry Carey and Erasmus Peshine Smith were both close collaborators of William Seward and served under him in the State Department during the Lincoln, Johnson, and Grant administrations. The political impact of Smith's work, ironically, was much greater in Japan than in the United States.

   Through the recommendation of Seward, Smith was appointed as an official adviser to the government of Japan during the years 1871-1876. In this capacity, he set up the foundations of the dirigist Japanese credit system, industrial tariff system, and education system. It is interesting that these early years of the Meiji government saw the passage of the critical banking bills that remain the crux of the Japanese ability to fund innovative, nationally directed industrial research. The Japanese National Bank Act of 1872 and the Gold Notes Conversion Bonds Act of 1873 were specifically modeled after Hamilton's credit policies as these were imported into Japan by Smith; both are generally credited with "playing an important part in the 'take-off' of the Japanese economy during the second decade of the Meiji era (1877-1886), and with helping to lay a firm base for the development of modern industry," according to an official 1973 Bank of Japan study.

   Smith is well known in Japan today, his economic policies are studied, and his book is in print in Japanese! Recent speculation about the Japanese economy to the contrary, the "secret" to its success is merely that the Japanese continue to use the American System of economics: The United States should reimport Peshine Smith.
10. E.P. Smith, *Manual of Political Economy* (New York: George P. Putnam, Co., 1853), p. 62.
11. Hamilton is certainly the first of the American tradition of what was to become the "American System." He had a host of Whig followers before Henry Carey and Smith, among them Thomas Colton, Alexander Everett, Daniel Raymond, and Mathew Carey.
12. Smith's *Manual of Political Economy* contains this polemical formulation (p. 204): "In Belgium, which sustains a population of 336 to the square mile—one to every arable acre in the kingdom—which, according to Mr. M'Culloch, produces commonly more than double the quantity of corn required for the consumption of its inhabitants,' and where immense numbers of cattle are stall-fed for the sake of their manure, the liquid excrements of a single cow sell for ten dollars a year. The people of Belgium are able, by making their own population, animal and human, the most dense of any country in the world, to raise beef, mutton, pork, butter, and grain, cheaply enough to admit of their exportation to England, to feed people who believe in over-population."
13. Smith, *Manual,* p. 73.
14. Smith, in a letter to Henry Carey, Dec. 28, 1854, as cited in a doctoral thesis by M. Hudson, "Erasmus Peshine Smith: American System Economist," New York University, 1968. Hudson's thesis is a valuable source of information on Smith.
15. Smith, *Manual,* p. 107.
16. Smith, *Manual,* p. 74.
17. Smith, *Manual,* pp. 74-75.
18. See, for example, "Systems Analysis: White Collar Genocide," *Fusion,* March-April 1982, p. 19 and May, p. 39.
19. Smith, *Manual,* pp. 23, 83.

Landsat: Developing the Earth from space





by Marsha Freeman

At this very moment there are two satellites, called **Landsat,** orbiting the Earth and helping farmers, geologists, city planners, scientists, and explorers to learn more about our planet. The information that these satellites send back to receiving stations all over the world makes it possible to discover new areas of minerals and other resources hidden deep within the planet. Landsat also helps us manage water for agriculture and industry, and plan the future use of the planet's resources.

Since 1969, when astronauts in the Apollo spacecraft took pictures of the Earth on their way to the Moon, the National Aeronautics and Space Administration (NASA) has been improving the technology to study Earth from space. The Landsat satellites are sending us information every day that we cannot get from simply looking at the Earth close-up.

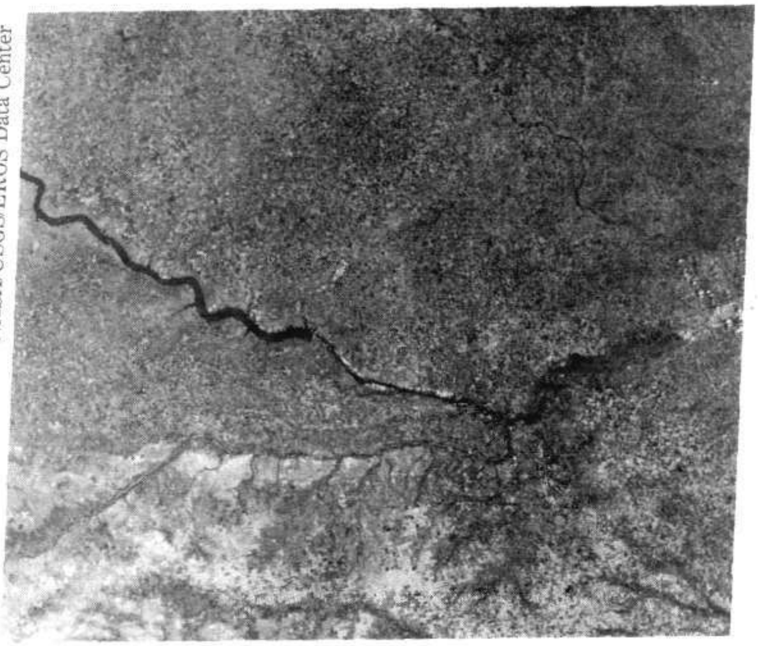
The work that Landsat does is called **remote sensing.** The simplest kind of remote sensing is the kind that you do, with your eyes. Remote sensing simply means getting information about something without touching it.

If you were a farmer and you wanted to know how your crops were growing, you could walk in the fields and simply look at them, but you wouldn't see very much. You might get into a car and drive around the edges of the farm. But you would still see less than 10 percent of the whole farm.

You could also rent an airplane and fly over your farm. But then you could see only small parts at a time, and if the weather were bad you could not fly at all. Besides, you would have to come down every time the pilot got tired or the plane ran out of fuel. It would be very expensive to fly over your crops every couple of weeks during the summer growing season to make sure the plants were healthy and were getting enough water.

Remote sensing from an airplane either with the eye or with a camera has been used for many years, but the development of space remote sensing makes it possible to look not only at a farm, or a county, or a state, or a country—but at the **whole** Earth over a short period of time. It also provides a way to get information without people having to do the looking, and it shows us things we couldn't see with our eyes, even if we were right there.

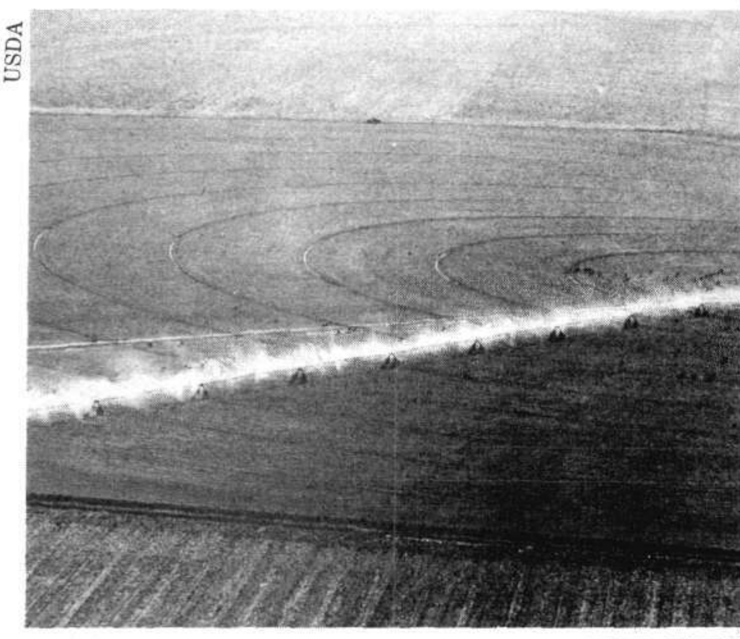
NASA/USGS/EROS Data Center



Above: Landsat monitoring of center pivot irrigation systems in Nebraska at different times of the year helps farmers plan for crop yield and ground water supplies. The center pivot irrigation plots are the tiny circles in the lower part of the photo. The rectangles throughout the rest of the photo are the more familiar field patterns. The differences in infrared radiation reflected into space and measured by Landsat tell scientists how the crops are growing, whether there is any disease, and how much irrigation is required.

At right: A center pivot irrigation system as seen on the ground in Amarillo, Texas. The arm of sprinklers on wheels rotates around the circular field.

USDA



How Landsat works

NASA launched the first in its series of Landsat remote sensing satellites in 1972. Since then it has launched two more, each with more advanced equipment. Each satellite weighs less than 1 ton and contains two basic instruments to "look" at the Earth, a Return Beam Vidicom and a Multi-Spectral Scanner.

The **Return Beam Vidicom** instrument is made up of two television cameras. Each camera takes photographs in black and white, each picture showing an area of land 58 miles long on each side. The photographs are similar to those taken from airplanes, but are of much larger chunks of land.

The second Landsat instrument, which is used to generate the color pictures, is a **Multi-Spectral Scanner,** or MSS for short. As indicated by its name, the MSS does not take individual pictures but does a continuous **scan** of the area on the Earth's surface.

It is **multi-spectral** because it can "look" at the Earth at four different wavelengths at the same time. Two of the wavelengths are different colors of light. We see different colors with our eyes because the objects we are looking at reflect light waves back to our personal remote sensors in very specific wavelengths.

Light is the visible part of the electromagnetic spectrum of energy, which ranges from the very long wavelengths of heat to the very short wavelengths of ultraviolet light and X-rays. *(See figure page 49.)*

The Landsat MSS can sense light reflected from the Earth to the satellite in the colors, or wavelengths of green and red, which are part of the visible spectrum. But the MSS can also "see" infrared waves, which are too long for our eyes to see. These are similar to the radio waves that travel from the radio station to your home radio, passing through the air invisibly.

Landsat can sense two lengths of infrared radiation, and this information can be combined with the green and red light it senses to produce a picture with a great amount of information. For example, when you look at another person you can see him or her in wavelengths that tell you what color shirt the person has on, but not whether the person has a fever. Landsat could detect such a fever by sensing the infrared waves reflected from the person's body.

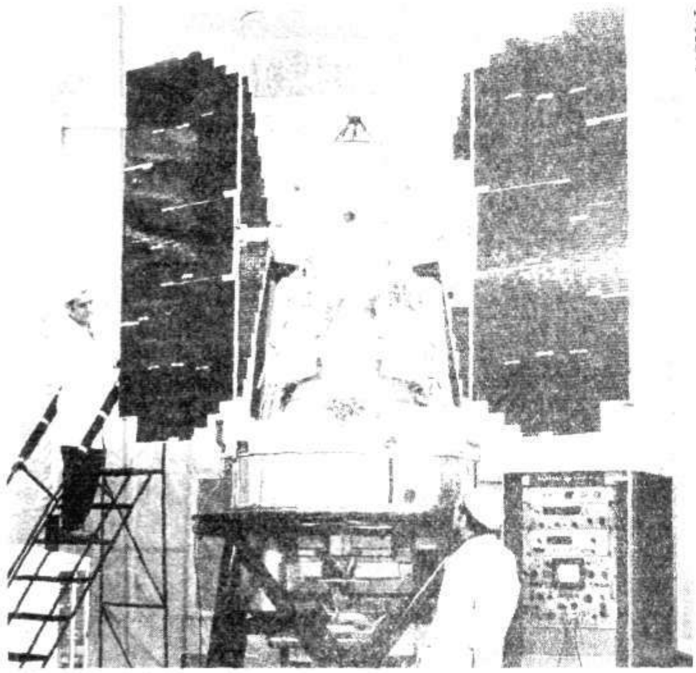
The Earth Resource Observation System

The Landsat instruments change the information they receive to electronic signals and send these pulses back to Earth, where three stations in the United States and ten more around the world receive the Landsat information. Once these signals are received, the stations relay them to the NASA Goddard Space Flight Center in Maryland, using a communications satellite.

At Goddard, the information is stored on film and on computer tapes. When the information has been changed into a more usable form, it is sent on to the **Earth Resource Observation System** (EROS) Data Center in Sioux Falls, South Dakota. There the pictures and tapes are stored and sold to people who request them.

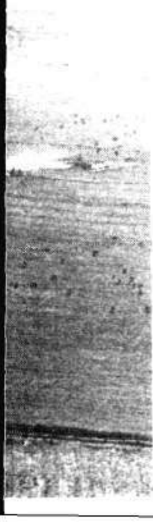
A lot of work must be done to transform the Landsat "raw data" into pictures that people can use. Each Landsat picture shows an area of about 13,000 square miles. The smallest object that the MSS can see is about 260 feet long. As the MSS is scanning the scenes below, it is sending more than 1 million pieces of information, or electronic pulses, back to Earth each second! It takes more than 30 million pieces of information to put together one picture showing this 13,000 square miles.

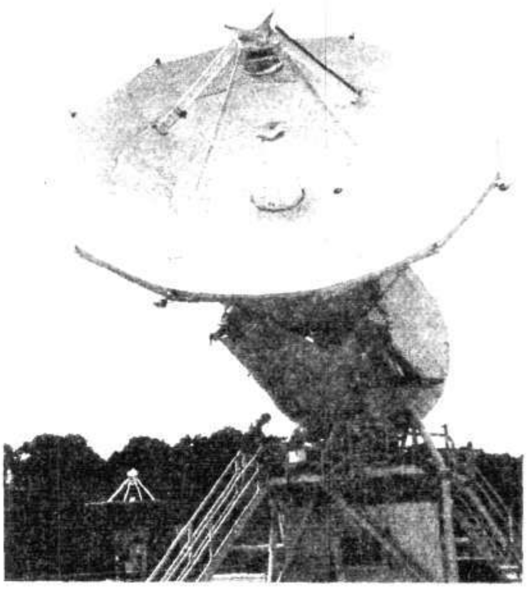
Advanced computers are used to put this picture together. The process is similar to the way NASA made photographs from the information that Voyager sent back from Jupiter and Saturn. Many of the pictures do not look



NASA

Above: NASA's Landsat-C undergoing final testing at General Electric's facility in Valley Forge, Pennsylvania, in 1978. The butterfly-shaped satellite takes photographs in black and white with the Return Beam Vidicom instrument. At the same time, the Multi-Spectral Scanner does a continuous scan of the Earth and records the infrared radiation reflected into space by the Earth's surface.





NASA

At left: NASA's 30-foot diameter antenna for the tracking center at Goddard Space Flight Center in Greenbelt, Maryland. The antenna receives video signals from Landsat's Return Beam Vidicom Cameras and Multispectral Scanner. This is one of three tracking stations in the United States and ten in the world that receive Landsat information.

"real," because the colors are not true to what we see with our eyes. NASA scientists add "false color" to the computer images to highlight the important features in the scene.

For example, the infrared information that Landsat "sees" is not the red color that we see with our eyes. So computer specialists combine different colors to make the infrared features visible to our eyes. It is as if you took a photograph of your kitchen and wanted to make all the hot areas near the oven red. You would have to say that red meant hot, no matter what the real color of the oven and the floor around it. This is similar to the way NASA uses false color in the Landsat images.

Why is the infrared important?

If we took an aerial photograph of the state of Kansas in July, almost everything would look green. But how could you tell which farmers are growing wheat, which farmers are growing corn, and which farmers are growing other crops? Suppose you had to know this because farmers' crops in another part of the world were suffering from a bad wheat disease and the farmers needed to buy American wheat. How would you know how much wheat was actually growing in Kansas?

Every different kind of plant reflects a different amount and intensity of infrared waves. Landsat can tell the difference between wheat and corn and soybeans, for example, by the kind of infrared radiation these plants reflect into space. Therefore, Landsat can tell exactly how much wheat is growing in the state of Kansas.

The infrared rays will also change if the plants are diseased, are not getting enough water, or are under stress and might become diseased soon. Using the MSS Landsat images farmers can tell where their crops are in danger while there is still enough time to get more water, pesticides, or other remedies to these crops. Even on hazy days, Landsat can photograph the crops, because infrared waves can pass through the haze in the Earth's atmosphere.

Other parts of the infrared spectrum can also tell the amount of heat given off from different plants, rocks, and soils. Geologists are hopeful that they will find the infrared "signature" for different kinds of rocks, just as farmers use the infrared signatures of their crops. If they could tell what kinds of rocks are where, these geologists could help locate minerals, petroleum, and other natural resources beneath the Earth's surface. Then geologists could do resource exploration from space instead of digging a lot of expensive holes in the ground to search for resources. Geologists would also have a better understanding of how the Earth formed and how it developed.

Hundreds of uses

In fact, the information gathered by Landsat is being used by more than 100 countries around the world. Scientists are measuring the amount of snow that falls in mountains in the winter in order to tell farmers how much water they will have when the snow melts in the spring. If there has not been enough snow, the farmers will know in the winter, when there is still time to change their spring planting plans or get water from other sources. If there has been too much snow, they will have a warning for possible floods in the spring.

Landsat images have been used to look at large areas of the world and identify fault or fracture lines in the Earth's crust that are not visible to more limited vision. These fractures could indicate places where earthquakes might take place or where deposits of minerals might be located.

Pictures from Landsat are important in using all of our Earth resources most productively. Very often the photographs are combined with other remote sensing observations from airplanes or on the ground to give a more complete picture of the Earth. More advanced technology scheduled for the next Landsat satellite to be launched this summer will allow us to see features as small as a city block.

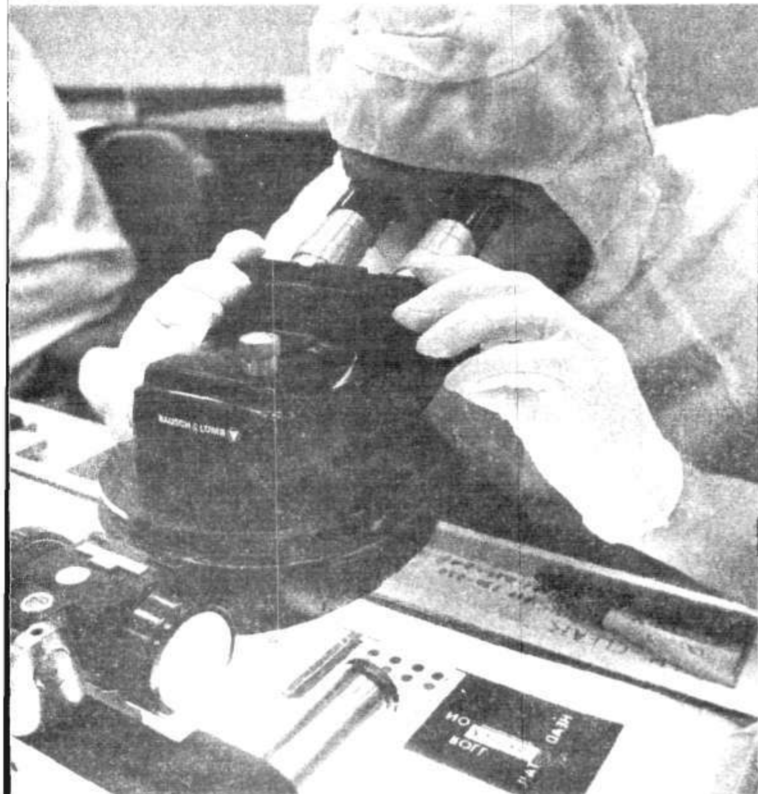
The uses for Landsat are nearly limitless. More exciting ways to use the images and improve the technology are being developed all the time. Perhaps during the 1980s we shall develop remote sensing so well that space will become the major means for developing Earth.

For more information on Landsat, write to:

Phyllis Wiepking
U.S. Geological Survey
EROS Data Center
Sioux Falls, South Dakota 57198

The Landsat color photographs on the cover are from the book *Earth Watch* by Charles Sheffield (New York: Macmillan Publishing Company, Inc., 1981).

NASA



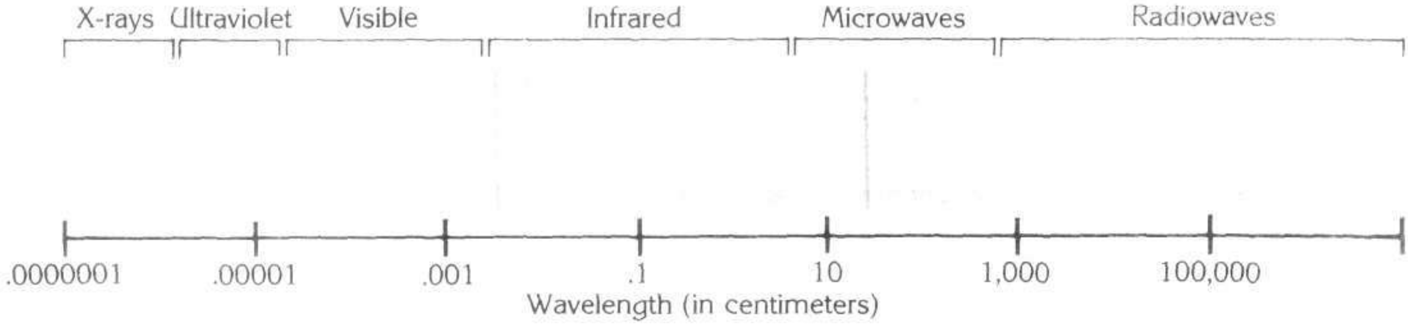
Above: *A photo technician examines the details of data from the first Landsat satellite in an analyzer. Each Landsat picture represents 30 million pieces of information.*

Below: This array processor performs millions of computations per second to process satellite images and remove any imperfections in the millions of pieces of transmitted data in each picture.

Floating Point Systems

The Electromagnetic Spectrum

The visible light recorded by our eyes or conventional photographic film is just a small part of the spectrum of electromagnetic energy or radiation. Most electromagnetic energy travels in waves of various lengths that are invisible to the naked eye but accessible to satellite cameras. On either side of the electromagnetic spectrum are types of radiation that provide valuable information on plant life, water, heat movement, and many other things. The electromagnetic radiation with wavelengths slightly shorter than visible light is called ultraviolet (because it is adjacent to the violet part of the visible spectrum), and the radiation with longer wavelengths is called infrared. Beyond infrared, at even longer wavelengths, there are microwaves and radiowaves. In the other direction, beyond the ultraviolet, there are X-rays of increasing energy and shorter wavelengths.



Dmitri Mendeleev: Scientist and leader

The Russian chemist Dmitri Mendeleev (pronounced Men-de-lay-ev), who lived from 1834 to 1907, is best known for his discovery of the Periodic Law of the Elements, which organizes the elements according to atomic number and chemical property.* Less well known is the important role Mendeleev played in the industrialization of Russia, the reform of its educational system, and the modernization of its agriculture.

"The greater a man's natural gifts, the greater his responsibility to society," Mendeleev wrote. His dedication in applying his mind to solve major problems in many fields was something he shared with other great 19th century scientists.

Mendeleev was born in a little town in Siberia, which was then a more isolated and wild frontier than the American West. Siberia would remain this way until the building of the Trans-Siberian Railway, a project that Mendeleev was deeply involved in during the 1890s. The railway permitted the industrialization and colonization of Siberia, "our own America," as Mendeleev often called it.

Mendeleev's grandfather had founded the first newspaper in Siberia, and his family operated a glassworks. Looking back on his early years, Mendeleev wrote:

> *I grew up near a glassworks. My mother was its manager, supporting the children she had been left with [when his father died]. Since childhood I knew what factory life meant and . . . that the factory is one of the nation's breadwinners, even out there in Siberia; that is why, while devoting myself to such an abstract and real science as chemistry, I was interested from early days in factories and workshops.*

Even though Siberia was largely a wilderness at that time, Mendeleev's home town of Tobolsk had an active intellectual community. This community was composed of many exiles from the Decembrist Revolution in St. Petersburg, a failed attempt by young military officers in 1825 to set up a constitutional republic in Russia, which was directly inspired by the success of the American Revolution several decades earlier. Mitya, as young Dmitri was called, was tutored by these intellectuals in geography, mathematics, geometry, and botany.

The creation of national industries

Mendeleev's adulthood was a period of great change in Russia. Between 1855 and 1881, Tsar Alexander II introduced numerous reforms: In 1861, Russia's 40 million serfs were freed. This humanitarian act was the necessary first step in preparing the country's large-scale industrialization. The task facing the country was awesome. More than 95 percent of the population could not read. The average peasant lived only 30 years. There was virtually no skilled labor. The feudal nobility was trying to maintain the most primitive, labor-intensive forms of cultivation, which made Russian agriculture among the least productive in the world.

Mendeleev emerged as a national scientific and political leader in shaping this early phase of Russia's industrial development, which occurred at the same time as the post-Civil War industrialization in the United States. In 1865, Mendeleev founded Russian agrochemistry, drawing on the ideas of the German chemist Justus Liebig. Mendeleev set up experimental field stations in regions with each of Russia's five soil types and began investigations into the effects of mineral fertilizers. He determined the correct type of fertilizer for each soil type, which resulted in a many-fold increase in bushels grown per acre. In 1868, Mendeleev established correspondence with the U.S. Department of Agriculture, so that he could introduce the latest American discoveries to his country.

During the closing years of the 19th century, Mendeleev proposed and then guided the founding of the Russian chemical and oil industries. He insisted on introducing the most advanced technologies from Europe to tap Russia's immense natural resources and establish the country's economic independence. In particular, Mendeleev emphasized the importance of

# of his nation

creating a sulfuric acid industry and a sodium carbonate industry. Sulfuric acid was used in all stages of industrial processing and purification, and sodium carbonate was necessary in textile, glass, and soap manufacture. At that time, production methods were so backward that forests were burned down to obtain the soda ash used in manufacturing soap. All sulfuric acid had to be imported.

International cooperation

Mendeleev got many ideas on how to build up these industries from a tour he took of European chemical companies, after the International Exposition in Paris in 1867.

Mendeleev also represented Russia at the U.S. Centennial Exposition in Philadelphia in 1876. He used this opportunity to study the fledgling U.S. oil industry and to recruit American engineers to work in the Baku oil region in southern Russia.

Before the 1880s, Russia did not have any oil industry at all. For lighting, homes used candles or kerosene that was either imported or obtained from shallow pits. Factories were powered by burning wood. Again, Mendeleev proposed using the most advanced technology available at the time: in this case, machine-powered deep drilling, new distillation techniques, and centralized refinery, pipeline, and railway complexes. By 1900, Russia produced one half of the world's oil!

Like Mexico and the Arab oil-producing countries today, Russia's industrialists understood that exports of surplus oil would enable their country to import technology to develop other industries, while supplying other countries with the fuel they needed. Increased industrial output would then give Russia the surplus to industrialize Asia, beginning with China and India.

A scientific elite

Mendeleev was also a leader in the efforts to provide education for all Russians and to create a new generation of scientists who would be able to carry on his work. As an adviser to the government, he was instrumental in increasing the number of night schools for workers and in founding regular schools for children. He gave the first chemistry lessons to women; previously women were forbidden even to enter universities.

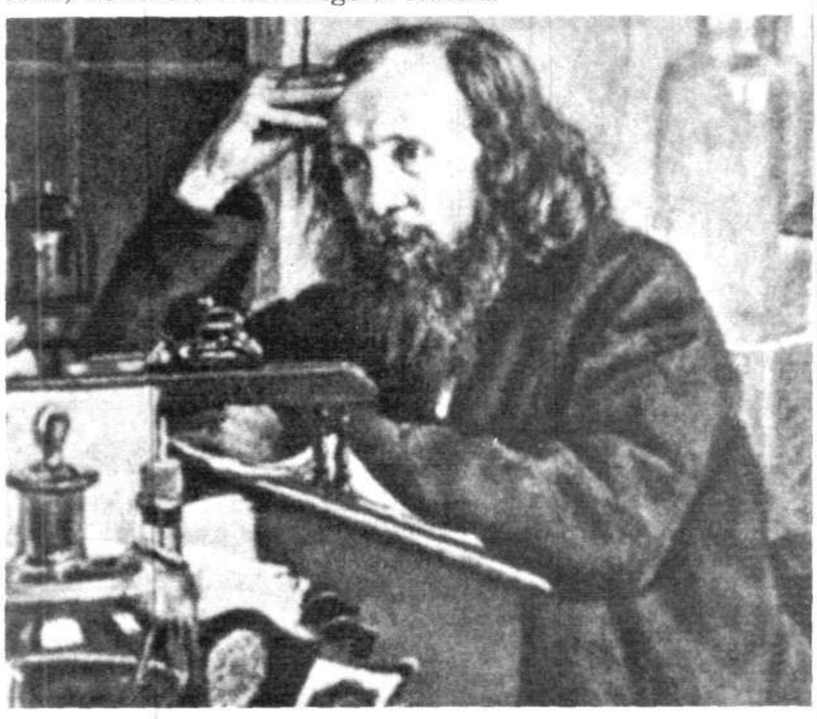
In 1868, Mendeleev founded the Russian Chemical Society to serve as a forum for scientific thought, directed to "building up the wealth of the country." At its monthly meetings all the latest scientific experiments and discoveries were reported and then later published in the *Journal of the Russian Physico-Technical Society.*

In this struggle to create a modern society with education, opportunity, and a decent standard of living for everyone, Mendeleev ran up against the environmentalists of his day. These were followers of the mystic and author Leo Tolstoy, who believed that the ignorant, diseased, half-starved peasant should be allowed to remain in his "natural" state.

In *Toward a Knowledge of Russia*, written in the last year of his life, Mendeleev boldly

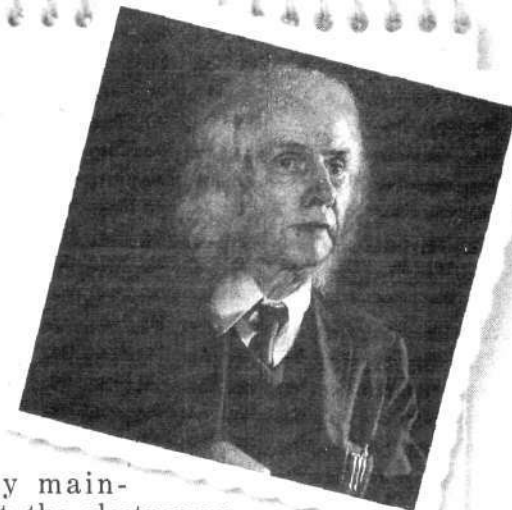
Continued on page 56

Dmitri Mendeleev in his study, a drawing by a friend that appeared in Mendeleev's 1906 book, Toward a Knowledge of Russia.



Interview

With Dr. Robert Moon



Dr. Robert Moon, professor at large at the University of Chicago, is a pioneer in the field of nuclear physics. He worked on the Manhattan Project during World War II, and since then he has been involved in developing ion beam fusion, spectrophotometry, and scanning X-ray systems. Dr. Moon is also a contributing editor to The Young Scientist. He is interviewed here by Melvin Klenetsky.

Question: How did you get interested in nuclear energy?

Moon: Lots of things started to come together in physics after the First World War—at first slowly, but then much faster. This made science tremendously exciting for everyone. Before then, in 1892, some scientists in the British Royal Society in England were saying that physics was a closed book. They said that Maxwell's field equations and Lord Rayleigh's work on this had explained everything. But after that, within a very short period of time, radioactivity, X-rays, and radium were discovered, and these things couldn't be explained with existing knowledge. Nineteen years later, in 1911 when I was born, physics was a wide open book, just as it is now, with scientists still seeking answers to unexplained questions.

Question: How do you mean that physics was considered a closed book?

Moon: The Royal Society maintained that Clerk Maxwell's work with electromagnetism and his field equations explained everything. To give you an idea of how closed things were at the time, the Royal Society maintained that the electromagnetic energy was carried *inside* the telegraph wire. The physicist Sir Oliver Heaviside and others argued that the electromagnetic energy was carried *outside* of the wire. But for five years, the British Royal Society, which set the standards for science in Britain, refused to publish Heaviside's work. Of course, Heaviside turned out to be right, but people had closed minds then, until the discovery of X-rays and radio waves put everything they knew into question again.

Question: When did you first get involved with science?

Moon: One of the first things I did was to build a radio. I was 7 years old, and it was right after the First World War. Radios were used by the Signal Corps on the front line, and after the war people started to build their own sets. Every town had a radio transmitter, so it became popular for people to build their own crude radios that would pick up the signals from the local transmitter.

Back around 1875, people like Thomas Edison and Heinrich Hertz used a spark gap for transmission; but by the end of the war vacuum tubes were developed. Vacuum tubes were used to amplify or strengthen the transmitting current. They consisted of a filament in a vacuum with a grid around it. The grid had fine wire wound on it and was insulated from the filament and also from the plate that surrounded the whole apparatus.

The idea was to set up an oscillating

current within the tube so as to induce a current in an external circuit. This works like a swing, but much faster, exchanging energy back and forth between an inductor and a capacitor. These oscillations are sent out from the transmitting antenna as a high-frequency radio wave.

Question: Is this how radio waves are transmitted, through the oscillating current?
Moon: Yes. The radio transmitter is in some ways like the telegraph. The dots and dashes of the telegraph are transmitted by turning on the high-frequency oscillator for short bursts during the dots and longer bursts during the dashes.

With the radio, the sound oscillations [Figure 1a] are "carried" by the continuous, high-frequency radio waves [Figure 1b]. The sound from the microphone modulates [varies] the amplitude or wave height of the carrier frequency, using a method known as amplitude modulation or AM. In AM, the height of the carrier radio waves is made larger or smaller corresponding to the voice or music sound vibration. The microphone modulates the top and bottom of the carrier wave equally, but in an opposite direction [Figure 1c].

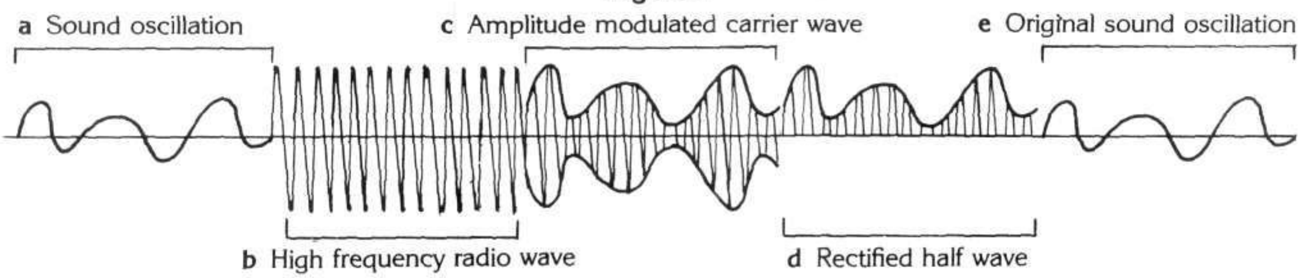
Question: What was your radio set like?
Moon: My first radio was a crystal set, made with galena. There's a lot of galena in southwest Missouri. It's a shiny, black substance that is easy to find by farmers, and it makes a beautiful little crystal. The crystal (which is also called a detector or rectifier or diode), allows the current to flow in only one direction [Figure 1d]. In this way, the crystal cuts off half of the received radio wave, and helps separate the lower frequency sound wave [Figure 1e] from the higher carrier frequency.

We put what's called a "cat's whisker" on the galena crystal. This is a fine phospher bronze wire that slides up and down the crystal searching out good semiconducting spots that would then rectify, or demodulate, the radio signal.

In the old days, the favorite tuning circuit for building a radio was a loose coupler. To make this, we would take two oatmeal boxes, putting a smaller one inside a larger one, winding wire around each one. The smaller one had its winding tapped every so many turns. The outer one had a brass slider, which let you change the inductance. The capacitor was fixed and you could pick up radio signals by varying the inductance. This was done by varying the number of turns in the inductor, tapping out some of the turns of wire.

I admit that this was crude and fussy equipment, but it did work after all, and I can't tell you how much fun we had making it.

Figure 1

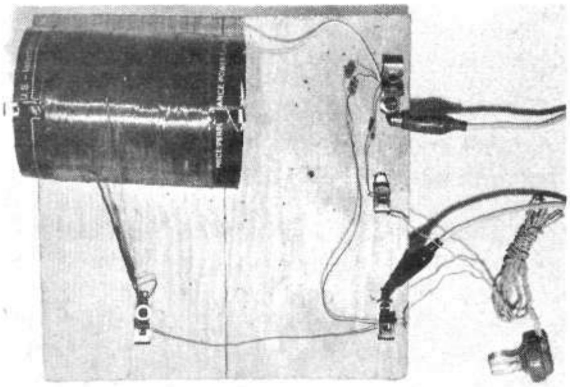


Wave Forms in AM Radio

To send a sound oscillation **(a)** *created by speech or music to radio receivers in homes and elsewhere, radio stations generate high frequency radio waves* **(b)**. *Each station has its own high frequency to send on; you receive these waves by tuning your radio to match the station's frequency. The high frequency waves* **modulate** *(vary) the* **amplitude** *(wave height) of the sound oscillation so that it looks like* **(c)**.

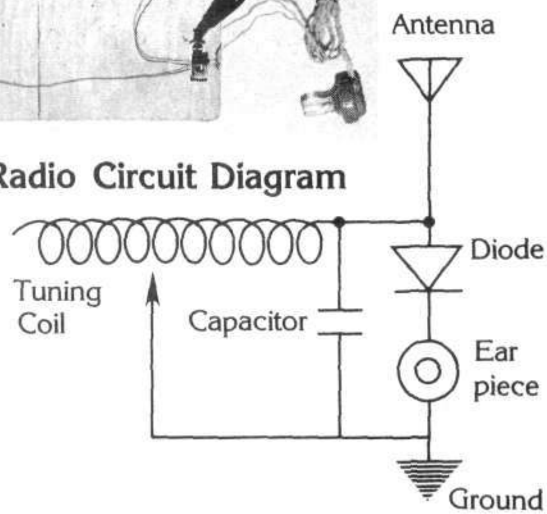
Note that the top and bottom of the carrier wave is modulated equally, but in opposite directions. This is called an amplitude modulated (AM) carrier wave, and it is picked up by the antenna of your radio. The capacitor helps remove the high frequency waves, and the diode in combination with the ear piece "rectifies" the waves **(d)** *so that your ear hears the original sound oscillation (music or speech) produced in the radio station studio* **(e)**.

Building a crystal radio set



Carlos de Hoyos

Crystal Radio Circuit Diagram



A crystal radio set similar to the one Dr. Robert Moon made when he was a young boy (see Interview) is shown in the photograph and in the figures. Note that the radio has no battery and is not plugged in to house current!

Today you can buy crystal radio "kits" for about $5—but we recommend that you purchase the necessary parts separately and build the radio shown here. You will learn much more than you can with a prefabricated kit.

The crystal radio takes its name from the material used to detect the radio waves transmitted from radio stations. In the early days of radio, after the First World War, a crystal of the mineral galena or of iron pyrites was used as a detector, together with a wire "whisker" to locate a sensitive spot on the crystal to demodulate the radio signals.

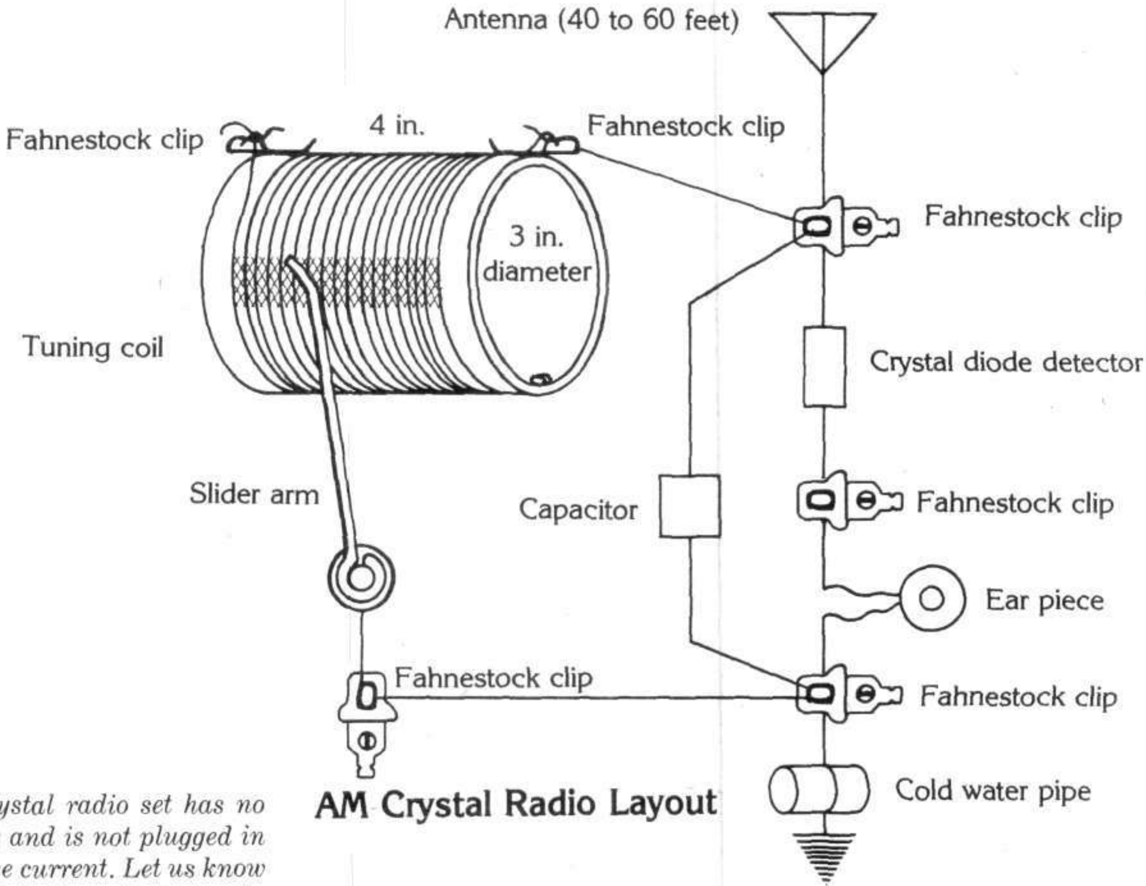
Galena crystals are hard to find today. Instead of galena, our experiment uses a crystal **diode**—a tiny crystal of germanium enclosed in a small tube. The "whisker" is inside the tube and needs no adjusting. These diodes can be purchased cheaply, and give better results than the early crystals.

We have also used a simpler version of the "loose coupler" described by Moon—a tuning coil and a slider arm.

In the crystal set, the antenna picks up the high frequency carrier radio waves transmitted by radio stations. The tuning coil with its slider arm selects the frequency of the AM station that you wish to receive. The capacitor, crystal diode, and ear piece then work in combination to block out half of the carrier wave and the high frequency wavelengths. This is called **rectification** (and detection). The sound you hear will be the same as that produced in the radio station studio.

Materials you will need

- 3 inch diameter (approximately) plastic or PVC tube, 4 inches long
- 1 dozen Fahnestock clips
- metal strip, preferably beryllium-copper or brass, 4½ × ⅜ inches, about 1/16 inch thick
- crystal diode, 1N34A
- capacitor (20, 50, 100 picofarad)



AM Crystal Radio Layout

The crystal radio set has no battery and is not plugged in to house current. Let us know what kind of reception you get.

- very high impedance crystal ear piece*
- 100 feet No. 20 shellacked magnet wire
- antenna wire, up to 100 feet (any wire can be used, including magnet wire)
- ground wire (25 feet should be adequate)
- 6 inches bus wire (00)
- 2 inches of No. 10 clean copper wire for slider
- 2 glass rod insulators
- clamp to attach ground wire to cold water pipe
- a few 6-32 ¼ inch bolts with matching nuts
- a few small brass washers with inner diameter of ⅛ to ¼ inch
- 9 inch × 9 inch wooden board
- sandpaper, medium and fine
- electrical insulating tape (small amount)
- soldering gun or small soldering iron

Tuning coil

Use a hollow plastic or PVC cylinder 4 inches long and approximately 3 inches in diameter to make the tuning coil. The PVC (this stands for polyvinylchloride) is much cheaper and should be available in plumbing supply stores. Dr. Moon cautions that for greater sensitivity, the ratio of the diameter of the cylinder to the length of the coil should be 1 or even a little larger.

Drill a hole ⅛ inch in diameter half an inch from each end of the cylinder. These holes are for mounting the tube on your board. On the other side of the cylinder, drill another pair of holes, ⅛ inch in diameter, half an inch from each end of the cylinder. Mount a Fahnestock clip in each of these two holes with a nut and bolt.

Use the No. 20 magnet wire to wind a coil on the cylinder. Magnet

* We were not able to locate a supplier who would fill mail orders for the very high impedance ear piece. If you cannot find a local supplier, we suggest that you purchase a commercial crystal radio kit just to obtain the correct type of ear piece. Kit No. 28-07 at Radio Shack stores includes the ear piece and diode. You could, of course, build the crystal radio both ways—from the kit and from the assembled parts.

wire has a transparent coating for insulation. Remove the coating from ¼ inch of one end of the magnet wire by scraping with sandpaper, and attach and solder this end to one of the Fahnestock clips. Carefully wind the coil, keeping it taut at all times until you reach the clip at the other end. Secure the windings with electrical tape so that they will not unwind. Cut off the remaining wire, leaving a free end of ¼ inch. Sand this end and solder it to the clip.

Mount the tuning coil on a 9 inch by 9 inch wooden board by putting wood screws through the two holes left in the cylinder. Remove some insulation coating on the windings by sandpapering a 1 inch strip the length of the cylinder. The copper wire exposed by sanding should appear shiny. This sanded strip must be where the slider arm will touch the coil.

Slider arm

Drill a hole toward one end of a 4½ inch by ⅜ inch metal strip. Then solder a 2 inch length of No. 10 copper wire to the strip. The strip should be made to curve slightly at the top to limit contact of its No. 10 copper wire to only one or two coil windings, for the sake of finer tuning ability.

The end of the slider arm with the hole in it is to be fastened to the board with a wood screw. You must fasten it so that the attached wire will stay in contact with the sanded strip on the windings as you swing the slider arm back and forth. Mark the board with a pencil at the best point for mounting it. Place a Fahnestock clip there; on top of it place a metal washer.

Finally, place the end of the slider arm on top and fasten these three with a wood screw. Now test that the arm makes firm contact with the coil as you move it.

If you wish, the slider arm could be made more simply from large diameter (No. 00) bus bar copper wire. Other substitutions are also possible.

Antenna

The length of the antenna should be less than half the wavelength of the expected radio wave, according to Dr. Moon. We have found that an antenna of 40 to 60 feet gives adequate reception. Conditions may differ, however, and a longer antenna may be necessary. The antenna is mounted using two glass rod insulators to avoid contact with conducting surfaces.

It is important to remember always to disconnect the wire coming into the house from the Fahnestock clip when the radio is not in use and, of course, when lightning storms are in progress.

Capacitor and ear piece

The value of the mica capacitor will have to be determined by experiment. In this circuit design, we found a 20 picofarad capacitor adequate. You may want to have others on hand, such as 50 picofarads and 100 picofarads.

The circuit here uses a very high impedance crystal ear piece. If another ear piece is substituted—even one as high as 20,000 Ohms—your reception will be weaker. (See note on the ear piece.)

Connecting the circuit

As shown in the diagram, the antenna is connected to a Fahnestock clip that then connects to the tuning coil, the capacitor, and the crystal diode. The diode is also connected to another Fahnestock clip and then to the ear piece.

Connect the ground wire to a cold water pipe or a radiator with a clamp. For the best reception, you should solder the wire to the clamp.

By tuning your radio, moving the slider arm across the tuning coil, you should be able to pick up some of the AM radio stations in your area. In rural areas, you may need a longer antenna to pick up the nearest radio station. Our reception in New York City was excellent with this set, and it improved at night.

We would like to hear from readers about their successes and problems with the crystal radio.

—by Michael Tobin

Tales of Science

Continued from page 51

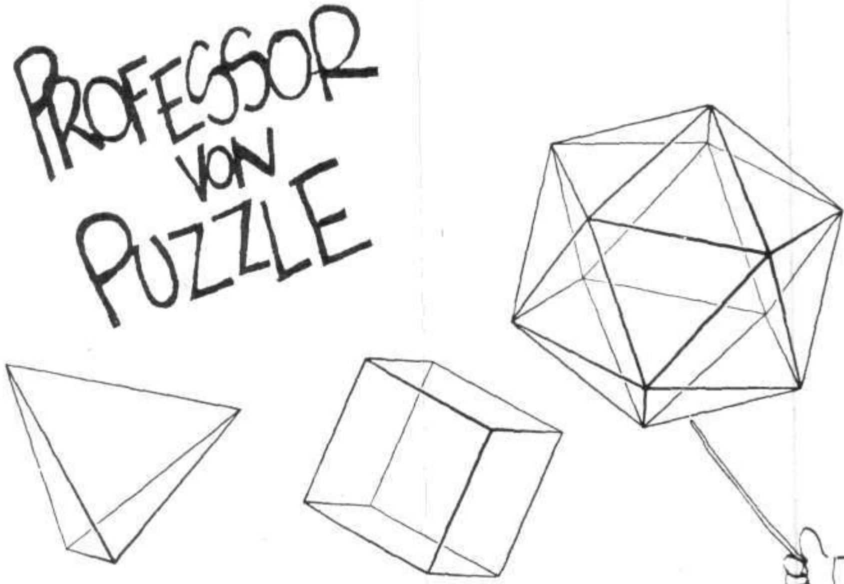
criticized what he called the "Malthusian gibberish" of the zero growthers of his day. The single most important resource, Mendeleev wrote, is the creativity of the human mind.

"Not only 10 billion, but a population of many times that size will find nourishment in this work, not only through the application of labor but also through the persistent inventiveness which governs knowledge. This philosophy of Jean Jacques Rousseau and now of Tolstoy for a back-to-nature existence is semi-childish. Because in a patriarchical society as well as among higher animals there is a definite limit to growth, but human beings taken as a whole recognize no such limit.

In Russia, we have one-and-two-thirds times the number of people but the feeders and supporters are the same as in the United States. This is where we must seek the root of all our suffering and poverty. We must have love of work, which comes from freedom."

—by Barbara Frazier

* You can read about Mendeleev's work on the Periodic Law in these two books: Pisarshevsky, O.N., *Dmitry Ivanovich Mendeleev*, (Moscow: Foreign Languages Publishing House, 1948); and Posin, Daniel Q., *Mendeleev, Story of a Great Scientist*, (New York: McGraw-Hill, 1948).



Welcome to the puzzle page. If you have puzzles that you think other young scientists would enjoy, send them in with your answers. Send them to me, Professor Von Puzzle, Fusion Energy Foundation, Box 1438, Radio City Station, New York, N.Y. 10101.

The Platonic solids and the discovery of Euler's formula

A polyhedron is a solid figure, like a box, whose faces are flat surfaces. When all the faces of the polyhedron are the same in size and shape, and join each other at the same angles, the figure is called a **regular polyhedron.** The most common example of a regular polyhedron is the cube, made up of six faces, each of them a square, which meet each other at a right angle (an angle of 90 degrees).

It is a remarkable fact that there are only five possible regular polyhedrons. These were studied intensively by the ancient Greek geometers and are often called the **Platonic solids,** after the famous Greek philosopher Plato who lived in the fourth century B.C. Except for the cube, these figures are all known by the Greek words that describe the number of faces each one has:

- The **tetrahedron,** or 4-sided solid, is made up of 4 faces, each one an equilateral triangle (a triangle with three equal sides and three equal angles).
- The familiar cube, or **hexahedron,** has 6 sides.
- The **octahedron,** which looks like two pyramids placed base to base, has 8 faces, each one an equilateral triangle.
- The **dodecahedron** has 12 faces, each a 5-sided figure called a pentagon. You may have seen a paperweight in the shape of a dodecahedron that is used as a calendar, with each face representing a month.
- The **icosahedron** has 20 sides, and like the tetrahedron and octahedron, each face is an equilateral triangle.

An ancient puzzle

Why these and only these five regular polyhedrons can be built is a fact that fascinated the ancient Greeks and later scientific investigators. Johannes Kepler, the father of modern astronomy, thought that the lawful relationships among the five Platonic solids might determine the diameters of the planetary orbits. He constructed a very accurate model of the solar system using this hypothesis.

The 16th-century German artist and scientist Albrecht Dürer made use of the Platonic solids to educate his countrymen in the science of mathematics. At the time he lived, Europeans were just rediscovering the scientific knowledge of the ancient Greek and the later Arabic culture. Dürer had to travel to Italy to find men who could teach him mathematics and the just-discovered science of painting known as perspective. When he returned to Germany from Italy, he wrote a book called **Course in the Art of Measurement with Compass and Ruler,** which was published in the year 1525.

In this book, Dürer presented the diagrams shown here that allow you to construct the regular polyhedrons. If you trace these and then cut them out around the outside lines and crease them along all the other lines, you will be able to make the regular polyhedrons—with the help of some tape.

Continued on page 59

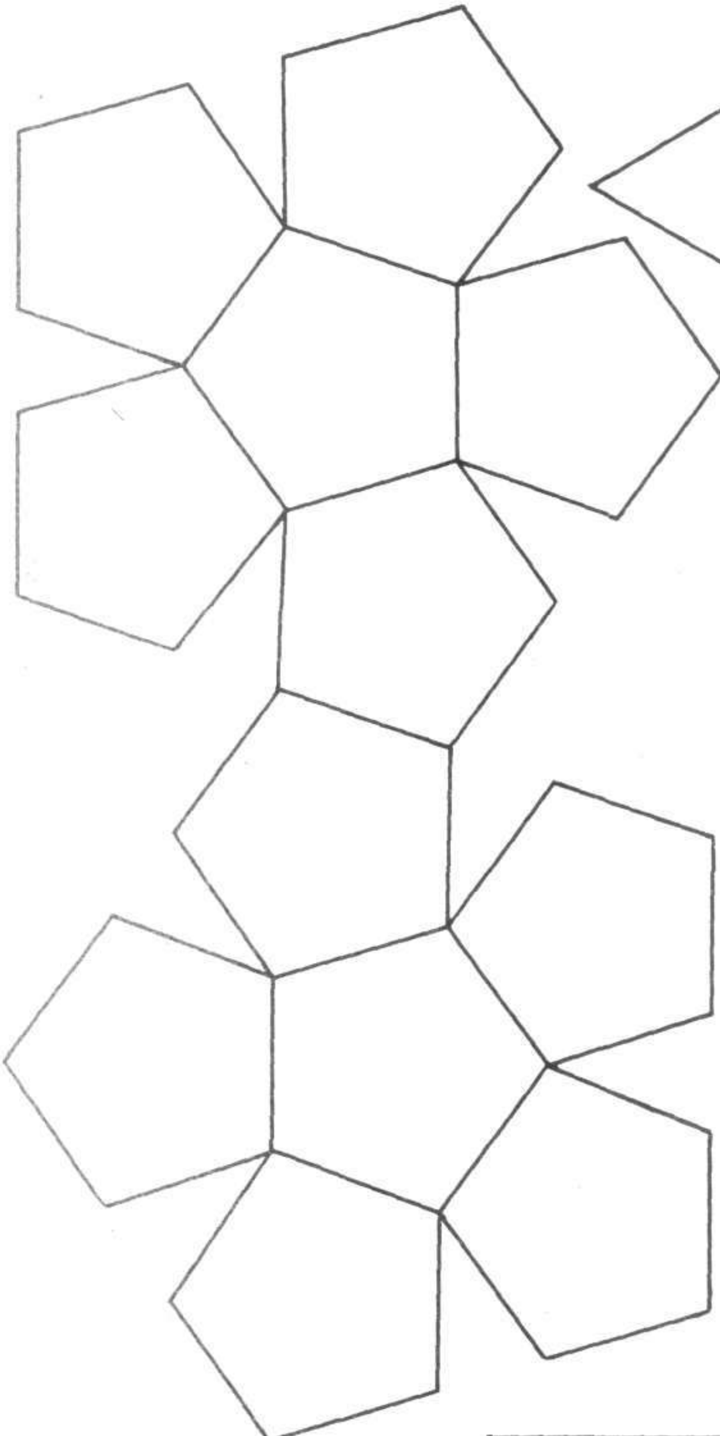


Figure 4
The dodecahedron

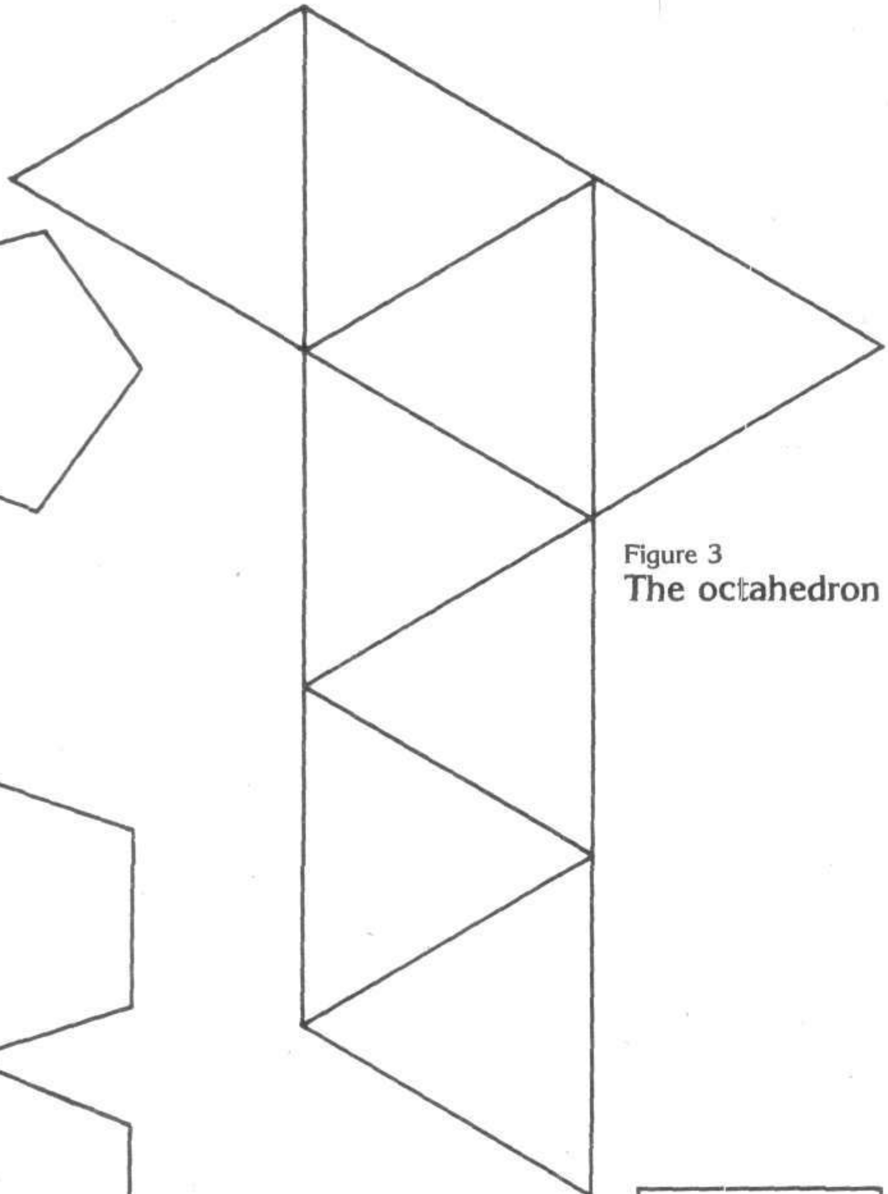


Figure 3
The octahedron

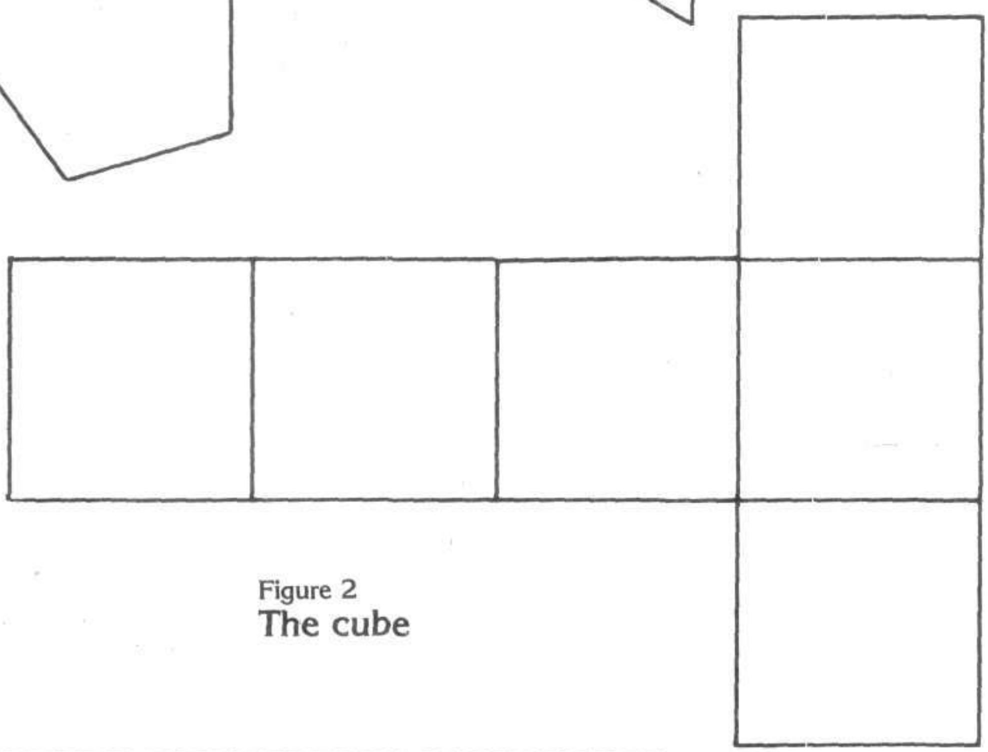
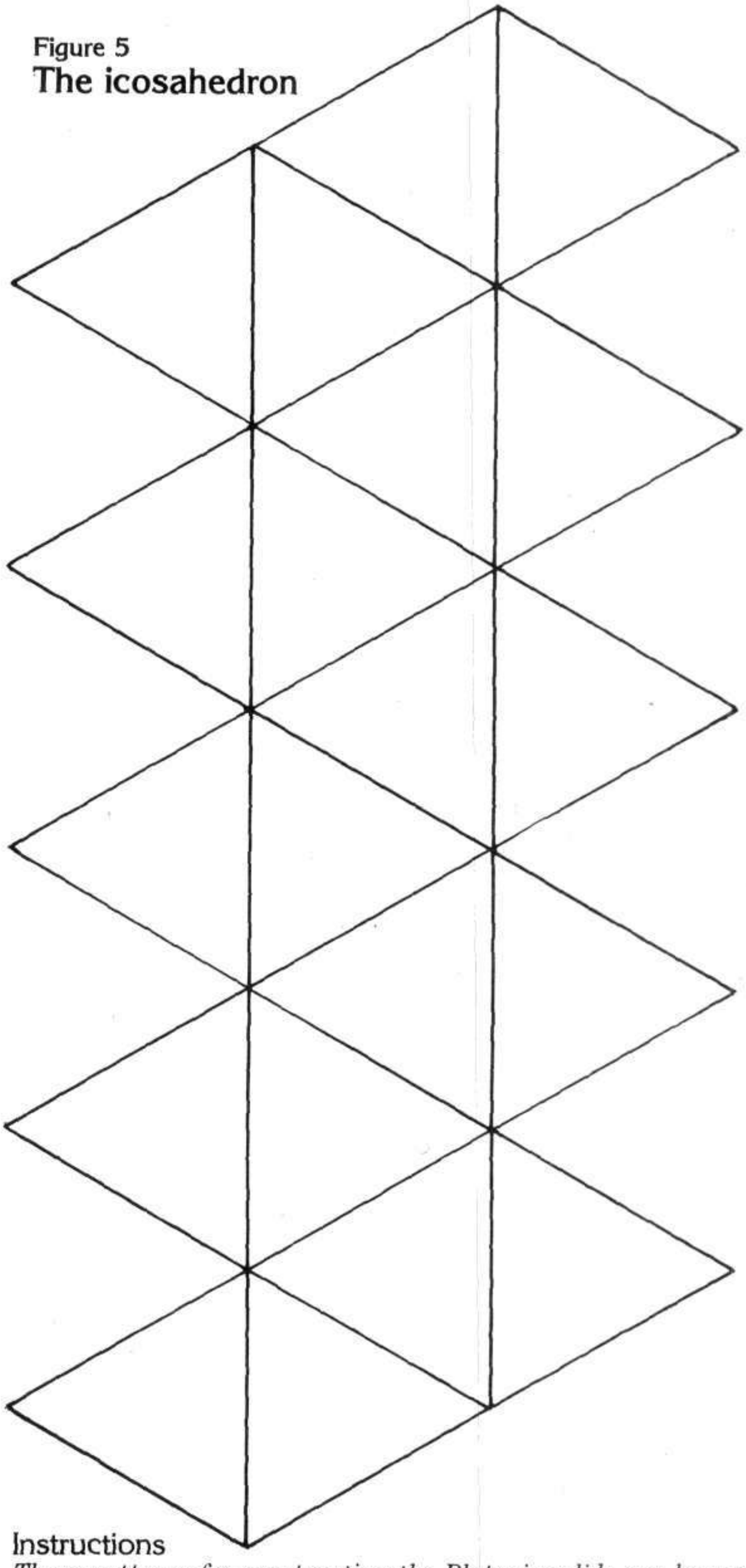


Figure 2
The cube

Figure 5
The icosahedron



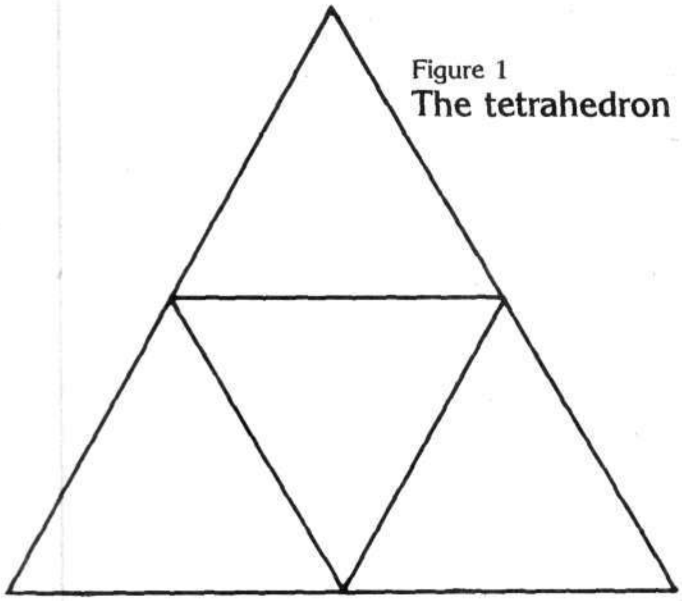
Instructions

These patterns for constructing the Platonic solids can be used in three ways: You can cut them out of the magazine; or you can trace them and mount them on oak tag or heavy paper and then cut them out (this will make the patterns stronger); or you can use a piece of graph paper to draw them larger (two or three squares for every one square on the pattern) and then cut them.

Cut the patterns out with a scissors, then lightly assemble the figure to get an idea of how it goes together. Seal the figure together carefully with clear tape.

If you mount the patterns on oak tag or heavy paper, they should be scored lightly with a sharp knife to help the folding.

Figure 1
The tetrahedron



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After you have constructed these figures, you will want to investigate some of their properties. Take the tetrahedron, for example. How many sides (or faces) does it have? How many edges (the line where two faces come together) does it have? How many vertices (points or tips) does it have?

Now do the same for the cube. Make a chart to keep track of the numbers. As shown here, make three columns labeled vertices, faces, and edges, and fill in the number for each polyhedron. If you have trouble counting the vertices and edges on the more complex figures, try using a crayon or marker to check off which ones you've already counted.

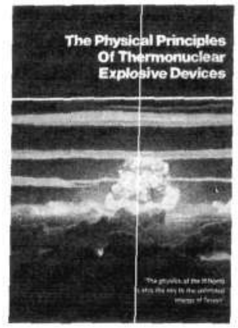
The puzzle

The puzzle now is this: Can you discover the formula that relates the number of vertices, faces, and edges for each of the regular polyhedrons? It is a simple formula. Once you know it, you will be able to fill in one column in the chart without counting, if you know the correct numbers for the other two columns. But finding it won't be easy. The formula was discovered and used by the mathematician Leonhard Euler (pronounced Oy-ler) in 1752, and is called Euler's formula. I have given you a clue by telling you in the chart that you add the vertices and faces and subtract the edges.

We will print the answer in the next issue.

Platonic Solids Chart

Figure	Vertices (+)	Faces (+)	Edges (−)	=
Tetrahedron				
Cube				
Octahedron				
Dodecahedron				
Icosahedron				



Thermonuclear Explosive Devices: 'An Enlightening Introduction'

The Physical Principles of Thermonuclear Explosive Devices
by Friedwardt Winterberg
New York: Fusion Energy Foundation
Frontiers of Science Series, 1981
$9.95

Originality in content, emphasis of physical understanding, and simplicity in mathematical representation distinguish this monograph on the physical principles of thermonuclear explosive devices by University of Nevada Research Professor Friedwardt Winterberg.

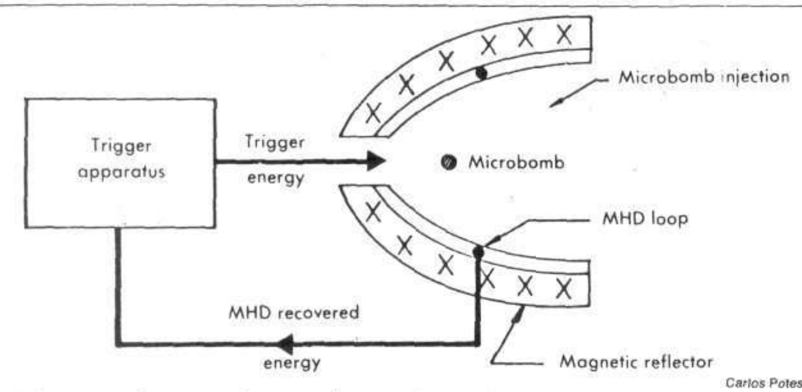
The author states that he never had access to classified or restricted government data and that his technical models may not be identical to those used by the five countries that have developed thermonuclear weapons. He demonstrates convincingly that the basic physics behind these thermonuclear designs must be the same and is reducible to rather simple ideas, which can be understood by means of "ordinary college physics." Many of the concepts described appear to be entirely new, such as the magnetized booster target concept for the chemical ignition of thermonuclear explosions. This book is not a mathematical physics text, but rather an enlightening introduction into the basic physics of thermonuclear explosive devices, intended not only for physicists but also for engineers and even for the educated layman.

Although thermonuclear fusion research in the West has been plagued by acceptance, duplication, and improvement of Russian fusion concepts (most recently through the tokamak concept), Winterberg has conceived many original ideas in thermonuclear fusion for which he is now recognized here and abroad. He first proposed light-ion and heavy-ion fusion, or impact fusion, in the early 1960s, long before "inertial confinement fusion research" became fashionable, for example.

In addition to his invention of the magnetically insulated diode in 1969, which made possible the generation of megaampere-megavolt intense light ion beams, at about the same time he invented the first concepts for inertial fusion reactors, incorporating both the wetted wall and magnetically protected wall ideas. He also originated the nuclear microbomb propulsion idea, using a magnetic reflector, a concept thereafter adopted by the British Interplanetary Society in their famous Project Daedalus study of an interstellar probe.

Most recently, he has promoted the notion that the inertial fusion reactors could also lead to a breakthrough in high energy physics, if used to drive particle accelerators, with the prospect of reaching energies up to 10^5 GeV.

In the historical overview, Winterberg traces the origin of thermonuclear research back to a paper by Atkinson and Houtermans published in 1928, which attempted to explain stellar energy sources. But the first man-made thermonuclear reaction became a reality only with the discovery of uranium fission by Hahn and Strassmann in 1938. The idea of using an exploding fission bomb as a thermonuclear trigger must have occurred to many, and the use of ^{6}Li-D for a "dry" hydrogen bomb can be found as early as 1950 in a paper by U. Jetter. However, simply placing a thermonuclear explosive beside an exploding fission bomb would give a negligible yield because the fusion material, before "catching fire,"



Schematic drawing of Winterberg's design for a nuclear microexplosion unit to be used for an efficient rocket-propulsion system by which large payloads could be moved at great speed within the solar system.

would be blown aside by the radiation pressure of the exploding fission bomb.

The author states: "The problem of igniting a thermonuclear explosion has thus been aptly compared to the problem of igniting a cigarette in a storm with a burning match. Long before the cigarette can catch fire, the match will be blown out."

As shown, most of the energy in the plasma of an exploding fission bomb is in the form of blackbody radiation of several tens of million degrees Kelvin, with the energy flux of this radiation reaching 10^{20} watt/cm^2. In the same way as one can prevent the blowing out of a match before a cigarette has caught fire by curving the hand around the cigarette and match, the thermonuclear ignition problem is solved by a curved wall formed around the fission and fusion explosives that confines the radiative energy.

This suggests that the fission and fusion explosives be installed inside a cavity having the form of a prolate ellipsoid, with the fission explosive in the first and the fusion explosive in the second focus. The radiative energy released by the fission explosion is then focused, either by shock waves or directly by radiation (which for temperatures greater than several tens of million degrees Kelvin are soft X-rays) onto the thermonuclear material. The distinction between shock waves and direct radiation coupling is to some extent academic, since the shock wave is radiation-dominated because its energy transport is determined by blackbody radiation.

The ellipsoidal configuration assures that the thermonuclear fuel is simultaneously hit by the blackbody radiation from all sides. This has the further advantage that the radiation thereby compresses the thermonuclear fuel, greatly increasing its thermonuclear reaction rate. Another more compact configuration described, promising good direct radiation coupling, is a truncated solid cone located inside a cavity, with the fission explosive positioned at the apex of the cone, and the fusion explosive behind the cone along its axis. The soft X-rays from the fission explosion produce in this case a cylindrical radiation implosion.

Other ignition configurations discussed by the author employ not only one, but several fission explosions; the most obvious arrangement has several fission bombs at the corners of a polyhedron. Such a configuration is suggested if pure deuterium is used as explosive. After the fission explosives are simultaneously ignited, a convergent shock wave is produced that can reach the much higher temperatures needed to ignite the DD reaction. For improved energy focusing, multishell implosions simulating convergent shock waves may be employed as well.

For the attainment of large yields, the thermonuclear burn has to proceed from its point of ignition as a detonation. In the autocatalytic detonation wave, the thermonuclear fuel is precompressed by soft X-ray precursors, fed by the thermonuclear reaction itself and racing ahead of the detonation front. This concept promises compact, large-yield thermonuclear assemblies. The neutron bomb is explained in terms of a small ^{6}Li-DT dry fusion bomb with a thick ^{9}Be blanket, replacing the ^{238}U blanket of the dry ^{6}Li-D thermonuclear bomb.

The very interesting question of nonfission ignition by chemical explosives is discussed, among other things, in connection with the author's recently proposed magnetic booster concept. In this concept, a small, very dense reversed theta-pinch is initially ignited by chemical explosives. The blackbody radiation produced by this first low-yield magnetic booster stage then ignites a second dense high-yield stage.

Thermonuclear microexplosion concepts are analyzed, including some recent work on blackbody radiation implosion, the possibility of thermonuclear lenses and shaped charges, and their application to basic research and Orion-type nuclear bomb propulsion. It is shown that Orion-type propulsion, using thermonuclear shaped charges, promises a much higher specific impulse than otherwise possible. Of special interest is also the idea of using the X-rays released in a low-yield fission (fission fizzle) explosion of highly compressed plutonium to drive a thermonuclear microexplosion.

Both the author and the publisher are to be congratulated for this original and stimulating monograph, which is recommended highly to anyone interested in the physical principles of thermonuclear fusion, advanced energy research, and weapons technology. The mathematical physicist or the applied mathematician, who may be more interested in the difficult mathematical aspects of thermonuclear processes and systems, is referred to Winterberg's original publications.

—*H. E. Wilhelm, Physics Division*
Naval Weapons Center
China Lake, California

Do Scientists Start Wars?

"I have never believed that it can serve any purpose to keep physics facts that can be obtained from any college textbook a 'secret.'"
—Dr. Friedwardt Winterberg

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Reagan Budget

Continued from page 20

federal spending, have created a situation where nuclear energy, fusion, and space programs are suffering more delay under the protechnology Republicans than they did under the avowedly antiscience Carter administration.

For the second year, the administration is refusing to live up to the letter of the 1980 Magnetic Fusion Energy engineering law and begin the next-step fusion engineering development work. Although a $20 million increase is recommended for the magnetic fusion program, which brings the funding up to $467 million, there is still no funding for the mandated engineering device.

The only fusion budget increase is for operating expenses, which are needed for the new Tokamak Fusion Test Reactor at the Princeton Plasma Physics Laboratory that began operation Dec. 24. The next-step Elmo Bumpy Torus tokamak/mirror hybrid experiment has been eliminated from the budget, because the administration refuses to build any substantially large, new machines.

Loving the Breeder to Death

The Reagan administration thinks the Clinch River Breeder is so promising that it could be completed within the decade. Unfortunately for the Clinch River Breeder Reactor, this classifies it as a near-term technology, which, according to the free market rhetoric of Reagan's economists, means that industry should pay for it—not the government.

Considering the extremely poor economic health of the electric utility industry and the nuclear manufacturers, it has not been easy to find anyone to volunteer to pay for part of the project. Industry, the Department of Energy, and Congress may save the program by arriving at some compromise. But the pronuclear President has nearly succeeded in killing the breeder reactor program.

Other near-term energy technologies, which had been zeroed out in the 1983 budget but were partially restored by Congress, were again zeroed out by the administration. These include promising fossil fuel technologies, such as magnetohydrodynamic energy conversion, that will have to be government supported if they are to reach commercial viability. It is again

FEF News: The Beam Weapons Debate

Continued from page 19

war obsolete, providing the capability to knock out incoming ICBMs in midflight, but would at the same time usher in a new era of scientific and technological progress.

In an FEF white paper titled "Beam Weapons and U.S. Economic Recovery: the Economic Impact of Directed Energy Beam Weapons," Bardwell and Sylvia Brewda of the FEF indicate how a beam weapons development program would be the unique "science driver" for recovery from the world economic crisis.

The econometric study shows, based on a correlation with the impact of NASA spending on U.S. productivity in the 1960s, that a beam weapons development program would over the near term generate more than 200,000 new jobs in high technology industry and $190 billion of new investment yearly. Over the long term, the program would accelerate the development of fusion energy and a host of plasma age technologies such as the plasma torch for materials processing and energy production with no moving parts. One of the ironies of the program, the study points out, is that it would not cost the United States a single penny; the payback would begin even before the program was fully under way, as U.S. industry geared up in anticipation.

It is this aspect of the proposed program that has jolted even advocates of beam weapons development.

In covering Bardwell's views on the near-term feasibility of the X-ray laser systems, for example, the newsletter *Defense Daily* noted that Bardwell is an associate of 1980 Democratic presidential candidate LaRouche, "an advocate of a number of radical theories, including his current campaign promoting the development of beam weapons systems because of their enormous benefits to the civilian economy, through technological spinoffs."

Who Is Winning?

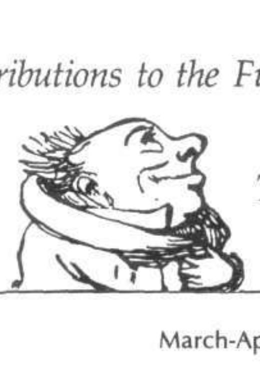
The potential of a beam weapon development program to reverse the slide into depression, which itself constitutes a threat to national security, will be addressed at three upcoming FEF conferences on the military, economic, and scientific implications of beam weapons—March 18 in Los Angeles, April 8 in Dallas, and April 13 in Washington.

Bardwell will speak at a major beam weapons event at Boston University on April 16. On April 28, the N.Y. Chapter of the American Institute of Aeronautics and Astronautics is cosponsoring a debate between Bardwell and IBM fellow Dr. Richard Garwin.

At every debate between Bardwell and the freeze to date, the questions have been addressed almost entirely to him—How will nuclear energy feed people in the Third World? How can you be sure work on beam technologies will result in breakthroughs in fusion energy as well? Why can't we develop fusion directly? These questions show that college audiences are beginning to think in terms of development and that the protechnology side has the edge in the debate.

—*Lydia Schulman*

Contributions to the Fusion Energy Foundation



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likely that Congress will not let these programs die, but they are losing ground each year, and timetables are being pushed farther and farther back.

Space at a Standoff

The civilian space program received a paltry increase of 4 percent, from \$6.8 billion to \$7.1 billlion. This amount does not even keep the space budget constant, given inflation, and key new efforts were not OK'd by the White House over the objection of the Office of Management and Budget. NASA did not get the go-ahead for a fifth Shuttle orbiter or a space station—two key requirements for the manned space program.

The reduced costs in the Shuttle budget, now that the system is operational and R&D is nearly completed, has freed up enough money for a few new starts. These include the first new planetary start in five years, the Venus Mapper Mission; an advanced communications satellite project; a numerical aerodynamic simulation facility for aircraft design; and increases for Shuttle-related advanced programs and space station design.

Not even the fact that the Soviets have continued their space station experiments in the Salyut 7 station has spurred the Reagan administration to give NASA the go-ahead for a mission deadline and funding for a U.S. permanent presence in space, however.

Finally, for the first time in 25 years, the military space budget is larger than NASA's, and the DOE military programs have outstripped the civilian energy R&D programs. Ironically, without a leading-edge civilian science and research capability, it is not possible to attain the administration's desire for military security.

—*Marsha Freeman*

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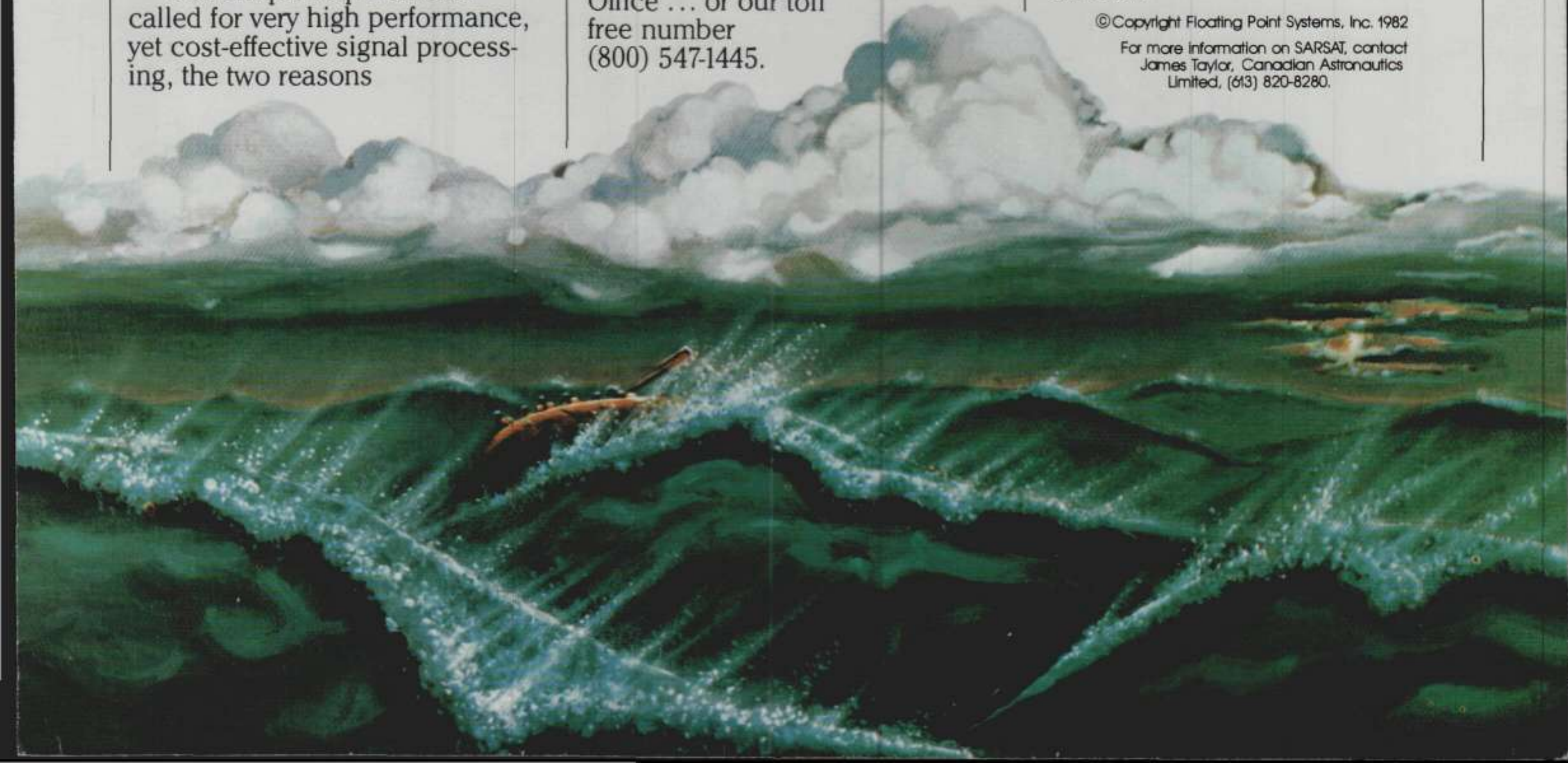

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In This Issue

BEAMS FOR DEVELOPMENT

Yes, there is a way to stop nuclear holocaust—by developing directed energy beam weapons, defensive weapons that can knock out a nuclear missile in the first few minutes of its launch. The development of beam technologies will not only remove the fear of nuclear war, but will revolutionize our lives by bringing us into the plasma age. Featured in this issue is one such beam technology, the X-ray laser, that will give us complete mastery over atomic and molecular structures, catapulting biology, chemistry, medicine, and all of industry into the 21st century.

These advanced technologies, as we show, are also the key to lifting the world economy out of the depression and industrializing the developing sector. It is for this latter reason, as documented in the Special Report, that the nuclear freeze movement's Malthusian leaders are so adamantly against nuclear power and advanced technology in general.

DEVELOPING THE EARTH FROM SPACE

The spectacular photographs on our cover show the beauty and diversity of the Earth's surface and at the same time, using advanced technologies, provide valuable information for science, agriculture, and industry. The conditions of crops, the amount of rainfall, and the type of vegetation are some of the data that NASA's Landsat satellite images can supply, as described in *The Young Scientist* section.

The Landsat satellite records information about the intensity of different kinds of light reflected by the Earth's surface—both visible wavelengths and wavelengths that are invisible to the eye. To produce the images you see here, scientists selected the information they wanted, used a computer to process the data, and put the data through color filters onto film.

In these false color photographs, green vegetation appears red, and variations of the red tones may indicate different plant species, stages of growth, or the health of the plants. Cities and roads are bright, usually light blue, because of the different qualities of reflection of concrete, rooftops, grass, and trees. Deep clear water is black, while shallow or silty water appears light blue to white. Rocky and mountainous regions appear deep green.

A Landsat view of the Jordan River flowing to the Dead Sea, with Israel on the left and Jordan on the right. Most of the land is desert. The lighter blue areas of the Dead Sea are shallow evaporation flats. The city of Jerusalem is to the west of the northern end of the Dead Sea.