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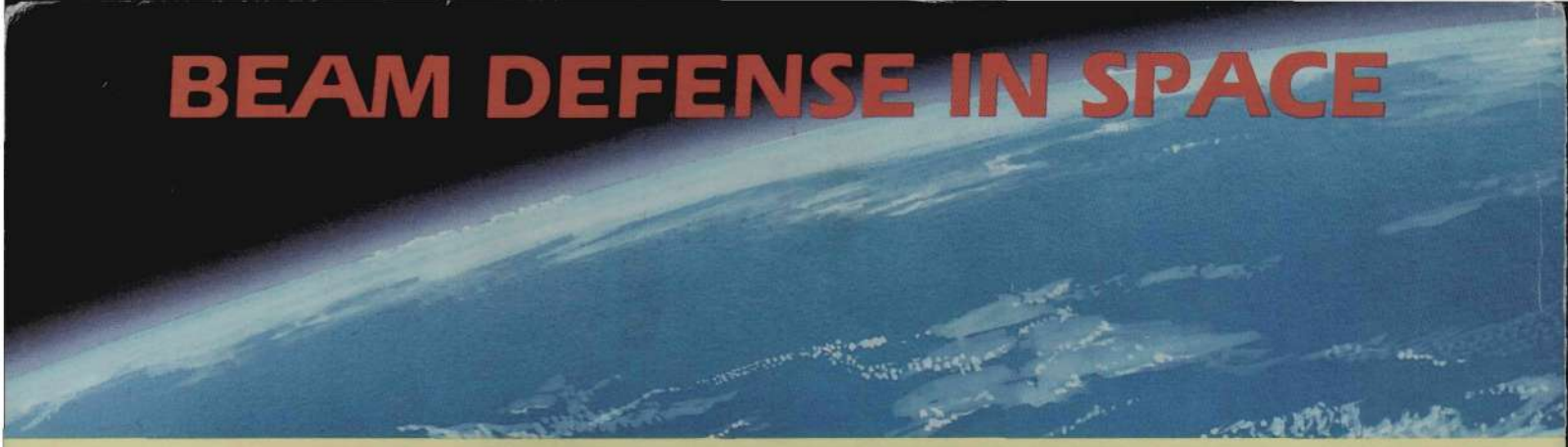
Big Tokamaks– Two Years to Energy Breakeven

Benjamin Franklin and the Forgotten Classical Origins of American Science



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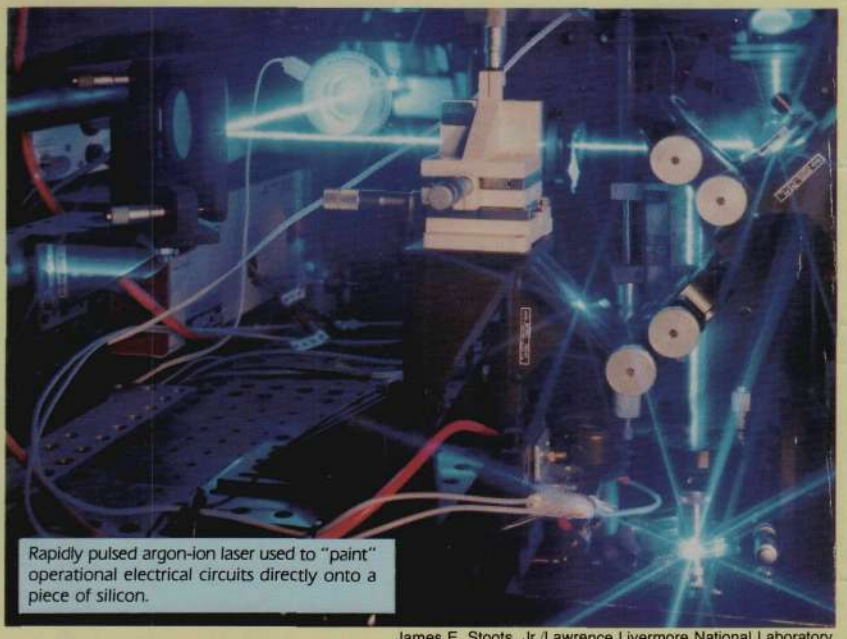

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Features

News

Departments

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On the cover: The vacuum vessel of JET, the world's largest tokamak, in its construction stage. Photograph courtesy of JET Joint Undertaking; cover design by Virginia Baier.

Congratulations on 10 years of distinguished effort and tremendous accomplishment, such as the McCormack fusion bill and President Reagan's March 23, 1983 speech on the Strategic Defense Initiative.

Keep up the good work!

Charles W. "Chuck" Britzius,
President, Science, Energy Technology Council Minnesota

The DiMarco family sends congratulations to FUSION for enlightening mankind for the past decade. Continue to do so for millenniums yet to come!

The DiMarco Family
Burlington, N.J.

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Editorial

The Next 10 Years

The year 1984 marked the end of the Fusion Energy Foundation's first decade. Looking back over the past 10 years we can be justly proud of what we have accomplished—even though we have by no means accomplished all of our goals.

Ten years ago when we said that fusion power could be commercially viable as an energy source by the end of the century or sooner, we were dismissed as visionary madmen. Yet today, were it not for cutbacks in funding, the magnetic fusion program could reach energy breakeven—the point at which a fusion device produces more energy than it takes to operate the machine. All of the scientific problems have been resolved; if not for the politically mandated austerity, the United States could be on target as spelled out in the 1980 fusion legislation with a prototype commercial reactor on line by the turn of the century.

The Fusion Energy Foundation and this magazine take justifiable pride in the fact that the President's Strategic Defense Initiative not only is now U.S. policy, but has been endorsed internationally, particularly by the governments of Japan and West Germany. We have been campaigning for this policy since 1977, when we wrote a special report, "Sputnik of the 1970s: The Science Behind the Soviets' Beam Weapon," proposing beam defense research and development as an alternative to the doctrine of Mutual Assured Destruction.

Again, this was a proposal that most people, most especially the U.S. scientific community, thought was completely unrealizable. And many of the members in the American Academy of Science and the Union of Concerned Scientists are still publicizing their incompetence by arguing that the Strategic Defense Initiative won't work.

We were able to assert confidently that what then to many seemed to be insuperable problems connected to developing the commercial fusion program, or to utilizing directed energy as beam weapons, could and would be solved. We understood this because we approached fundamental scientific problems from the standpoint of Gauss, Riemann, and Cantor—the Platonic tradition of continental science as opposed to British empiricism.

We knew, for example, that breakthroughs in containment would necessarily occur as physicists began to utilize the tendency of high-energy plasmas toward self-organization—what is typically called the nonlinear effects of plasma. We knew that similar effects would have to occur with laser propagation. And indeed, the beam weapon program is now utilizing precisely these in the form of self-focusing and self-induced transparency of laser beams to achieve major breakthroughs.

There has been a massive discontinuity, over the past century, between technological accomplishments and fundamental breakthroughs in science, which has been lawfully produced by the increasing hegemony of the British school of science over the continental tradition. Yet even the major accomplishments of technology—such as the space program—are directly linked to the continental tradition, as exemplified in the person of space pioneer Krafft Ehricke, for example.

It is this tradition that the FEF seeks to proliferate, for it is key to rescuing fundamental science from its present sterile dependence upon the methods of British empiricism, as exemplified in quantum physics. And, as we have shown, this classical tradition is also key to reviving our national economy.

The Promise of the SDI

At present not only are we in the grips of a depression, but the Malthusian antiindustrial policies of the International Monetary Fund threaten to turn what is now a reversible situation into an irreversible slide into a new Dark Age. Just as basic industry is being closed down, and U.S. steel-producing capacity is being wantonly destroyed—literally so with the demolition of blast furnaces—so, too, we see the shutdown of the nuclear industry and austerity-caused stagnation in the nonclassified fusion program. Yet the interplay between the development of directed energy in the form of laser and particle beams and developments in plasma fusion are obvious to anyone not brainwashed by the mindless imperative to cut the budget at all cost.

These facts nothwithstanding, there is reason for optimism. The Strategic Defense Initiative program has created a Division of Innovative Science and Technology and at least $100 million has been set aside in its budget for the development of revolutionary technologies for civilian application of lasers and particle beams. The new program's director, Dr. James Ionson, will be working directly under General James Abrahamson, head of the Strategic Defense Initiative.

If the President's budget request for the SDI—$3.8 billion—goes through in full, some scientists estimate that as much as 5 percent of this budget will be assigned to the new division. Much of this money will be allocated to 50 U.S. universities for unclassified research in areas such as the gamma-ray laser. In all, if the President's budget is accepted, 30,000 scientists will be engaged in research on some aspect of the SDI. This is not only three times the number of scientists who worked on the Manhattan Project at its height, but more than the total number of scientists in the United States at that time!

The Fusion Energy Foundation's major tasks in the next decade will be to establish the hegemony of the Platonic method in science. Only by doing so will we be able to exploit the incredible potentialities that the development of the frontiers of space and the fusion program will open.

News Briefs

Stuart K. Lewis

Abrahamson: "You cannot imagine how fast the progress is developing."

BEAMS MAKE 'UNEXPECTEDLY GOOD PROGRESS,' ABRAHAMSON SAYS

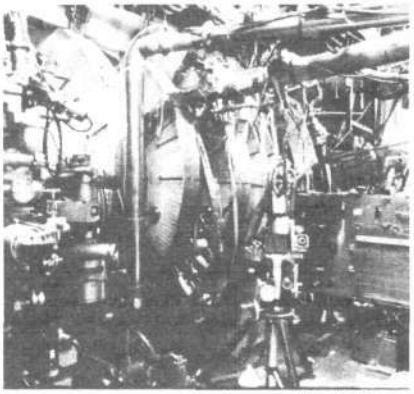
President Reagan's Strategic Defense Initiative (SDI) is already making "unexpectedly good progress" and is being rapidly accelerated, SDI director Lt. Gen. James A. Abrahamson revealed in testimony Feb. 21 before the Senate Armed Services Committee and in an interview in the Feb. 18 *Aviation Week & Space Technology* magazine. Two years are being chopped off the development time for pointing and tracking systems by making early use of NASA's Space Shuttle, he said, and further acceleration will be achieved by going piggyback on the scheduled NASA and Defense Department Space Shuttle flights. Technology "is coming across this entire country in a way that you cannot imagine just how fast the progress is developing," Abrahamson said. He cited three recent developments: (1) rapid, multifire electromagnetic rail guns; (2) laser channels for charged particle beams in space; and (3) the establishment of an SDI division for innovative science to "look beyond the cutting edge of technology."

X-RAY LASER TECHNOLOGY 'FURTHEST ALONG'

"The project furthest along is development of an X-ray laser pumped by a nuclear bomb. . . . Demonstration of technology feasibility through underground testing is complete. . . ." This was the assessment of Strategic Defense Initiative projects told to *Aviation Week* magazine Feb. 18 by William W. Hoover, Assistant Secretary of Energy for Defense Programs. One X-ray laser module, popped up on one sea-launched missile, could destroy scores of offensive ballistic missiles before they rocket out of the Soviet Union, Hoover said. He noted that only total system integration, such as adding pointing and tracking capabilities to direct X-ray laser beams, was needed to make this most efficient missile killer ready to deploy.

PRINCETON S-1 OPENS PATH TO COMPACT FUSION REACTORS

Researchers at the Princeton Plasma Physics Laboratory in New Jersey report that the S-1 spheromak has now reached true plasma operation with temperatures above 1 million degrees Celsius (100 electron volts) and energy confinement times of about one-thousandth of a second. These results confirm the spheromak as the most promising advanced concept for economic and compact magnetic fusion reactors. In the nearer term, spheromaks have numerous potential applications to the development of pulsed power and directed energy beam technology. The S-1 success is particularly significant because it proves that an entirely different kind of spheromak from that of the Los Alamos CTX works. Since the spheromak confines the fusion plasma with magnetic fields generated by electric currents within the plasma itself, the plasma donut—called the plasmoid—can be made much smaller and more efficient, and the plasma conductor can sustain much higher current levels than conductors made out of ordinary solid-state materials. As a result the spheromak offers a most efficient and economical means to achieve the high energy flux densities that are essential for both fusion and directed energy beams.



Kiyoshi Yazawa

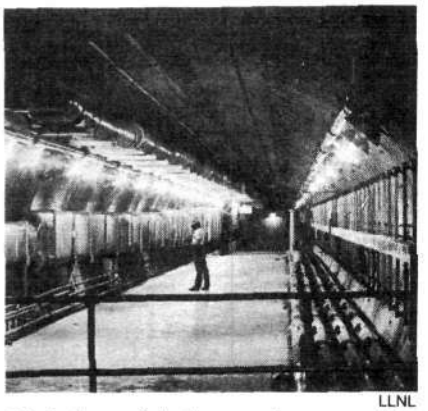
Princeton's S-1 spheromak: True plasma operation at above 1 million degrees Celsius.

In addition, since the plasmoid is a self-organized magnetic plasma, it can be physically removed from the formation chamber and moved about. For power reactors, the ability to transport the fusion plasma around can dramatically decrease the engineering problems and capital costs. Containing actually a very small amount of mass confined within an intense magnetic field, the plasmoid can be easily accelerated to hypervelocities in excess of 10,000 kilometers per second. Traveling at such speeds, the plasmoid could deliver a power flux on target in excess of 10,000 trillion watts per square centimeter. Alternatively, a highly compressed or accelerated spheromak plasmoid represents a versatile technology for power amplification for driving other types of particle beams,

lasers, and microwave generators. Since the S-1 is statically generated with a complex magnet core system, while the Los Alamos CTX is dynamically created with a plasma gun, success with both systems represents a substantial rate of progress in the science of compact tori. In the near future Princeton researchers will be attempting to decrease the size of the S-1 so that higher plasma electric current densities can be achieved. They will also be exploring the use of the dynamo effect found on the CTX, which could permit the spheromak to be sustained in a steady-state mode of operation.

ANTIGONE: 'WIRE IN THE SKY' WILL REVOLUTIONIZE BEAM WEAPONS

A new concept called Antigone, or "wire in the sky," would make possible the propagation of well-focused charged-particle beams through space, reported Dr. Louis Marquet, the Defense Advanced Research Projects Agency's director of directed energy weapons. This new idea, developed by Lawrence Livermore National Laboratory scientists, is based on creating a "wire in the sky"—a plasma channel generated by a pulse of laser light to charge-neutralize the beam—that permits the charged particles to be propagated through space as a well-focused beam. Because charged-particle beams are thousands of times more effective in destroying missile warheads than are laser beams, this will revolutionize beam defense. Livermore scientists carried out the Antigone experiments within the Advanced Test Accelerator electron beam experiment.



LLNL

Birthplace of Antigone: Lawrence Livermore's Advanced Test Accelerator.

FEF BOOK ON BEAM DEFENSE PUBLISHED IN WEST GERMANY

The first West German book to support a crash program to develop beam weapon defense for the United States and its allies was released at a press conference held Jan. 25 at the National Press Club in Washington, D.C. *Strahlenwaffen—Strategie im Umbruch* (*Beam Defense—Strategy in Transformation*) was written by the scientific staff of the Fusion Energy Foundation and of *Executive Intelligence Review* magazine in West Germany and published by the military publishing house Verlag fuer Wehrwissenschaften in Munich.

"This is the first comprehensive analysis of the strategic importance and the scientific and technological basis of strategic missile defense," said Heinz Horeis, a co-author, discussing the new book in the context of the strategic situation in Europe and ongoing Soviet efforts to sabotage U.S.-European collaboration, including the recent wave of terrorist attacks on NATO military installations. "The book comes out at a time when the West German government, after a long period of hesitation, has finally decided to go along with the American Strategic Defense Initiative," Horeis told the press conference.

Copies of the book are available from the FEF at $25, postpaid.

LOUSEWORT LAURELS TO INTERNATIONAL CONSERVATION GROUP

This month's Lousewort Laurels goes to the largest conservation group in the world, the Geneva-based International Union for Conservation of Nature and Natural Resources, for its call to save endangered plants and animals from extinction—but not people. Funded largely by the World Wildlife Fund and peopled by such notables as England's Prince Philip, the group singled out for protective action the smallest known mammal, the bumblebee bat, "which lives in remote caves in Thailand and is threatened by . . . . proposed hydroelectric projects," and the world's largest flower, "the giant rafflesia, a bright-red bloom that measures a yard across and smells like rotten meat to attract pollinating flies."

The only mention of human groups in danger of extinction from starvation was the inclusion on the list of "a nut that could help prevent famine in the Horn of Africa, which is now threatened by drought, overgrazing by goats, and war."

Viewpoint

Europe Should Collaborate in The SDI

by Rolf Engel

U.S. Defense Secretary Weinberger has advocated the participation of Federal Republic of Germany in the technological research programs associated with President Reagan's Strategic Defense Initiative (SDI) program against nuclear weapons. I wholeheartedly endorse his offer and shall devote my energies to bringing about European/American cooperation in this great enterprise.

Presidents of the United States enjoy a unique position to make important decisions, and President Reagan made such a decision on March 23, 1983. U.S. secretaries of defense also have unique opportunities to open new paths for the future security of the West, new hopes of our citizens that they may live in freedom, flourish economically, and contribute significant discoveries on the frontiers of science and technology.

But now, when much progress has been made in efforts from many sides to overcome the danger of decoupling the defenses of Western Europe from the United States, and when progress has been made to demonstrate in Europe the American commitment to defend the West as a whole, and when Secretary Weinberger addresses himself to German citizens and Europeans to win their support for an effort upon which our survival depends, it is also time for us all to take stock of the tasks ahead and what they require of us. We must all acknowledge that what Europe demands of the United States, is people at all levels who know that you Americans *need* Europe, its intellectual resources, its industrial and technological capacities. You need Europe; Europe is not merely a dead weight for you to drag along behind you for as long as you think you can "afford it."

The friends and allies of America are always disappointed when America turns away from its own principles and its commitment to progress. That is what happened back in 1966 when, under the influence of Defense Secretary Robert McNamara, the United States began to turn away from the NASA space program begun under President Kennedy.

At that same time the British government also decided to withdraw from the European space program. That meant that 28 percent of the funds to build a European booster rocket to carry satellites into orbit was gone overnight, and it was by no means certain that the European space program would survive at all. We in Europe were not behind the times in terms of modern booster technology, but we needed a broad base of cooperation to realize such a project.

A 'Troika' Proposed

As I was deeply involved in aerospace work in general, and the booster rocket project in particular, I proposed that we try to win the Americans to large-scale cooperation in the European space effort. In effect, my proposal was to form a kind of "Troika," consisting of France, the Federal Republic of Germany, and the United States as the core group, with the main technological and industrial capacities, but also including all the smaller countries of Western Europe.

What then happened in the United States was, unfortunately, typical. NASA, at the top, was positive about the project. The State Department was apparently positively inclined, if noncommittal, but expressed skepticism about whether the Senate Committee on Space could be won over. It proved impossible to speak with the relevant senators, and more direct access to decision makers in Washington was impossible. I therefore set out to determine how American industry would view the "Troika" idea. Boeing was excited. McDonnell Douglas was all for it. Rocketdyne was for it. When I returned to Washington with this support, I found out from the European Section of the State Department that the senators I could not talk to were intransigent in opposition.

At this stage, we were proposing that America would build the first booster stage of a European rocket. It was the opening of a real potential for the United States to be involved in the development of the European booster program, and, moreover, it would have launched European/American cooperation on a scale, and with political, industrial and technological implications, that would have set aside the narrow-minded sort of competition mentality once and for all.

American industry at that time was looking forward to new developments, and had no reason to be jealous of its technological know-how or to fear it might be creating "harmful competition." Instead, by passing up the opportunities for real cooperation, real competition did develop—the Ariane.

Of course, we Europeans had to develop the in-depth capacities to realize technologies we understood quite well and create the myriad sinews of an industrial infrastructure by ourselves, which increased costs, duplicated U.S. efforts, and slowed down the overall pace of progress. But we have created the main competition to NASA in the Ariane. Today, people are upset because the Ariane—with a handsome buffer capacity of 36 options—does represent real competition.

Had the cooperation gotten off the ground, the French would have built the second stage, we the third stage, and the United States the first stage. We were willing to contribute our high-energy rocket technology, the hydro-

Continued on page 16

Dr. Engel, the former chief of the Aerospace Department of Messerschmidt-Buelow-Blohm, is an expert on Soviet space technology.

Krafft Ehricke: Space Pioneer

In this century there have been few men who combined a richness of creative ideas on how to expand the frontiers of space with the moral commitment to see these ideas implemented. Space pioneer Krafft A. Ehricke, who died of leukemia Dec. 11, 1984, was one of that handful.

Throughout his life, Ehricke was working day-to-day on the frontier technical challenges posed by spaceflight. At the same time, he was studying and designing the space initiatives for the future to carry man out of the "closed world" tied to the Earth, on to the worlds that could exist beyond it.

Ehricke helped lay the basis for the technical achievements that in 1969 took man to the Moon. He also prepared the groundwork for the colonization and industrialization of the Moon as the stepping-stone for full-scale human exploration and settlement of the solar system. The tremendous scope of Ehricke's scientific and engineering ideas will be able to guide man for decades to come.

In recent years, Ehricke passionately confronted the antiscience ideas of the environmentalists, their cultural pessimism. He also saw first hand the increasing danger of the protofascist Green Party in Germany. In 1981, when he and his wife, Ingeborg, made a tour of European universities with the Fusion Energy Foundation, Ehricke battled to get across the ideas of progress and no limits to growth, despite threats of physical violence from rock-throwing, antinuclear Greens.

The Classical Tradition

Krafft Ehricke brought with him to the United States the great tradition of German science, to which he had access through the Humboldt curriculum during his studies in Berlin. Recently, he joined the advisory board of the Schiller Institute to continue the fight to spread classicial culture internationally, creating a renaissance to combat the pessimism and hopelessness of the Malthusians. Throughout his life, he fought to meet the challenge of this task, defeating the voices of despair and moving human civilization off its home planet to a "new open world," as he put it.

"The concept of space travel carries with it enormous impact, because it challenges man on practically all fronts of his physical and spiritual existence. The idea of traveling to other celestial bodies reflects to the highest degree the independence and agility of the human mind. It lends ultimate dignity to man's technical and scientific endeavors."

"If God had wanted man to be a space traveler, he would have given him a Moon," Ehricke told an October 1984 NASA meeting on a manned return to the Moon in the banquet address. The audience of scientists, former astronauts, and engineers gave Ehricke a standing ovation. Here Dr. Michael Duke, conference organizer, presents Ehricke with a painting of lunar industrialization.

As a young man in the 1930s, already fascinated with the idea of conquering space, Ehricke had filed two patents on rockets in Berlin. He had gained his technical foundation there with Hermann Oberth, the father of German rocketry. When the World War II rocket program at Peenemünde was accelerated, Ehricke was sent to work there with the some of the best minds in German science. Under the direction of Walter Thiel, Wernher von Braun, and others, Ehricke worked on solving chemical rocket propulsion problems for the V-2 project and also examined the potential of nuclear energy for space propulsion. He concluded at that time that nuclear power would be required for future spaceflight.

Ehricke never wavered from his scientific conclusion that nuclear power was necessary, both for civilian energy and propulsion. During the 1970s this position made Ehricke's work somewhat unpopular with the media and even with part of the scientific establishment that bowed to the antinuclear ideology and its unscientific solar solutions.

At the end of the war, Ehricke and his wife came to the United States and he joined the more than 100 other Peenemünde scientists who were working for the Department of the Army at Ft. Bliss. After a brief stay at the Redstone Arsenal in Huntsville, Alabama, Ehricke joined the staff of Bell Aircraft in upstate New York.

During the 1950s, Ehricke was in the forefront of the technical developments required in the U.S. intercontinental ballistic missile race with the Russians. At the Convair division of the General Dynamics Company, he contributed to the Atlas program—the first U.S. ICBM.

In 1958, still at Convair, Ehricke tackled and solved the problem of taming highly energetic liquid hydrogen for propulsion. The Centaur rocket, placed on top of the Atlas, gave the United States the capability to place payloads into higher orbits, or even to escape the gravitational pull of the Earth.

The Centaur, still used today to launch probes throughout the solar system, laid the basis for the liquid-hydrogen-fueled engines of the Saturn rocket that carried American astronauts to the Moon. To the present day, the United States is the only nation that has an operational liquid-hydrogen rocket.

The Philosophical Basis for Spaceflight

When Sputnik was launched in 1957, Krafft Ehricke had already outlined why man should go in to space, how he could do it, and when.

As he put it in a November 1957 article, titled "The Anthropology of Astronautics," in the American Rocket Society magazine, *Astronautics*: "Altogether, in the United States and other countries, billions of dollars are spent on the development of a technology which gives every indication of being or becoming an astronautical technology. This is extremely gratifying to all those who, during the first part of this century, fought for the recognition of space travel as a serious, practical, and worthwhile effort—not at some future time, but right now, in this century and in this age of ours.

"The campaign for technical and scientific recognition of spaceflight is won. However, the fight for recognition of astronautics as a vital part of man's future, rather than as just an accepted technical or scientific specialty, has hardly begun. Astronautics is the science of operating in space and traveling to other worlds. The implications are such that it now becomes increasingly important to develop the philosophy, as well as the utilitarian aspects, of this new science.

"The concept of space travel carries with it enormous impact, because it challenges man on practically all fronts of his physical and spiritual existence. The idea of traveling to other celestial bodies reflects to the highest degree the independence and agility of the human mind. It lends ultimate dignity to man's technical and scientific endeavors."

Natural Law and 'Realism of Vision'

In this article, Ehricke establishes three laws, which he calls the "basic tenets in the pioneering of space flight": first, nobody and nothing under the natural laws of this universe impose any limitations on man except man himself; second, not only the Earth, but the entire solar system, and as much of the universe as he can reach under the laws of nature, are man's rightful field of activity; and third, by expanding through the universe, man fulfills his destiny as an element of life, endowed with the power of reason and the wisdom of the moral law within himself.

"We must be realistic," Ehricke says in summary, "but there is a wrong kind of realism, timid and static, which tells man to live for his existence alone and not to rock the boat. The kind of realism we need is the realism of vision—the realism of a Columbus, of our Constitution, of a Benjamin Franklin, of an Albert Einstein, of a Konstantin Zoilkowsky, and of a Hermann Oberth."

Ehricke's realism led him to actively intervene in policymaking to put forward the creative ideas he knew needed to be implemented. In 1957, he was the chairman of the American Rocket Society's . Spaceflight Committee, which recommended the formation of a civilian spaceflight agency to President Eisenhower. In the same year, he was asked to participate in a congressional report, "The Next Ten Years in Space," which contains forecasts by leading authorities in space.

Based on his knowledge of the state of the art and his vision of what technology could accomplish over a decade, Ehricke stated that in the next 10 years (to 1967), we could expect to see: communications and relay satellites in geosynchronous orbit; global weather-monitoring systems; radio-navigation satellites for ships at sea; one or more small manned space stations; nuclear auxiliary power supply systems for satellites and stations; satellites around the Moon and landings with instrumented probes; manned circumnavigation of the Moon, and "probably the first landings by man"; interplanetary probes covering the entire solar system; and close international cooperation.

"Man will have sufficient information to decide for or against a permanent lunar base and will begin to look to the planets Venus and Mars as his goals for the decade to come," Ehricke said.

Throughout the 1960s, Ehricke worked on the advanced space technologies made possible by the Apollo mission to go to the Moon and to probe the planets. At the same time, he was readying his lunar development plan, which he elaborated in the early 1970s. By that time, the opponents of the "power of reason" were readying their forces for a head-on collision with western civilization and the goals Ehricke sought.

The Extraterrestrial Imperative

In February 1971, Ehricke addressed the National Space Meeting of the Institute of Navigation in Huntsville, summarizing his concept of the development of the Moon as the "seventh continent" of the Earth. Noting the "wave of pessimism" that could "un-

"We must be realistic, but there is a wrong kind of realism, timid and static, which tells man to live for his existence alone and not to rock the boat. The kind of realism we need is the realism of vision."

Krafft Ehricke talks about the extraterrestrial imperative at a 1981 conference in West Germany. On the dais with him are Michael Weissbach and Helga Zepp-LaRouche, chairman of the European Labor Party (EAP).

dermine Man's confidence in a soaring future," Ehricke states that "a science policy that places the protection of our environment over Man's overall needs of tomorrow is not realistic, however well-meaning, because preservation of the environment is only a necessary, not a sufficient requirement."

"Space is obviously not a panacea for all of Man's problems," he said. "Neither is Earth, in the long run, because of its sensitive biosphere and its limited resources. We need both. Man has needs that will outgrow his planet in time."

In this brief speech, a summary of a book he and his collaborator Elizabeth Miller had ready for publication on what he called the extraterrestrial imperative, Ehricke outlined what the energy requirements will be for space industrialization and why nuclear power—both fission and fusion—will be the only way to reach these goals. Ehricke describes the new possibilities for using nuclear technologies for extraterrestrial mining and outlines the transport and other capabilities this space manufacturing step will require.

In a 1973 article for *Acta Astronautica*, Ehricke adds detail to the lunar resources available to combat the limits of Earth resources, based on the data from the Apollo missions. Again, he attacks the "closed world," "limits to growth" ideology:

"The world of modern industrial Man is no more closed within the biosphere than it is flat. Preservation cannot be limited to the environment at the expense of human growth. Human growth must aim at nothing less than the achievement of a humane living standard for all. The preservation of both environment and civilization hinges on technology and its translation into industry. Many technologies are needed to overcome the present apparent limits to growth. But the one underlying, ubiquitous technology that makes many other industrial technologies possible (either directly or by spin-off) is space technology."

There "is no limit to growth, only to multiplication," he insisted.

His book called *The Extraterrestrial Imperative* was never published, for all the major publishers to whom it was submitted said that the book was too progrowth, too optimistic, and too pronuclear. These ideas, Ehricke was told, were not "popular" in the political environment of the 1970s. And a decade later, upon returning from a European tour sponsored by the Fusion Energy Foundation in November 1981, Ehricke described to a New York audience the frightening political situation in West Germany with the rise of the antinuclear Greens:

"It is a little bit disconcerting that the same shocktroop kind of tactics stand at the end of one's life as I have seen as a very young person in Berlin in 1929, '30, and '31."

Assailing the "back to nature" mentality of the Greens, Ehricke stated, "If 4 or 5 or 6 billion people will fall back on a lifestyle of a very embryonic mankind, it will destroy mankind by billions, and it will devastate the biosphere. . . . In the 'Year of the Child' of the United Nations two years ago [1979], 12 million children did not reach their first birthday. That's 50 percent more than all the battle deaths in World War I. And that is an outrage to a species that calls itself civilized," he said.

In the last few years, Ehricke continued to refine and improve his scientific and technological basis for industrializing the Moon, producing a five-phase evolutionary plan, which includes unmanned orbiters and landers, lunar-orbiting space stations, lunar processing facilities, city building, and finally, a full lunar biosphere, Selenopolis. (Articles by Ehricke on lunar industrialization appear in *Fusion*, Dec. 1981 and May-June 1984.)

One of the totally new fields that Ehricke invented and developed is the science of harenodynamics, which in-

Continued on page 63

Military-Style Mobilization Needed

How to Stop the Famine in Africa

J. Scott Morrison presented this policy paper at the founding conference of the Schiller Institute in Arlington, Va., July 3-4. Morrison was the executive vice-president of Sea Land from 1964 to 1978, in international trade and containerization development. During the 1970s, Morrison served on shipping consulting boards for NATO and worked on the development of more than 20 ports in both developed and underdeveloped areas.

* * *

The starvation and economic collapse in Africa can and must be stopped. Yet there are literal lies in circulation about the impossibility of delivering enough food to relieve the crisis, and the impossibility of creating the physicial conditions of infrastructure and economic development to prevent such a crisis from ever occurring again.

I want to focus attention on the exact means by which millions of tons of food can be shipped and distributed in the short-term emergency approach we must adopt. We must make a military-style mobilization effort, coordinated government to government, between Western Europe and the United States, Canada, and other food exporting nations on the one hand, and the receiving nations on the other.

This is necessary, first, to furnish the full amounts of food stocks required, which have been consistently understated by the U.N. Food and Agriculture Organization, the U.S. Departments of Agriculture and State, prominent charities, and the international grain trade companies. Second, government-to-government coooperation is also necessary to requisition the ships and logistical back-up—floating piers, trucks, and other equipment, needed to do the job.

In the course of spanning the disaster regions of Africa with food-supply lines, routes will be opened up for initiating the water, health, and transportation infrastructure that goes along with creating large-scale development and power projects. We must use every lesson learned from the past, including wartime lessons, to accomplish our goals.

Stuart K. Lewis

"All that is required is the moral commitment and political decision-making to do the job." Above: The author showing a sample of the kind of foodstuffs necessary to stop famine.

According to the estimates of the Fusion Energy Foundation and the Club of Life, Africa requires, over and above existing food imports, an additional 17 million tons of grain a year as food aid or commercial sales beginning immediately, and for the next few years, to alleviate the disastrous conditions in the 22 worst affected nations. At present, less than 3 million tons of grain a year have been flowing into those same nations. Africa as a whole has been importing drastically less foodstuffs than required, despite the fact that the total amount of food produced per capita has declined for the last 10 years and food aid and commercial imports have not filled the shortfall.

It should be noted that the Soviet Union is currently importing about 33 million tons of grain every year. Diverting just half this amount to Africa for emergency food aid would turn around the current starvation conditions.

In addition to cereals imports, large tonnages of dried milk, soy and corn milk powder, and other protein food supplements are required to treat widespread protein deficiency diseases and upgrade the diet. These food shipments exceed any present storage or handling facility capacity in the African ports and hinterlands.

The existing ports and inland food shipment lines and depots are inadequate to handle the sizable food freight delivery required, so that military-style facilities (floating piers, off-road trucks, and so forth) must be brought into play for the first couple of years. These emergency systems can remain in place for a few years, during which time permanent advanced technology facilities can be built, creating growth spots around the African continent, and "boom towns" in the nations exporting the infrastructure capital goods.

In the earliest phase of food shipments, LASH (Lighter Aboard Ship) and SeaBee ships should be used, which are in the 30,000-40,000 ton range. These are self-contained, barge carrying ships, which would be good to equip with food already bagged—grain, rice, beans, for easier inland delivery. The ships could deliver to existing ports from which tugs would move the barges loaded with food cargo to water accessible locations. There are about 13 of these ships in the U.S. fleet. Hapag-Lloyd of West Germany has a couple. A number of these from several shipping lines should be requisitioned and chartered for the African food convoys.

Also in the first phase of shipments, about three to six roll on-roll off (Ro Ro) ships must be used to bring in the

maximum tonnage of food on loaded trucks to deliver it inland to distribution points. These trucks would stay on site for handling future shipments brought in by the LASH and later bulk cargo ships. In addition, these Ro Ro vessels would deliver tankers for fuel distribution, electric generators, and other temporary infrastructure.

The Ro Ro ships are about 20,000 tons each, and equipped with self-contained ramps—like floating garages. There are 50 or more properly equipped vessels in the free world fleet. Six to nine vessels would start the process and cover the early 6 to 12 month period.

The Ro Ro ships should be equipped with wheeled construction cranes on deck so they could also handle loading and unloading of nonwheeled supplies such as generators, water purification equipment, and other necessities.

Each ship should carry 150 off-road type trucks of between 15 and 20 ton capacity each, with heavy tires for difficult terrain. In addition, there should be 150 road type, heavy duty trucks.

While as many of these LASH and Ro Ro ships as possible are ferrying in food for truck distribution to the points of need, another effort would be initiated in tandem: the installation of military-style semipermanent port facilities to handle the continuing flow of food from a fleet of 40 to 50 bulk carriers in the 60,000-ton range. The De Long floating pier technology can be installed within only months at key locations on the west and east African coasts.

From the pattern of the present emergency regions of Africa, it would be advisable to establish three emergency port facilities on the East Coast and three on the West Coast. These ports could *each* handle at least 50 to 60 arrivals per year of bulk carriers.

The De Long-type pier is a floating pier with hydraulic caissons that self-anchor. The piers are towed into place, then installed for use. The De Long pier is just a sophistication of the concrete piers that were towed into Normandy and installed after the beachhead was secured. The U.S. military has DeLong piers now—sitting in mothballs.

The piers should be equipped with cranes, and with grain sucker discharge equipment. It would take about two to three months to prepare and equip the De Long piers, then another 45 to 60 days towing time, and one to two months to set up. Therefore, one or two of six emergency food ports could be in operation by December of this year, and the rest by early next year, if the decisions are made this summer.

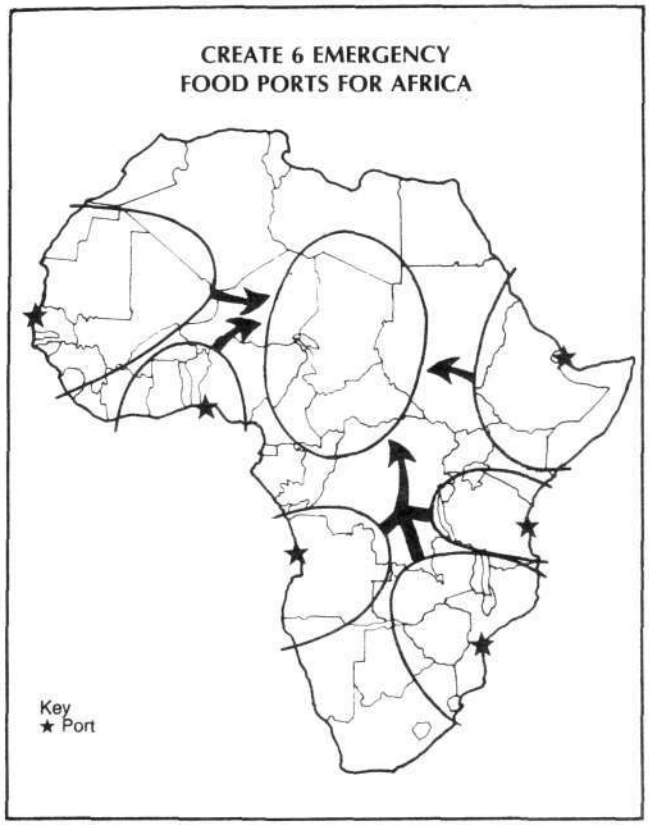
The De Long piers can remain in operation for years, handling construction equipment and other needs for development programs in the hinterlands. De Long piers were used by Sea Land during the Vietnam War to solve the port bottlenecks by containerizing the cargo and creating new ports; two or three De Longs were in Kham Ran Bay, Vietnam, and may have been abandoned. They are probably still in use today by the Vietnamese.

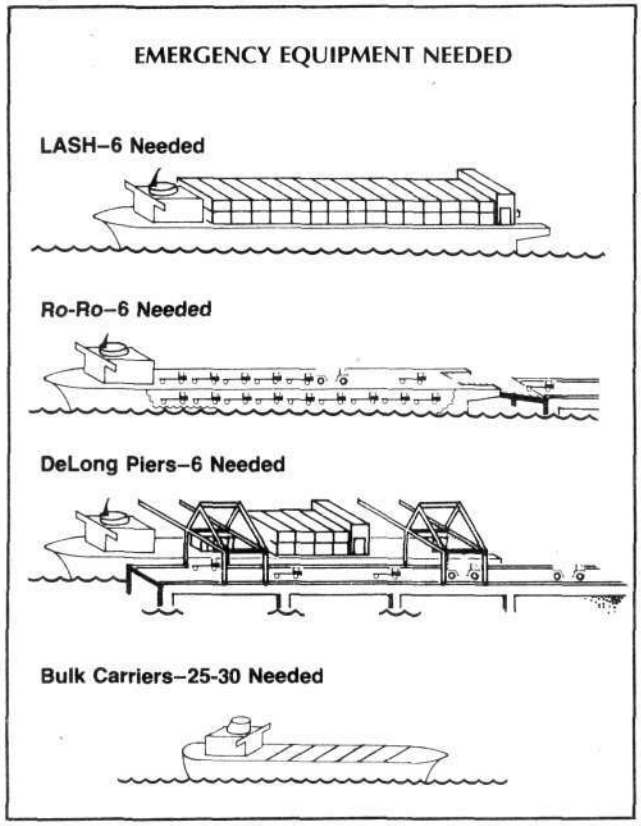
Both at dockside, and at inland-distribution points, air bag storage facilities can be erected in a very short time, to minimize the food destruction and pest damage now common in open-air storage. Grain shipments should be irradiated at the point of origin for optimum preservation. The practice of sending subgrade, moldy corn and grain must be stopped.

The costs of these emergency shipping methods, excluding grain, is at most 20 percent more than conventional transport in the first two years,

U.S. Coast Guard/Don C. Hansen

We have the shipping technology to get the food there! Above: A Navy ship in World War II laden with supplies for the troops.





and then equal to conventional transport thereafter.

In contrast to this practical approach to supplying emergency food to Africa, the United Nations and the World Food Program are merely playing with food shipments while watching millions starve. The 1,500-ton Danish coaster hired by the Program's Transport Branch last year is a joke. It will deliver 10,000 tons of grain to southern Mozambique in 10 voyages over three months. Part of the grain will be unloaded on the former resort island of Santa Carolina—"Paradise Island"—then transshipped by a landing craft to villages on the mainland beach. There is no excuse for this immoral joke.

Look at the experience of the U.S. Navy in World War II. The picture (page 11) shows a wartime supply ship loaded with trucks, gasoline tanker trucks, cranes, and other emergency materiel, just the way in which we could be convoying supplies to Africa, and driving the cargo inland to every village in need.

All that is required to accomplish this is the moral commitment and political decision-making to do the job. We must create a new ad hoc international commission to locate the food, requisition the ships, and set in motion the logistics. There is today a "glut" of shipping tonnage; farmers and farms are being put out of existence. If American and European farmers were allowed to produce, and some excess vessel tonnage put to work solving this human need, the results would be immediate and measurable. These resources should be put to work now.

—J. Scott Morrison

The Present Emergency Mobilization Is Not Enough

Since July 1984 when I prepared this report, the food crisis in Africa has worsened. Yet, despite all the publicity about airlifts and fundraising, there has been no proper mobilization of the transportation and supply infrastructure needed to deliver the food and do the job of ending starvation.

The United Nations Food and Agriculture Organization has gone so far as to consign even greater numbers of people to starvation in Agrica, based solely on accepting logistics deficiencies. In the December 1984 issue of the FAO *Bulletin*, the FAO reports that in 1985 food shortages in Africa will be worse than 1984, but the FAO reduces the tonnages of food aid it says will be needed, explaining tht "logistical constraints" will prevent the food from being distributed!

For example, in the case of Chad, the FAO *Bulletin* says that 125,000 tons of food aid are need this year; but in a footnote, the FAO adds, "[This figure is] based on present logistical capacity; total requirement is estimated at 325,000 tons."

This is murder.

Hitler's Euthanasia Policy: Today's Nazis Want to Make It Legal

This report was prepared by Linda Everett of the Club of Life, an international group formed to combat the Malthusians. Leaders of organizations, political spokesmen, and concerned citizens are invited to collaborate in a campaign to stop the practice of Nazi euthanasia. The Club of Life can be reached at 1010 16th Street, N.W., Washington, D.C. 20036.

* * *

Throughout history, there has never been a nation more equipped to save and prolong life as the United States is today. We have medical breakthroughs like the artificial heart, laser surgery, and the elimination of kidney stones by sonic shock waves. Yet there is a movement across the country to legalize euthanasia, the killing of the elderly and sick, a crime for which the Nuremberg Tribunal sentenced men to death by hanging 40 years ago.

The extent to which the euthanasia practice has taken hold is alarming. We are actually facing the outbreak of mass murder of the elderly on a scale never before seen in history. There are three levels on which euthanasia is being advanced:

(1) The quiet acceleration of murders occurring daily at the hands of doctors, families, and insurance companies in nursing homes and hospitals; (2) the steady accumulation of court decisions, on a state-by-state level, that condone euthanasia for broader and broader categories of persons; and (3) the propaganda for acceptance of euthanasia as an appropriate social policy for the so-called postindustrial age.

The depth to which our civilization has slid into acceptance of this barbaric practice is horrifying. Literally hundreds of thousands of families have been forced in quiet desperation at the cost of life-saving medical care into murdering their loved ones. There is nothing ideological about this action.

Karl Brandt, Hitler's personal physician, as he heard the death sentence pronounced for him during the Nuremberg Tribunal, August 1947. He was hanged for the euthanasia crimes advocated today by Colorado Governor Richard Lamm (inset).

UPI/Bettman Newsphotos

In many cases it is carried out while the insurance company or another bill collector is standing with the figurative gun to the grieving individual's head until he pulls the plug on his relative.

Pulling the plug is on its way to becoming U.S. law. On Jan. 17, for example, the State Supreme Court of New Jersey made euthanasia legal. In the case of Claire Conroy, an 84-year-old nursing home patient, the court decided that all life-sustaining medical treatment, including food, can be withheld or withdrawn from terminally ill patients, whether they are legally competent or not.

Crimes Against Humanity

At the Nuremberg Military Tribunal after World War II, individuals were executed for the crime of euthanasia. Most notorious was the case of Nazi doctor Karl Brandt, who was hanged in 1947. The Tribunal charged:

"Defendants Karl Brandt . . . unlawfully, willfully, and knowingly committed crimes against humanity . . . in that they were principals in, accessories to, ordered, abetted, took a consenting part in, and were connected with plans and enterprises involving the execution of the so-called 'euthanasia' program of the German Reich, in the course of which the defendants herein murdered hundreds of thousands of human beings, including German citizens, as well as civilians of other nations.

"This program involved the systematic and secret execution of the aged, insane, incurable ill, of deformed children, and other persons. . . . Such persons were regarded as 'useless eaters' and a burden to the German war machine."

Dr. Brandt defended his actions using words familiar today among the right-to-die advocates: ". . . When I said 'yes' to euthanasia I did so with the deepest conviction, just as it is my conviction today, that it was right.

Death can mean deliverance. Death is life—just as much as birth."

Worse Than Hitler: Gov. Lamm

One of the most prominent advocates of killing the elderly, the terminally ill, and the comatose, is Colorado Governor Richard Lamm, who is using the national media to accustom Americans to accepting the Nazi policy of euthanasia. Actually, Lamm far surpasses Adolf Hitler in the scope of genocide he envisions, as can be seen from the excerpts below from his mid-January series of lectures at the Pacific School of Religion, in Berkeley, Calif.

Lamm advocates what he calls "Reality Theology and Triage Ethics," demanding the extermination of the world's 2 billion starving poor, elderly, and sick and calling it, "God's way of reasserting balance in the world." He proposes a concept of 'Toughlove,' in which we simply accept the starvation in much of the Third World.

Lamm reiterates the gloom and doom stories from the Club of Rome Malthusians and the *Global 2000* crowd that are popularized throughout the Eastern Establishment press—overpopulation, finite resources, shrinkage of the animal species, pollution, overimmigration, and "keeping corpses alive." Lamm writes off the Third World:

"It is my sad and reluctant conclusion that the economy within the United States cannot keep up with all the problems outside of the United States and that we are foolish to try. It is my conclusion that 'Toughlove' means that we let God's judgment take place in much of the Third World and by trying to relieve this suffering all we do is postpone it.

". . . It is sad but true that most of the world's poor will stay poor—and that there is nothing the developed nations can do to alter this. Our maximum generosity could not make a dent in their poverty. . . .

"We *ethnocentrically* thought the Earth belonged to us. But alas, *ecologically* we belong to the Earth. And the Earth is now claiming its due from a myopic species called Man."

Lamm's Reality Theology strips man down to the kind of natural spirit the Nazis talked about. It is with this naturalness that Lamm's technology monster interferes. "There is something blasphemous and obscene about a corpse rotting on a breathing machine," he says. "We don't force life upon our terminally ill dogs; yet we do our elderly. We are daily making sacrifices to the new secular God, technology. . . ."

The Duty to Die

"Suicide is the ultimate self determination," Lamm says. "We seek more than a living will. . . . We demand, for our sake and the sake of our nation, the right to timely suicide."

Lamm then calls for "the next liberation movement" to be one of "freedom from counterproductive medical technology." Not content with comparing the elderly to terminally ill dogs, he says:

"I submit that it is a duty and a burden of our humanness that we die. Do leaves have the 'right' to remain on the trees? Does the tide have the 'right' to refuse to flow? Does a snowflake have the 'right' not to fall? No."

According to Lamm, "Life is no second God, and therefore the respect due it cannot rival the reverence owed to God." Lamm neglects to mention that coma recovery programs, just to take one example, have a 92 percent success rate in coma recovery for previously "brain dead" patients and a 35 percent success rate among former so-called vegetables who are fully recovered, fully functioning men, women, and children.

Cost-Cutting with Human Lives

Under Nazi economics, human muscles were used wherever possible to replace technology. Expensive technology could not be wasted, but cheap human labor could. This same thinking provided the economic rationale for Nazi euthanasia; it was just too expensive to keep the terminally ill alive.

As Lamm puts it: ". . . Yesterday's generosity and emergency aid has become today's 'international obligation.' But the new reality is that we cannot save all the starving children; we cannot help significant numbers without ruining our own economy. . . . We see children who need new kidneys and elderly who could use a heart transplant, but the reality is that the demand and the cost of these procedures exceed our resources."

Perhaps the only difference that the modern Nazis can claim in their implementation of euthanasia is that they have convinced many of their victims to openly sign for it in "living wills"—with the support of a population convinced that there is no other choice in postindustrial society.

Stuart K. Lewis

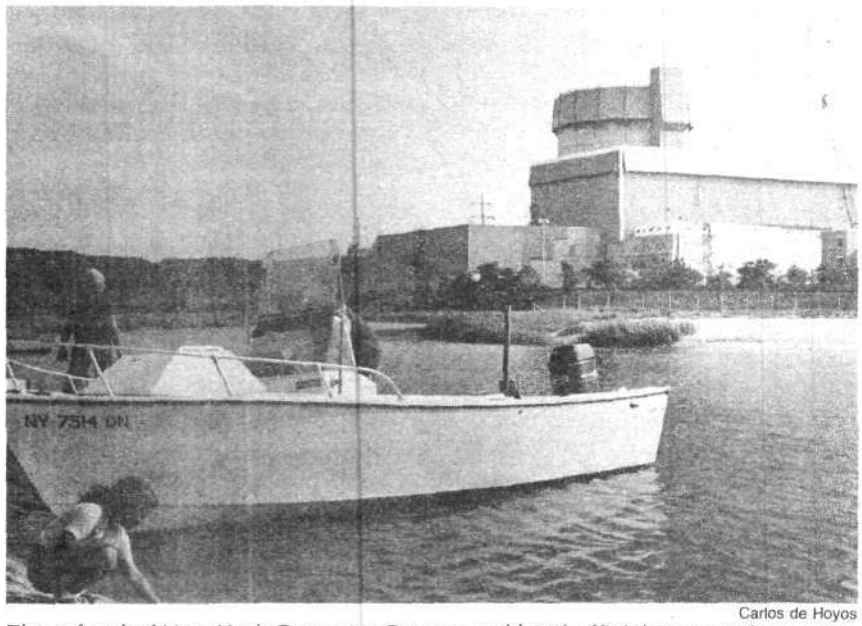
Club of Life demonstrators protest New Jersey's proposed euthanasia law.

U.S. Nuclear Policy: Purely a Political Battle

While the liberal media continue to surround their captive audience with nuclear scare stories, three recent reports dramatically underline the opposite—that nuclear power is safe, cheap, and absolutely necessary for industrial growth.

A January 1985 study by the N.Y. State Society of Professional Engineers shows that even the apparently energy-surplus state of New York will need more electricity generation over the next decade, and that nuclear is the best option; a study issued by the European Community says that by the turn of the century the Western European nations will be 50 percent nuclear in electricity generation; and the American Nuclear Society concludes that the risk of human harm from even the most severe nuclear accident is at least 100-fold less than previously estimated.

The antinuclear obstructionists in the United States, however, are still up to their same old tricks—shutting down progress. The Washington, D.C.-based Government Accountability Project, for example, has just announced that it intends to shut down the 160 nuclear power plants worldwide that were designed by General Electric. Although it is not likely that this outrageous attempt will garner any credibility overseas, the question is whether this kind of sabotage will continue to cripple the nuclear industry here at home.



Carlos de Hoyos

The refusal of New York Governor Cuomo and local officials to permit an evacuation plan has forced the Shoreham nuclear plant to remain idle, at a cost per day to Long Island Lighting Co. of $1.5 million.

Europe Goes Nuclear

The European Community released a study Jan. 31 by the EC Commission outlining specific goals for its 10 member states over the next 15 years. By the turn of the century, the EC expects 50 percent of their electricity to be generated by nuclear power plants. Just 5 years from now, the EC plans to have 128 reactors in Europe, producing 98 gigawatts—almost double the 1983 figure.

The Commission stresses that European independence from foreign supplies of oil is a definite goal, and that the slowdown in uranium prospecting worldwide should be reversed. At the time of the 1973 oil crisis, Europe produced 5.4 percent of its power from nuclear reactors. In a decade, this jumped to 22.4 percent.

In the United States, on the other hand, the change from 1973 to 1983 was from 4.3 percent to only 12.6 percent. While Europe continues to go nuclear, the United States is triaging its nuclear industry and destroying the basis for future economic expansion.

Safe and Economical

During the incident at the Three Mile Island nuclear power plant in March 1979, so little radiation was released that experts had surmised that there was little damage to the fuel core. The clean-up has revealed, however, that there was substantial damage to the core and that some nuclear fuel probably melted.

The American Nuclear Society (ANS) did a study to investigate this unexpectedly low radiation release and concluded that the previous standard analyses of risk during a nuclear power plant accident are too conservative *by a factor of 100 or more.*

Since the Nuclear Regulatory Commission requirement for a 10-mile radius evacuation zone around a nuclear plant is based on the earlier analyses of radiation release, the new study might mean that a substantial reduction in the evacuation area is needed. This would end the near-endless debates over ridiculous evacuation plans that have been demanded by the Nuclear Regulatory Commission, which in some cases involve evacuating cities with millions of residents.

In New York, the antinuclear governor and local officials have refused to participate in any such evacuation plan, thus putting on hold the completely ready Shoreham nuclear plant, which costs the sponsoring utility $1.5 million every day that it remains idle.

The ANS study, released in November 1984, was prepared by a committee that included experts from the United States, Europe, and Japan. It also concluded that a nuclear power plant accident that would release enough radiation to endanger the public is vir-

tually impossible.

Whose 'Nuclear Follies'

What about the supposedly horrendous cost of nuclear power plants? *Forbes* magazine Feb. 11 devotes 15 grueling pages to an "expose" of what it calls "nuclear follies." *Forbes* describes the problem as the "largest managerial disaster in business history" and claims that bad management has created a situation where "for the U.S., nuclear power is dead."

Forbes puts little blame on usurious interest rates, years-long legal battles with environmentalists, or federal overregulation. Instead, it chooses to focus on a handful of plants that have been delayed and whose costs have skyrocketed because of a drop in electricity demand or endless legal intervention.

In contrast to the *Forbes* attack on utilities, the study issued by the N.Y. State Society of Professional Engineers shows that in some cases interest payments are responsible for one third of the monthly cost of building a nuclear plant. The study also demonstrates that in all but the handful of plants pilloried by the opposition, nuclear power is still cheaper per kilowatt hour than both oil and coal.

New York will need to build between 8 and 10 power plants in the next decade to replace aging capacity and meet even the most minimal growth, the study says. Do we really want to become dependent upon a foreign country for electric power, which has to be transmitted a thousand miles, the study asks, referring to a state proposal to buy power from Canada.

National Security

The choice facing many utilities is not that different from that facing American farmers—bankruptcy. Yet both provide a commodity that the economy cannot do without.

So far the Reagan administration has lost the battle for nuclear energy, simply by not putting up a fight against the increasing and irrational demands of the antinuclear environmentalists. To turn this situation around requires decisive action of the sort the President took to launch the Strategic Defense Initiative. At stake are the same issues—national security and a healthy economy.

—Marsha Freeman

Viewpoint

Continued from page 6

gen-oxygen technology, and ultimately we set up a special company together with the SEP in France to build a cryogenic rocket. We gave the French all of the technology for cryogenic combustion, and today the fourth stage of the Ariane is all German technology, from Messerschmidt-Buelkow-Blohm (MBB).

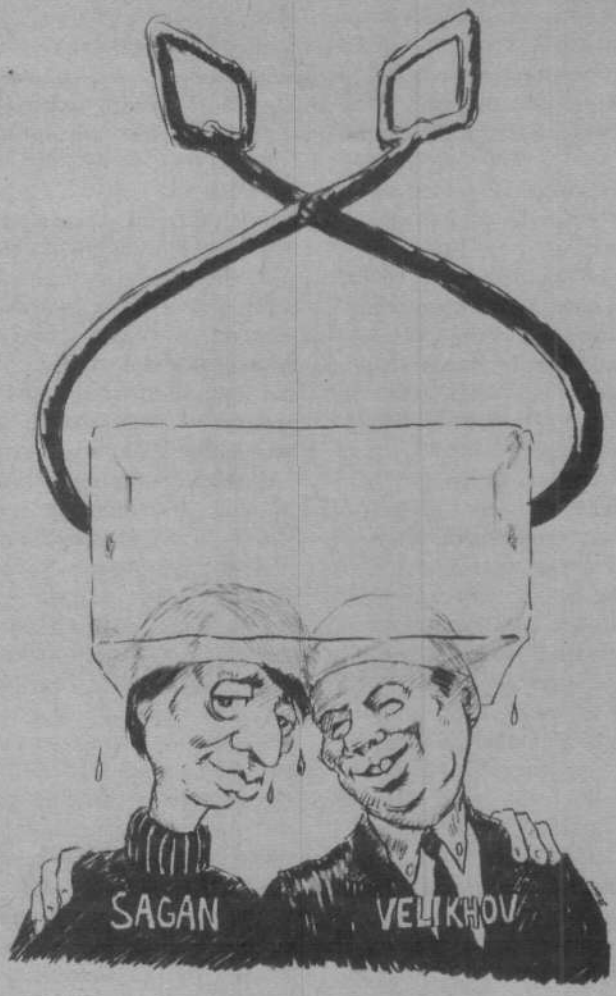
In fact, we gave this basic technology to the American Rocketdyne firm, and it is now incorporated into the main booster of the Shuttle, built by Rockwell. The high-pressure technology with incredible cooling capacity is ours, and MBB still gets license fees from NASA every year.

Real Cooperation

Real cooperation reaches far beyond such pragmatic instruments as patents and license fees, however. Today, such cooperation is necessary if we are to jointly realize the SDI program.

It is obvious that, had some form of in-depth cooperation begun back in the mid-1960s along the lines of the "Troika," we would have been spared the disappointments then that have considerably contributed to the attitudes of skepticism or even rejection that initially greeted President Reagan's strategy of "Mutual Assured Survival."

Those in America who support Weinberger's proposal that West Germany and Europe contribute to the SDI program must understand their true task. Had such cooperation occurred in the area of space flight, there would today be a pool of intellect and talent capable of understanding both the technological and strategic implications of the SDI. The true task underlying the SDI involves, in part, creating such a pool where it does not now exist, although the potential for it is indeed immense. It means cooperating to accomplish a common goal, cooperating at the frontiers of science and present engineering know-how, rather than insisting that one's allies "reinvent the wheel," an approach that ultimately slows down one's own efforts, and creates the potential for the real enemies of the Alliance to drive in the wedges of "divide and conquer."



The All-Wrong Assumptions of Sagan's 'Nuclear Winter'

by Robert Gallagher

The "nuclear winter" thesis launched by Carl Sagan et al. in October 1983 has by now blanketed American media and minds with one of those thick covers of pseudoscientific disinformation that makes penetration by truth exceedingly difficult. Articles in the establishment scientific journals like the British *Nature* have torn Sagan's nuclear winter thesis to shreds scientifically. Nevertheless, for most Americans, the specter of a nuclear winter in which any surviving life after an nuclear exchange will be obliterated by an impenetrable cloud of smoke and debris, is now taken as a given.

Part of the problem is that none of the established scientific criticisms of Sagan's nuclear winter thesis has hit directly at his underlying, erroneous assumptions. They, like Sagan, ignore the theoretical understanding of wave phenomena dating back to Leibniz and Riemann.

First, let's summarize what Sagan et al. have prophesied.[1] According to the nuclear winter thesis, nuclear explosions in a war that unleashes a total power of 5,000 megatons of TNT would throw some 225 million tons of smoke and soot into the upper atmosphere from fires started by the explosions. This material would form a uniform blanket encircling the Earth within a couple weeks of the nuclear exchange.

Such a blanket would cut 98 percent of the Sun's light and heat from the Earth's surface "for weeks to months," according to this thesis, with the result that average land temperatures in the northern hemisphere would drop by 50 to 60 degrees Celsius, photosynthesis would cease, and widespread extinction of plant and animal life would occur.

After his first media splash, Sagan immediately went on the campaign trail to promote the nuclear winter thesis. He called for a reduction, or "build-down" of U.S. and Soviet nuclear arsenals from an official total of approximately 12,000 megatons to 100 megatons—the threshold below which he asserted a war would not trigger this "winter" doomsday machine.

At the time, President Reagan was attempting to win congressional approval of his plan to modernize the U.S. missile force with the deployment of 100 MX missiles. Sagan, joining forces with E.P. Velikhov—a leading scientist in the Soviet ABM program—used his "nuclear winter" threat to testify against the MX at a congressional conference sponsored by Sen. Edward Kennedy (D.-Mass.) and the Nuclear Freeze Foundation.

(One of the interesting political facts that has not penetrated to Sagan and other freeze advocates is that despite all the Soviet rhetoric about nuclear winter, the Soviet Union has an elaborate civil defense system and a military war-fighting doctrine that has prepared that nation to win and survive a nuclear war.)

The Scientific Refutation

Now for some of the refutations in print. Sagan's nuclear winter scare has been refuted by Dr. Edward Teller,[2] S.

Fred Singer of the University of Virginia,[3] Sherwood B. Idso of the Institute for Biospheric Research in Arizona,[4] and a special committee of the National Academy of Science's National Research Council,[5] among others.

Their criticisms are summarized in the accompanying box (page 20). Although Teller, Singer, Idso, and the Council have wounded the credibility of the Sagan scenario, however, they have not struck at the heart of the beast by challenging its underlying scientific assumptions. Sagan's model is attacked from the standpoint of contemporary atmospheric science, and no physical principles contrary to those assumptions are put forward.

For example, the mechanisms that Teller proposes to break up the Sagan smoke blanket are all orthodox atmospheric mechanisms accepted by the scientific community—such as the development of large-scale interactions between regions over oceans and those over land.

Left unchallenged is Sagan's principal assumption that on the order of the small—the microphysical—nature displays no differentiation. All weather modeling—including that that has produced the nuclear winter forecast—assumes (1) no significant phenomena that could affect the macroscopic behavior of the atmosphere occur below the model's scale of spatial resolution; and (2) atmospheric processes can be reduced to the percussive interaction of gas particles.

In other words, Sagan's model assumes that on the scale of the microphysical, nature is incapable of differentiation that could perform work against the atmosphere as a whole. The spatial resolution of the best atmospheric models is a few hundred kilometers.

Inadequacies of Weather Modeling

Such weather modeling is incapable of characterizing the microphysical processes that would make the formation of an opaque blanket of smoke improbable and that would certainly rip it apart, if ever formed, restoring the atmosphere to its normal, productive state. In its report, the National Research Council committee discusses this problem:

"The available tools [for the study of the atmospheric effects of nuclear war] include a variety of models, of which the most advanced are the general circulation models (GCMs) developed for application to studies of weather prediction and climate dynamics. . . . For applications to the problem of atmospheric effects of dust and smoke from nuclear war, however, GCMs are deficient in several respects. . . .

"No existing GCM simulates the full physics of a radiatively active trace material where net heating effects drive the circulation while the distribution of material is itself continuously varying in response to the flow and to complex flow-dependent removal processes. Formulations of boundary layer processes in these models are necessarily somewhat crude because of the low spatial resolution. . . . Perhaps the most serious for the nuclear war particulate problem, the cloud microphysical processes that are primarily responsible for the removal of particulates from the atmosphere cannot now be included in detail in these models."

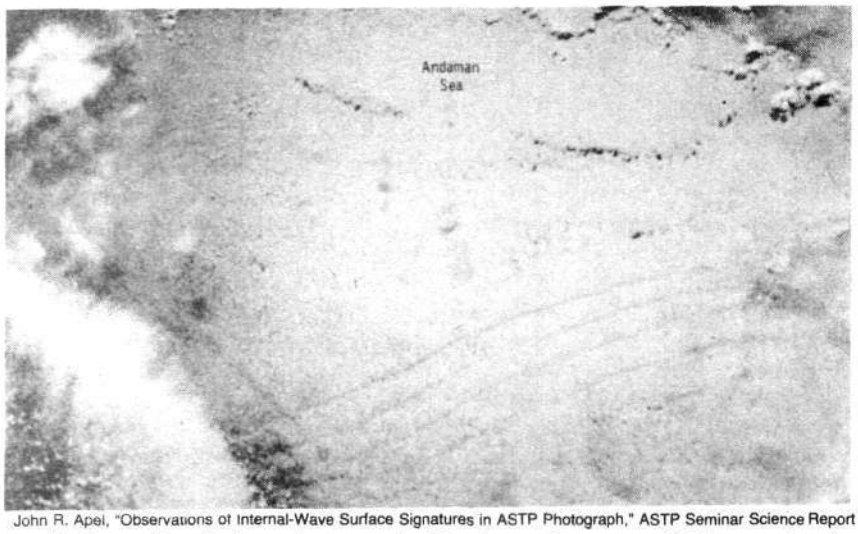
Incredibly, however, after admitting that these models are deficient for the task, the National Research Council committee makes its own "winter" forecast of "large temperature decreases near the surface [of the Earth] and temperature increases aloft for a period of weeks to months" after a war. This forecast underscores the methodological incompetence of existing criticisms of Sagan's nuclear winter.

Even assuming that a 225-million-ton blanket of smoke and soot is formed over the Earth—reflecting sunlight—how long could such a structure persist? Teller points out that the smoke-laden air in the troposphere would raise the temperature at the tropopause from −60 degrees to about +5 degrees Celsius. Meanwhile, surface temperatures on the continents of the northern hemisphere at mid-latitudes would drop to −30 degrees Celsius. How long could a blanket of mere smoke maintain such a huge temperature gradient? Even assuming the blanket is established, how could the air supporting the blanket withstand the solar energy input at the tremendous rate of 2,000 megawatts per square kilometer without developing large-scale turbulence that would destroy the blanket?

Sagan insists, furthermore, that this insulation blanket does not radiate heat down to the atmospheric layers below it. Were this true, these layers would constitute an ideal container for structure formation within the blanket. (Were it not true, the Earth would be warmed.) Clearly, the excited medium would destroy the smoke blanket. This would not even require the formation of shocks as they are commonly understood in the sonic boom and other such macroscopic phenomena. Vortex formation could produce the same effect.

The Soliton Phenomenon

An example of how this could occur is provided by the phenomenon of sol-



John R. Apel, "Observations of Internal-Wave Surface Signatures in ASTP Photograph," ASTP Seminar Science Report

Apollo-Soyuz Test Project photograph of Andaman Sea, west of Malay peninsula, showing four soliton wave packets with very long linear features.

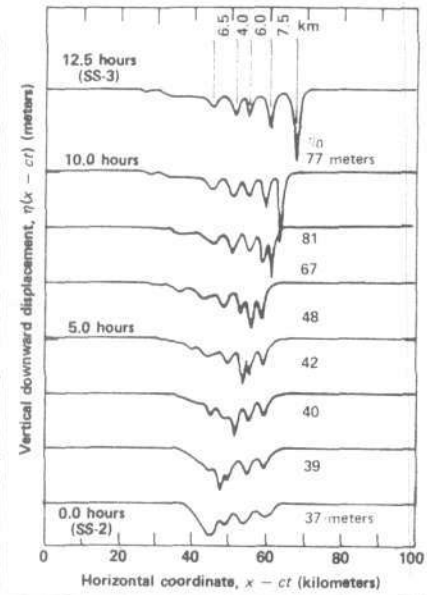
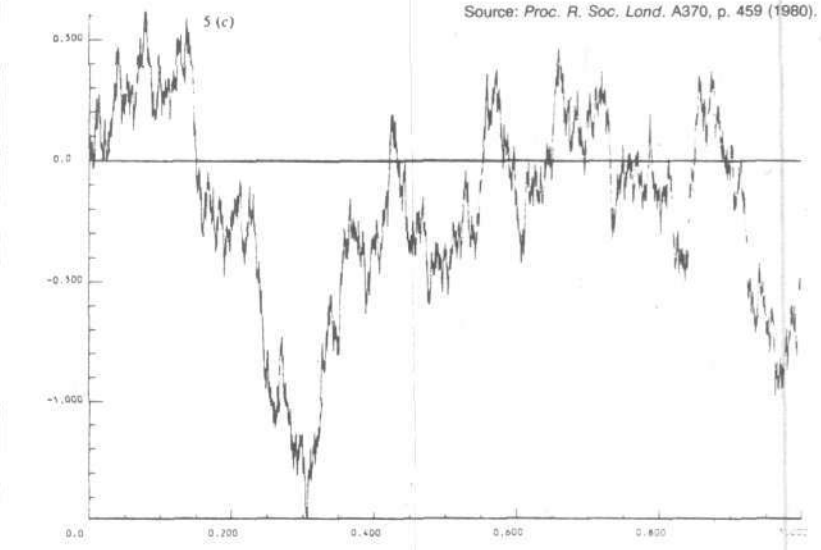


Figure 1
NUMERICAL SIMULATION OF SOLITON PACKET

A numerical simulation of the evolution of a packet of five solitons from location SS-2 (bottom) to location SS-3 (top) in the Sulu Sea. The figure shows clearly the formation of singularities in the waves from a smooth undulatory bore at SS-2 in an adiabatic process into a rank-ordered sequence followed by a linear dispersive tail. The wave singularities are identified by the pointers at SS-3.

Source: J.R. Apel and J. R. Holbrook, "Internal Solitary Waves in the Sulu Sea," *Johns Hopkins APL Technical Digest*, Vol. 4, No. 3 (1983).



Source: *Proc. R. Soc. Lond.* A370, p. 459 (1980).

Figure 2
MODIFIED WEIERSTRAUSS FUNCTION

A graphic representation of a modified Weierstrauss function, which is continuous everywhere but differentiable nowhere. The particular case shown here models Brownian motion.

itary waves or solitons in the ocean. Several investigators have shown that the tides regularly create solitons—in an adiabatic process—out of the potential difference existing between ocean layers of different densities. The tidal pull of waters with layers of different density over a barrier (such as an underwater mountain range) produces an undulatory bore or current between the fluid layers, as shown in the graph at the bottom of Figure 1.

The figure shows the evolution of a packet of five solitons from a simple wave at the bottom of the figure to a structure characterized by singularities.

Such solitons have been observed with a lifetime of three days, wavelengths of 10 to 20 kilometers, speeds of 9 kilometers per hour, and amplitudes of 100 meters. They have posed a threat to oil drilling rigs on the continental shelves.

One recent report has generalized this phenomenon to all planetary fluids, including the atmosphere:[6] "Internal gravity waves . . . may occur within the body of a fluid whose density varies in the vertical, whenever that fluid is disturbed by some means. . . . [Such] internal waves exist in the continuously stratified fluids of the Earth's atmosphere and oceans. . . . The combination of solar heating and gravity results in a stratification of a planetary fluid such that its density decreases with height. . . . Under stably stratified conditions, any forces that excite vertical excursions of these fluids will generally result in the propagation of internal waves away from the source. . . . If the amplitude of the wave is high enough, it takes on nonlinear characteristics. The gradient containing region acts as a kind of waveguide."

Self-Destructing Blanket

According to this analysis, not only would Sagan's smoke blanket be unstable, but the blanket itself—separating atmospheric layers of vastly different energy density—would act as a waveguide for the propagation and focusing of solitary waves that would destroy it. The propagation of such solitons is nonlinear and was described in 1895 by D.J. Korteweg and G. de Vries after the first recorded observation of solitons with the following equation:

$$\partial u/\partial t + au\,\partial u/\partial x + \partial^3/\partial x^3 = 0,$$

where u is the wave velocity in the x direction in time t and a is a constant.

This is the sort of nonlinear partial differential equation—a form of analysis invented by Leibniz—whose geometric character Riemann elucidated. It encapsulates the principle of the negentropic action of the Leibnizian delta on the universe as a whole.

Demonstrations of Leibniz's concept of direct relevance to the problem of computerized weather modeling came from Karl Weierstrauss and Georg Cantor, who developed mathematical functions that represent the infinite differentiation that Leibniz had insisted existed. Before Weierstrauss, it was assumed that all continuous functions were differentiable; that is, it was assumed that in the infinitesi-

Continued on page 64

Six Points That Demolish Sagan's 'Nuclear Winter'

(1) S. Fred Singer of the University of Virginia points out that Sagan's cooling effect is based on the smoke blanket having unique and peculiar optical properties. For the cooling to occur, the blanket of smoke must (a) reflect visible solar radiation back into space but (b) permit infrared radiation, heat, to pass through the blanket and escape from the Earth. This is the worst possible situation.

However, if the smoke blanket were opaque to all wavelengths, the heat given off by the Earth would be trapped by the blanket—reducing or eliminating a temperature drop at the surface. Second, it is also likely that a smoke blanket would absorb solar radiation and reemit it as heat, infrared radiation, to warm the Earth.

(2) Teller argues that Sagan ignores the principal natural mechanisms for removal of smoke from the atmosphere. Even if as much as 225 million tons of smoke is injected into the atmosphere over northern hemisphere mid-latitudes as a result of war, the amount of water already in the atmosphere over these regions is 10,000 times greater. He shows that in the first 10 days after a war—before the cooling effect occurs—an amount of water equal to a few thousand times the amount of smoke assumed to be thrown up, will rain out—cleansing the atmosphere.

(3) Singer and Teller both point out that fires themselves inject great amounts of steam into the atmosphere. This may be the source of the "capping cloud" of condensed moisture that forms over a smoke plume rising from a fire. Singer mentions that these clouds make it difficult to detect forest fires from space. Experiments have shown that these clouds created by fires reduce the number of small smoke particles—the ones Sagan relies on to shut sunlight out from the Earth—by 90 percent! Agglomeration of small particles into larger ones—that fall or rain out faster—is probably the principal mechanism.

(4) Teller adds that the Sagan model ignores the oceans and winds. The oceans are a huge reservoir of heat that will warm the air over them and establish a great temperature gradient between the oceans and land at the beginning of a "nuclear winter" so as to moderate it and set into motion atmospheric processes to break up the smoke blanket over the Earth.

Teller cites a model developed by the National Center for Atmospheric Research that in a limited way includes oceans and wind, but is otherwise similar to Sagan's. This model arrived at a temperature drop that was one half to one tenth—depending on the season—the size of that asserted by Sagan.

Teller writes: "If a nuclear winter were to begin, unusually great temperature differences would be established between the continents and oceans. This results in increased storms along the eastern coasts of the continents, with consequent mixing of air from high and low levels of the troposphere. Air from lower altitudes has a higher moisture content which is conducive to rainout. The storms are mentioned by Turco et al. [the Sagan report] but not taken into account in the calculation of particle scavenging. . . . If the rain removed smoke from one area while leaving it untouched in another, the smoke layer would be patchy. . . .

"The patchiness of smoke, in turn, could bring about further large temperature differences which will further drive the atmospheric processes that rain out more smoke. In this case, rainout of large smoke layers might proceed in an accelerating fashion."

(5) In a recent technical letter to *Nature*, Idso ridicules Sagan for his illogical reasoning: "In their recent complaint about [Nature editor] John Maddox's criticisms of their climate modeling work on the 'nuclear winter' concept, Turco et al. attempt to buttress their case by stating that the climate model they used was partly calibrated by (a) 12 years of research on Martian dust storms, (b) the climatic consequences of volcanic explosions on Earth, and (c) the possible collision of an asteroid or cometary nucleus with Earth at the time of Cretaceous/Tertiary extinctions. In addition, they say that their work was reviewed by a large number of experts and that it referred to many previous studies. If these reasons are indeed the basis for their confidence, the criticism they received was well justified.

"To begin with, what good is a technique that is only partly calibrated? And how can a model be calibrated against a possible phenomenon which may or may not have actually occurred, and at that in the distant past? With respect to the climatic consequences of volcanic explosions, Turco et al. indicate in their complaint that these are caused primarily by sulphuric acid aerosols and not by the smoke and dust that is supposed to operate in the nuclear winter scenario. So how can this comparison be of any use?

"In addition, of what real comparative value is the planet Mars? It has no liquid water on its surface, while Earth is 70 percent covered by seas; and its atmospheric mass is miniscule. Dust there operates almost as if it were in a vacuum; and, again Turco et al. claim that it is not dust but rather sooty smoke from fires that is the major cause of nuclear winter. And as for citing a lot of background material and getting the opinions of a large number of experts, what does that prove? Absolutely nothing."

(6) According to Sagan's scenario, the dissipation of the smoke blanket, after months of freezing temperatures, would expose the biosphere to being "fried alive" by ultraviolet radiation because of the reduction by one half of the thickness of the protective ozone layer by multimegaton explosions. Teller refutes this as well. He points out that (a) nuclear tests in the atmosphere indicate that a war with multimegaton weapons might deplete the ozone layer 30 to 40 percent. This is comparable to observed geographic and seasonal variations in the ozone column.

For example, the ozone over Miami is about 20 percent less than over Seattle. Therefore, he argues, "the changes are not likely to be significant." Furthermore, (b) the present U.S. nuclear arsenal has few nuclear weapons with the yield required to deplete the ozone layer in the first place.

Oncogene Research Promises New Possibilities For Cancer Cure

by Ned Rosinsky, M.D.

One of the major causes of cancer is the abnormal functioning of otherwise normal genes. New findings in oncogene research relating abnormal genes and abnormal control of normal genes to the processes that underly cell growth and tissue repair suggest specific possibilities for cancer treatment and prevention. Oncogenes, from the Greek word *onkos* or tumor, are those that have the potential to cause cancer.

This line of research began in the 1960s when the development of techniques for growing animal cells in laboratory tissue culture made possible the detailed study of conditions that can transform normal cells into cancerous cells. The effects of radiation, carcinogenic chemicals, chromosome breakages and abnormal reattachments, and viruses were all investigated.

Viruses became a focus of intense research in the early 1970s after a number of animal cancers were traced to viral infection, since this implied that it may be possible to produce a vaccine against cancer. Although only several relatively rare forms of human cancer were subsequently found to be caused by viruses, this line of research led to the isolation of the particular genes in the virus that were capable of transforming cells.

To situate the specific findings, and to emphasize that cancer involves tissue-level changes as well as genetic changes, it is helpful to have a general overview of cancer formation.

Although there are more than 100 distinct kinds of cancer as classified by tissue typing, some aspects are common to most. There is a loss of coordination of cell growth resulting in a chaotic microscopic tissue appearance, which is usually progressive as the tumor grows. There is also an increase in the cellular division rate in many cancers.

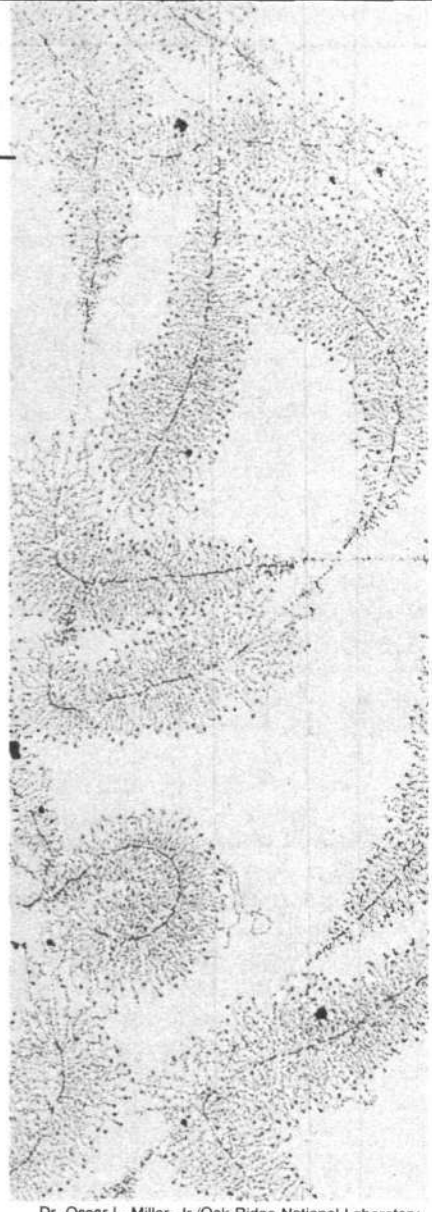
In addition to this apparently chaotic and increased growth, there are two key processes: invasion and metastasis. Invasion requires the destruction of normal tissue surrounding the tumor and extension of the tumor into new adjacent areas. Tumors may invade any tissue, including bone. Metastasis is the separating off of parts of the tumor, parts as small as individual cells, which leave the main tumor mass and travel to distant sites in the body to start new colonies of tumor growth.

Death occurs either by a mass effect of the tumor such as by blocking the lungs or intestines, or destroying the brain by pressure; by invading and destroying the major part of a vital organ such as the liver; or by generally weakening the body, including the immune system, so that infections become lethal.

A surprising result of this cancer-virus research was that the genes involved, termed *oncogenes*, were either identical or nearly identical to normal genes already present in the host organism, including humans. This implied that cancer involves either an abnormal functioning of otherwise normal genes or the slight modification of normal genes. These hypotheses were both confirmed when DNA added to the culture from cancerous cells led to malignant transformation of normal cells grown in laboratory tissue culture.

The Role of Oncogenes

Each gene is a long sequence of hundreds to thousands of nucleotide molecules that ultimately direct the production of a particular protein. Adjacent to each gene is a sequence of nucleotides that functions to determine the degree of activity of the gene; this is termed the promoter, enhancer, or activator region of the DNA.



Dr. Oscar L. Miller, Jr./Oak Ridge National Laboratory

Electron microscope photograph of genes at a magnification of 25,000.

Researchers have established that some oncogenes produce normal proteins but have abnormally functioning activators. Other oncogenes themselves are abnormal, in as small an area as one abnormal nucleotide in the entire gene. For example, the normal human gene *ras* becomes an oncogene with the change of only one nucleotide, causing the 12th amino acid in the protein amino acid chain to change from glycine to glutamine.

Additional oncogenes that are active in human cancer but are not found in any viruses have been identified, bringing the total of oncogenes to more than 20. While the original concept of oncogene included an invading virus as the source of the gene, this was later expanded to include any DNA that when added to cells transforms them into cancer. At this time, active oncogenes have been found in 15-20 percent of human cancers, including high percentages of the common tumors of the lung, breast, and colon.

Since the oncogenes seem to be either identical or nearly identical to normal genes, and we are interested in what these oncogenes do to cause cancer, the question arises as to what are the normal functions of these genes. Preliminary studies showed that most of the oncogenes are highly conserved in evolution, with nearly identical normal genes occurring in species as different as man, fruit flies, and yeast. This suggests that these genes are more than 600 million years old, and that their normal activity is probably related to some very basic functions of living organisms.

Excitement over these discoveries increased last year when Dr. Steven F. Josephs and others at the Laboratory of Tumor Cell Biology at the National Cancer Institute in Bethesda, Md. reported that the protein product of the *sis* human oncogene is a normal growth-stimulating substance called platelet-derived growth factor, PDGF, which is secreted by the microscopic blood platelets when a clot forms in the area of a wound and which stimulates the growth and multiplication of connective tissue cells, fibroblasts—a key part of the healing process. The *sis* gene was originally discovered in simian sarcoma tumors.

Another oncogene, termed *erb*-B, was more recently found to produce a protein that is very similar to a growth stimulus receptor found on the surface of normal epithelial cells; this receptor responds to epithelial growth factor, EGF. There is evidence that this receptor is crucial in early stages of embryological development. Twenty-five percent of human brain tumors have increased amounts of receptor to EGF on their cell surfaces. These two examples suggest that oncogenes may act at various stages of the cascade of steps involved in growth control and modulation, with *sis* producing a growth-stimulating hormone-type substance and *erb*-B producing a growth hormone receptor that is situated on the surface of the target cell.

Treatment Strategies

The study of oncogenes may in the future open up new aspects of basic questions in the biology of growth and thereby suggest ways to control cancer as well as other diseases of aging; however, the current state of knowledge may be sufficient to make significant inroads directly. Each level of the above-referenced cascade effect is open to such intervention. At a November 1984 Symposium at the National Cancer Institute, Dr. David Baltimore suggested the following oncogene grouping scheme, which reflects the cascade approach.

First is a series of 11 oncogenes that are similar in nucleotide sequence to the *erb*-B oncogene and that may produce other growth hormone receptors located on the surface of cells.

Second is a series including the *ras* human oncogene, which appears to mediate between surface receptor activity and cytoplasmic cyclic AMP; that is, its protein product carries the activation signal into the cell.

Third is a series of nuclear-associated oncogenes typified by the *fos* oncogene, which may carry the activation into the cell nucleus. The *fos* gene is normally active in mouse placenta growth, which interestingly involves not only rapid cell proliferation but also active invasion of the uterine wall in the course of normal development.

The fourth class is represented by the *sis* gene, which directly produces a growth-stimulating substance.

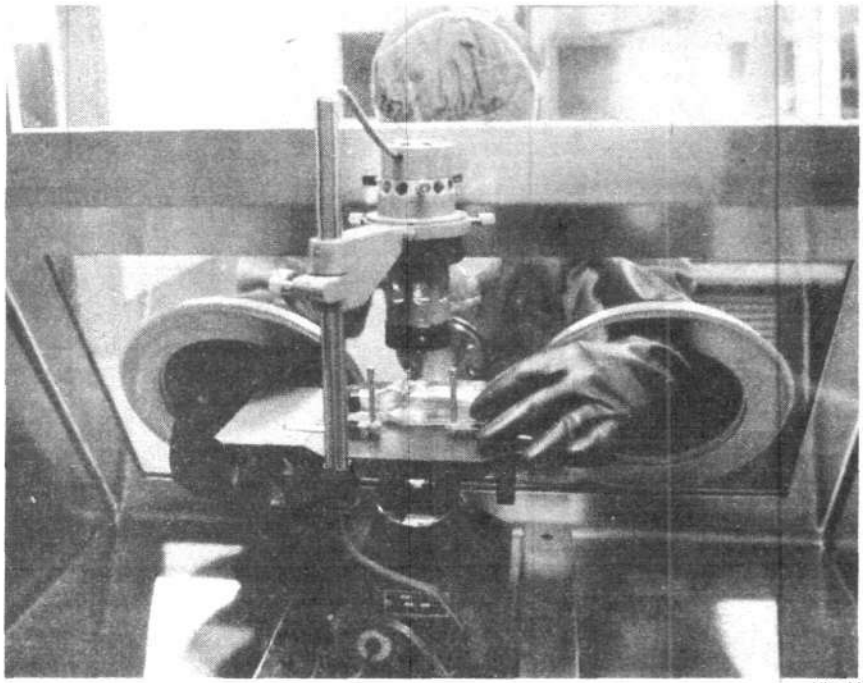
Oncogenes may be produced by several different modes. In Burkitt's lymphoma, a lymph-cell cancer, the *myc* oncogene is not itself changed, but its piece of chromosome is broken off and reattached to another chromosome, placing the gene very close to the DNA activator area which normally controls a gene for antibodies. It seems to be this mismatch that results in abnormal production of the *myc* protein product and the lymphoma. Interestingly, normal fibroblast cells that are stimulated by PDGF (which itself is the product of the oncogene *sis*), show an increase in the normal *myc* gene activity, again suggesting a regulatory cascade among classes of oncogenes.

There are numerous examples of pairs of oncogenes being needed to transform normal cells into cancer, and this is also consistent with the finding in long-range studies of human cancer that suggests that there are at least two steps involved, induction and promotion. In another case, the cells in Wilm's tumor, a virulent childhood cancer, frequently show the loss of a piece of chromosome near a known oncogene.

A second oncogene production mode is chemical carcinogen effects. The November symposium documented the discovery of two new oncogenes that were identified after exposing cells to known carcinogens. One of these, named *neu*, was isolated from a rat neuroblastoma tumor that had been induced by the carcinogen ethylnitroso urea. This oncogene is in the *erb*-B class.

A third mode is the viral effects, and here there can be either the insertion of a powerful viral promoter area near a normal animal or human gene, or the insertion of a variation of the animal or human gene from the virus. It is intriguing to speculate here that the virus does not "accidentally" pick up a copy of the oncogene in its self-replication in the cell and thereby spread it in an abnormal fashion, but that the incorporation of normal cell growth stimulators into the virus may itself be useful for the more rapid spread of the virus, by causing the abnormal proliferation of infected host cells. That is, what appears to us as viral-dependent oncogene activity may have arisen as part of an efficient mode of parasitism by the virus. This would, of course, be an aberrant activity of an otherwise normal or nearly normal growth-related gene.

While much remains to be learned about the functioning and production of oncogenes, the current discoveries are consistently pointing in the right direction, and the National Cancer Institute has responded by substantially upgrading the research funding for this area. In 1983, 3.7 percent or $36 million of the $1 billion budget was devoted to



Hitachi

New techniques in biotechnology have helped advance oncogene research. Here genetic engineering with bacteria, done with the protection of a safety cabinet.

pure oncogene work. This doubled to 8.4 percent in 1984 and will again double in 1985.

Specific Treatment Approaches

In the area of diagnosis, oncogenes are helping to assess tumor virulence. Oncogenes sometimes are copied multiple times in the same chromosome, and the degree of this gene amplification correlates with virulence in some tumors. Also, there are subtypes of some tumors based on the specific oncogene found; for example, in small cell lung carcinoma, 80 percent of tumors have active oncogene *myc*, but there are three distinct types of *myc* found in these tumors and this may correlate with response to specific therapies.

A further aid in diagnosis is the possibility of making specific antibodies to oncogenes or their protein products, attaching radioactive tracers to the antibodies, and using this complex to track down small cancers in the body that would not otherwise be found. The cancers can then be treated by either attaching toxins or powerful radiation emitters to the antibodies, or using some other available treatment such as surgery or direct radiation from outside the body.

Antibodies to specific oncogenes have already been shown to be useful in treating tumors. The specificity required to do this is considerable, but already monoclonal antibodies have been developed that can distinguish between the normal *ras* oncogene and its malignant variant, even though the difference between the two is only one amino acid in a protein containing hundreds of amino acids.

While the oncogene work points up the close connection of the cancer process to normal processes—and this may seem to imply that treatment will be even more difficult than previously assumed since cancer cells would have to be distinguished by any treatment modality—the specificity of monoclonal antibodies may weigh heavily in the other direction, particularly since oncogene research may help to pinpoint new targets for treatment intervention.

Another treatment difficulty in this work is that some of the oncogene products may be inside the cell and therefore not easily accessible to administered antibodies, since antibodies typically do not cross the cell membrane. However, the National Cancer Institute is now developing methods that have considerable promise for delivering the antibodies across the cell membrane.

Taking another line of attack, the *ras* oncogene is involved in cytoplasmic GTP activity (an analogue of ATP), and drugs that are analogues to GTP may be useful in interfering with this action.

As more is learned about the metabolic activities of these regulators, more targets for treatment will become evident. This is analogous to the action of antibiotics, which interfere selectively with normal bacterial cell functions, such as the production of the cell wall needed for bacteria to grow. As the examples of antibody usage suggest, the most efficient treatments and prevention strategies may ultimately be to induce the body's own immune system to more efficiently control the cancer process. There is much evidence that the immune system normally does this in many ways, and the increasing rate of cancer in the aged population correlates well with the decline of the immune system.

New Research Areas

A review of recent National Cancer Institute advances written by staffer Steve Weiss documents several new research areas that may dovetail with the oncogene work. A platelet-derived substance, transforming growth factor (TGF), causes a rapid proliferation of connective tissue cells (similar to the action of PDGF), and has now been used successfully to speed the healing of wounds in therapeutic situations. When placed on a laboratory culture of normal cells, TGF causes a rapid and uncontrolled proliferation that is similar to the behavior of transformed cancer cells. When the TGF is removed, the cells spontaneously revert back to normal growth patterns. Since this change is reversible, this may represent evidence that cancer is not necessarily caused by changes in genes.

The leukemia characterized by proliferation of the T-cell lymphocytes and caused by the virus HTLV-I (related to the HTLV-III which is involved in causing AIDS), is a fulminant disease that is usually fatal in three months. The T-cells are stimulated to proliferate by T-cell growth factor, and have T-cell growth factor (TCGF) receptors on their

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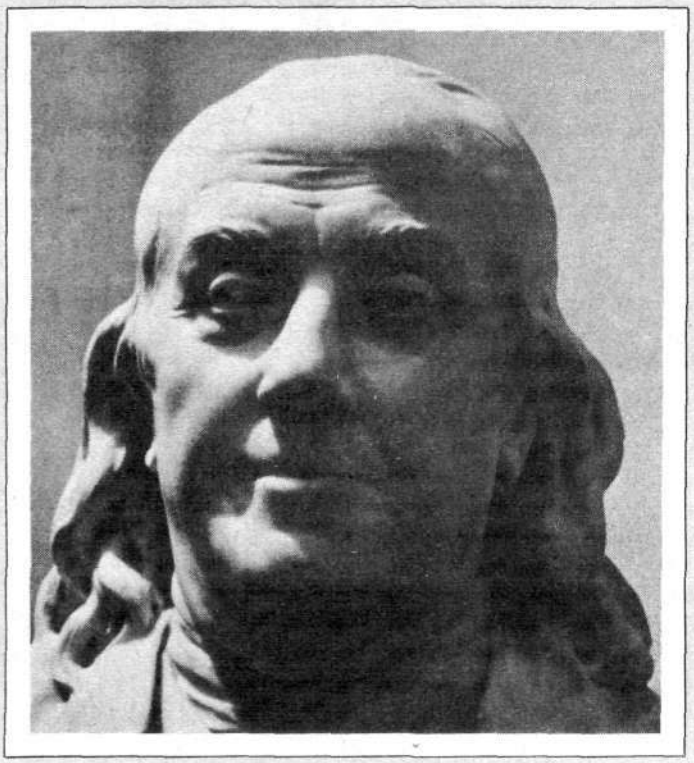
The Forgotten Origins of America's Scientific Tradition



Franklin, Leibniz, and The Göttingen School

by Warren J. Hamerman

To make a successful scientific-technological revolution, it is essential that American scientists rediscover their founding roots in the German classical scientific tradition of Kepler, Leibniz, Gauss, and the 19th-century Göttingen School culminating in Bernhard Riemann and Georg Cantor. Benjamin Franklin exemplifies this tradition in America.

Mediated through Benjamin Franklin's scientific discoveries, hypotheses, and institutions, the character of science in the New World was firmly established as a direct outgrowth of the magnificent scientific achievements of Gottfried Wilhelm Leibniz (1646-1716). The design of the American republic as a technology-vectored society dedicated to the idea of perpetuating progress was, in fact, Leibniz's grand conception. Leibniz, in the tradition of Cusa, Leonardo, Kepler, and Plato, pursued creative scientific study from the highest and most universal standpoint, acknowledging no fixed "borders" between the domains of knowledge. Thus, the methodological orientation of Leibniz and after him, Franklin—who still lived in an age that viewed basic scientific research as philosophy—was to reject any division between what later split into the natural sciences (*Naturwissenschaft*) and the so-called humanities (*Geisteswissenschaft*).

Today, although Americans still retain the capacity to respond to a large-scale crash technology-development program—like the space program or the beam defense program—with enthusiasm and cultural optimism, scientists and citizens alike suffer from a debilitating case of amnesia on the question of basic scientific method. Confronted with the necessity of making a series of fundamental scientific breakthroughs over the coming decades, scientists must now focus their attention away from the details of specialized knowledge and expertise, and grapple with the method for creative scientific discovery itself—the method of the *hypothesis of the higher hypothesis*; that is, the theory behind the formation of scientific hypotheses.[1]

Benjamin Franklin (1706-1790) exemplified this tradition. Franklin's extensive scientific works are permeated with the joy of hypothesis formation. The spirit of the method is captured in his ceaseless pursuit of hypotheses capable of generating "higher" hypotheses. For example, he wrote to his close collaborator in Britain, Joseph Priestley, Feb. 8, 1780: "I am glad my little Paper on the *Aurora Borealis* pleased. If it should occasion further *Enquiry*, and so produce a better Hypothesis, it will not be wholly useless. . . ." Franklin's hypotheses took him across every conceivable field of knowledge, from music and philology to astronomy and geology, mathematics, agriculture, medicine, basic physics, meteorology, oceanography, and chemistry.

The principal method of Franklin's scientific investigations is an approach traceable back to Leonardo da Vinci for an *electrohydrodynamic wave theory* to explain processes in the physical universe. Franklin's method immediately grew out of the work of Leibniz and his scientific collaborators like Christiaan Huygens, Jean and Nicholas Bernoulli and their students, and Franklin's contemporaries Leonard Euler and Daniel Bernoulli. The posing of the appropriate question for this approach is already explicit in Leonardo's notebook manuscripts, as his late 15th-century entry on the relationship of lightning and thunder demonstrates:

> Why the thunder lasts for a longer time than that which causes it; and why, immediately on its creation, the lightning becomes visible to the eye, while the thunder requires time to travel, *after the manner of a wave*, and makes the loudest noise when it meets with most resistance [emphasis added].

Thus it was not accidental that Franklin later based his scientific-political activities in the city of Paris, where Leibniz and Huygens had established their coordinating center for scientific research from the 1670s onward, the site with greatest probable access to Leonardo's *Notebooks*.

Despite the rich origins of American science in Leibniz's circle and the method of hypothesis, the American scientific community has been manipulated, tragically, to believe that its roots lie with the most bitter opponent of Leibniz, Sir Isaac Newton, the man whose very policy, *hypotheses non fingo est* (I don't form hypotheses), was proposed as the rival to the method of hypothesis. In fact, Benjamin Franklin's scientific research made him a public adversary of Leibniz's principal opponents on the question of basic scientific method—Newton, Descartes, and their followers. Furthermore, after he was educated by Leibniz's circle on the reductionist fallacies of John Locke, who championed an epistemology based on isolated empirical data and sense perceptions being collected on the blank screen of the mind, Franklin decisively repudiated Locke's mechanistic reductionism as well.

Franklin and Göttingen

Benjamin Franklin has been fraudulently disparaged as a second-rate figure in science. In reality, he was one of the leading members of the scientific community who made major contributions, as the Göttingen School later appreciated, to the advancement of science.

Leibniz's work had made a fundamental impact on Franklin much earlier in his formative intellectual development, in the 1720s (and even before), through the profound influence of the leading Leibnizian Jonathan Swift (1667-1745).[2] The depth of Franklin's own orientation to Leibniz and German classical science is indicated by the extraordinary tour Franklin made of Germany in summer 1766 when he visited the three major Leibnizian centers of activity—Hannover, Göttingen, and Mainz. Franklin's guides on his trip were none other than the two leading Leibnizian scholars alive who were then in the midst of a massive project to publish the scientific and philosophic papers of Leibniz for the first time, 50 years after Leibniz's death in 1716.

One of Franklin's guides in Germany was the Göttingen mathematician Abraham Gotthelf Kästner (1719-1800), himself a student of Johann Sebastian Bach in musical composition at the Thomas Church in Leipzig in 1737, and at the very end of his life one of the principal mathematics teach-

"The rapid Progress true *Science now makes occasions my regretting sometimes that I was born too soon. It is impossible to imagine the Height to which may be carried, in a thousand years, the Power of Man over Matter."*

Facing page, Jean-Antoine Houdon's 1778 bust of Benjamin Franklin, now in the Metropolitan Museum of Art in New York City.

Gottfried Wilhelm Leibniz (1646-1716), center, with his collaborator, the Dutch scientist Christiaan Huygens (1629-1695), right, and Leonard Euler (1707-1783), the Swiss mathematician who was part of the Leibnizian tradition in Franklin's day.

ers of Karl Friedrich Gauss (1777-1855). Franklin's other host was the geologist Rudolf Erich Raspe (1736-1794), the keeper of the Leibniz archives at the ducal library at Hannover where Leibniz had been based for the last 40 years of his life, from 1676 to 1716, as the librarian of the Royal Library in the service of three successive Brunswick family princes.

In fact, the year before Franklin's arrival in Germany, Raspe had published a volume of Leibniz's previously unpublished scientific manuscripts with a preface by Kästner. When Franklin visited Göttingen, Kästner was involved in editing the multivolume collected works of Leibniz, in close correspondence with Raspe. Just two years later, in 1768, their *Opera Omnia Leibnitii* was published in Geneva.

When Franklin toured Germany in 1766 he was already a leading member of the Scientific Society at Göttingen. During the decade before his trip, Franklin had developed much of the basic scientific vocabulary that the magnificent Göttingen School of Gauss, the Weber brothers, and Riemann later utilized as the jumping-off points for their breakthrough achievements in electrohydrodynamic wave theory. For instance, when Riemann was 27 years old in 1853, he described in a letter to his father how a new series of Göttingen experiments on a Franklin Leyden jar had stimulated the working out of his paper "On the Laws of Distribution of Potential Energy."

Eight years before Franklin toured Göttingen, his famous 1751 book, *Experiments and Observations on Electricity, Made at Philadelphia in America*, appeared in a Leipzig edition translated into German by the Swedish scientist Johan Carl Wilcke under the title *Des Herrn Benjamin Franklin Esq. Briefe von Der Electricität*. The book, also translated into French, Italian, and Latin, developed the basic conception that electricity, like all fundamental processes in the physical universe, was an action of *flowing*. It presented the fruits of Franklin's hypothesis for an *electrical fluid theory* and, in fact, contained the first use of the terms positive and negative electricity, plus and minus charge, electrical battery, electric fluid, electric shock, condenser, conductor, electrical discharge, and armature. In polemical contradistinction to both the Newtonian doctrine of a universe composed of discrete atomic particles colliding like billiard balls in empty space and the Cartesian "molasses" universe of pure extension, Franklin developed the experimental basis for the modern conception of electricity as a *fluid* or *current*. Thus, he opened the door for investigating the hydrodynamic basis for the accumulation of charge.

The hydrodynamic approach developed at Göttingen is responsible for the most important scientific discoveries of the 19th and 20th centuries. The great mathematician Karl Friedrich Gauss (1777-1855), along with Wilhelm Weber (1804-1891), developed at Göttingen the geometry and metrics for electrical and magnetic processes. In 1832, Gauss proposed a system of magnetic units using the millimeter, milligram, and second. Then in 1839, he defined *electric potential* at a given point in the electrostatic system as the *work* required to move a unit charge of *energy* from infinity to that point. By looking at the process on the total surface, Gauss provided a method to understand the charge within a local region; in other words, the entire geometric surface of the field is potentially involved in determining the charge at any given local point. Further, the "development" of the charge at any local point contributes to determining the character of the entire surface of the field in the next instant of time. Gauss developed the conception of *electric flux density*, a notion that provides a basis for measuring the *flow of energy* over an area. He also developed a mathematical approach for describing the overall electric intensity of a closed surface.

Weber, beginning in 1840, took Gauss's standard units of millimeter, milligram, and second, and applied them as units in the electromagnetic system.

The crowning achievement of the Göttingen tradition's work was Bernhard Riemann's mid-19th-century geometrical research into the nature of *shock waves* and the conceptualization of *retarded potential* through a unified electrohydrodynamic approach to light, heat, and magnetism. In

the late 1850s, Riemann and Weber in Göttingen, in collaboration with E. Betti and E. Beltrani in Pisa, developed a fully elaborated series of hypotheses on the geometric nature of electrical current flow. In 1858, Riemann submitted "A Contribution to Electrodynamics" to the Royal Society of Sciences at Göttingen, wherein he pursued the mathematical approach of bringing "the theory of electricity and of magnetism into close coherence with the theories of light and radiating heat."[3]

The University of Göttingen produced the great German scientists of the 19th century, all in the Leibniz hydrodynamic tradition. Here, a statue of the mathematician Karl Friedrich Gauss, (1777-1855), seated, and Wilhelm Weber (1804-1891). Inset, Bernhard Riemann (1826-1866).

Franklin's Electrohydrodynamic Theory

Franklin's coherent fluid theory of electricity replaced the then-prevalent "dual substance" theories of two followers of René Descartes, Charles Francois de Cisternay Dufay and the Jesuit Abbé J. A. Nollet. The Cartesians believed that any "electrified" body was surrounded by a "subtle, material effluvium" in whirling vortex motion. Within the "effluvium" they posited "two different component substances." In the words of Dufay: "This principle is that there are two distinct electricities, very different from each other: One of these I call *vitreous electricity*; the other, *resinous electricity*."

Abbé Nollet (1700-1770) attributed electricity to the movement in two opposite directions of two substances—an effluent and an affluent stream. In this theory, the "friction" between the particles in the two streams causes electricity.

In contradistinction to the "dual substance" theory, Franklin returned to the experimental approach of William Gilbert, a Platonist whose *De Magnete* was published in England in 1600. Viewing the Earth as a giant magnet, Gilbert had developed basic experiments to explore the nature of the magnetic field, polarity, induction, and the relationship between temperature, electricity, and magnetism. He systematized a long list of materials that could be electrified and designed an electroscope for demonstrating the electrical force involved in "charge."

In a letter to his botanist friend Peter Collinson May 25, 1747, Franklin presented his new hypothesis, which for the first time in scientific history drew a distinction between *positive* and *negative* electrical excitement. Later that summer (July 28, 1747) he sent Collinson a report on his discovery that the electrified Leyden jar becomes positively charged on the outside, and negative on the inside. Franklin drew the conclusion that electricity was not created by friction but was rather a "current" added to or taken from the glass by rubbing. As the Leyden jar became charged, one side took the polar opposite charge of the other, but the total quantity of electricity remained constant, with the glass being the dielectric. He also showed that a circuit could run without a shock, spark, or explosion of current. In 1749, Franklin advanced his famous electrical fluid hypothesis in a paper titled "Opinions and Conjectures, Concerning the Properties and Effects of Electrical Matter. . . ."

Franklin's fluid flow approach to electricity allowed him the insights to become the first scientist to prove that an electrical spark produced heat; he measured the increase in temperature produced by a spark discharge across the gap of a Leyden jar. Furthermore, he not only demonstrated that the "electrical fluid" could be *transformed* from energy into work, but that electricity could be a source of *power* able to qualitatively upgrade the economic output of human society. In 1751, he wrote to his close associate in Boston, Cadwallader Colden, about the infinite possibilities for electricity as a power source for upgrading the productivity of the human economy: "There are no bounds (but what expense and labor give) to the force man may raise and use in the electrical way."

Franklin's approach matured directly from the scientific outlook of Leibniz. Through technology, which organizes energy upon a qualitatively higher basis in order to perform useful work for society, the power of labor is qualitatively transformed. In the 17th century, Leibniz had recognized that if the "power source" could be upgraded from water

or wind to steam, one man had the power to accomplish the work of 100 of his predecessors.[4] The essence of the Leibnizian concept of technology, underlying Benjamin Franklin's world view, is that technology establishes an expanding "power relationship" between the amount of energy expended and the amount of work accomplished. Leibniz was directly involved in promoting Denis Papin's discovery of the steam engine, and, in fact, he proposed a self-regulating mechanism for the reuse of the steam in Papin's engine.

Franklin took the question of the power source a step further, with his inventions of the "electric motor" and "battery." In his writings on the electric motor as well as on lightning, it is clear that he had a conception of concentrating energy for the purpose of accomplishing work. This notion of energy flux density is implicit throughout many of Franklin's pursuits.

Franklin invented the term "electrostatics" to describe the fact that when a condenser (a Leyden jar) is charged, an equal but oppositely signed charge accumulates on each plate. The Leyden jar, when grounded, allowed charge to be accumulated. Franklin therefore came up with the idea to construct what he called a battery of Leyden jars in order to concentrate a large charge by connecting the jars to one another in series, instead of grounding each one separately. This made use of the dynamic current flow of electricity, and also allowed him to set up experiments exploring the nature of electrical resistance.

Franklin not only invented the electrical battery, but in September 1752 he succeeded in ringing an alarm bell with electricity captured from a storm via a lightning rod. In 1748, Franklin had designed an electrostatic jack, or motor. Franklin explained his demonstration of the fundamental nature of rotational action for transforming energy into work in his Letter IV to Peter Collinson, April 29, 1749:

> On the principle . . . that hooks of bottles, differently charged, will attract and repel differently, is made an electrical wheel, that turns with considerable strength. A small upright shaft of wood passes at right angles through a thin round board, of about twelve inches diameter, and turns on a sharp point of iron, fixed in the lower end, while a strong wire in the upper end, passing through a small hole in a thin brass plate, keeps the shaft truly vertical. About thirty *radii* of equal length, made of sash glass, cut in narrow strips, issue horizontally from the circumference of the board, the ends most distant from the center, being about four inches apart. On the end of every one, a brass thimble is fixed. If now the wire of a bottle electrified in the common way, be brought near the circumference of this wheel, it will attract the nearest thimble, and so put the wheel in motion; that thimble, in passing by, receives a spark, and thereby being electrified is repelled, and so driven forwards; while a second being attracted, approaches the wire, receives a spark, and is driven after the first, and so on until the wheel has gone once round, when the thimbles before electrified approaching the wire, instead of being attracted as they were at first, are repelled, and the motion presently ceases.
>
> But if another bottle, which had been charged through the coating, be placed near the same wheel, its wire will attract the thimble repelled by the first, and thereby double the force that carries the wheel round; and not only taking out the fire that had been communicated to the thimbles by the first bottle, but even robbing them of their natural quantity, instead of being repelled when they came again towards the first bottle, they are more strongly attracted, so that the wheel mends its pace, till it goes with great rapidity twelve or fifteen rounds in a minute, and with such strength, as that the weight of one hundred Spanish dollars with which we once loaded it, did not seem in the least to retard its motion.
>
> This is called an electrical jack; and if a large fowl were spitted on the upright shaft, it would be carried round before a fire with a motion fit for roasting. But this wheel, like those driven by wind, water, or weights, moves by a foreign force, to wit, that of the bottles.

Franklin goes on to describe a "self-moving wheel" constructed on the same principles. In experimental form, Franklin's work paralleled Leonard Euler's geometrical studies of motion and momentum in rotating systems.

Lightning and Shock Waves

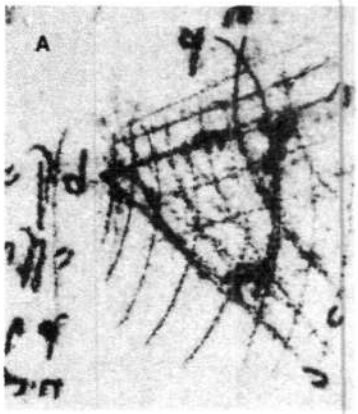
In a series of beautiful experiments, Franklin also demonstrated that electricity, light, heat, sound, and magnetism are part of a coherent physical process; namely, that electrical sparks generate heat and that electrically charged and coherently organized beams of light energy (lightning) generate sonic shock waves (thunder).

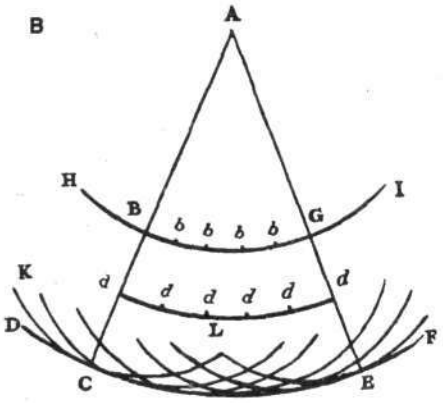
How did Franklin understand the scientific principles underlying his experiments? In his extraordinary "Letter XXIV" from Paris in September 1767, the year after his tour of the Leibnizian centers in Germany, he summarized the results of his research:

> Experiments made in electricity first gave philosophers a suspicion that the matter of lightning was the same with the electric matter. Experiments afterwards made on lightning obtained from the clouds by pointed rods, received into bottles, and subjected to every trial, have since proved this suspicion to be perfectly well founded; and that whatever properties we find in electricity, are also the properties of lightning. This matter of lightning, or of electricity, is an extreme subtle fluid, penetrating other bodies, and subsisting in them, equally diffused. When by any operation of art or nature, there happens to be a greater proportion of this fluid in one body than in another, the body which has most, will communicate to that which has least, till the proportion becomes equal; provided the distance between them be not too great; or, if it is too great, till there be proper conductors to convey it from one to the other. If the communication be through the air without any conductor, a bright light is seen between the bodies, and a sound is heard. In our small experiments we call this light and sound the electric spark and snap; but in the great operations of nature, the light is what we call lightning, and the sound (produced at the same time, though generally arriving later at our

HYDRODYNAMIC WAVE THEORY

The hydrodynamic approach of the Leibnizians had its roots in the work of Leonard da Vinci, whose 1504 drawing of a developing wave front is shown at right (a). It is remarkably similar to a sketch by Leibniz's collaborator Christiaan Huygens, who in 1673 described the principle of wave front formation (b). Nearly a century later, Franklin developed this hydrodynamic approach in his study of electricity and other phenomena, in opposition to the prevailing Newtonian notion of point masses.





Below is Franklin's portrayal of the global thermohydrodynamic process responsible for weather patterns, involving the Sun's heat, the atmosphere, evaporation from the oceans, and the energizing motion of winds. Franklin's work on the weather overturned the arcane theory of Descartes, who believed that the clouds falling on top of each other caused thunder that produced the weather movements. Franklin's drawing (c) shows a whirlwind at sea, where a column of warm air forced upward by the cool heavier air from the surrounding region.

ears than the light does to our eyes) is, with its echoes, called thunder. . . .

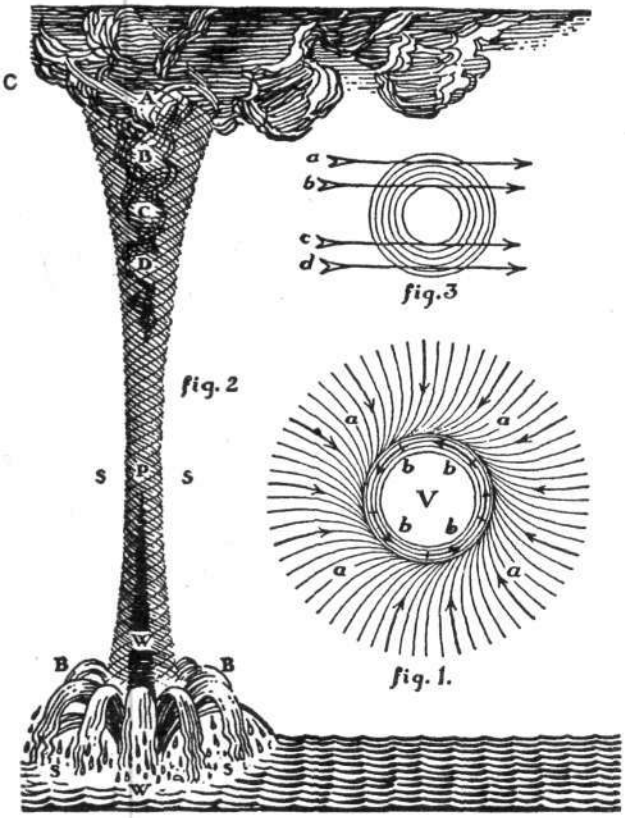
Franklin's famous kite experiment of June 1752 in Philadelphia not only demonstrated that lightning was an electrical discharge, but also that it could be harnessed by man in charging a Leyden jar. In the course of other experiments—observing the shapes of fields surrounding electrified bodies suspended in air and made visible with smoke from rosin—Franklin investigated the patterns and geometry of the electrical field surrounding a charged body.

Franklin's research into this subject through his lightning experiments is well known. Franklin developed the basic conception that lightning is an electrical discharge or spark between two clouds of opposite charge, or between a cloud and the Earth, or between two sections of a cloud. Such a large energy potential difference is established that electrical energy is transformed into light energy (lightning) and generates a sonic shock wave (thunder).

Franklin's conceptual understanding of the nature of lightning was summarized in his notebook entry Nov. 7, 1749:

> Electrical fluid agrees with lightning in these particulars: (1) giving light; (2) color of the light; (3) crooked direction; (4) swift motion; (5) being conducted by metals; (6) crack or noise in exploding; (7) subsisting in water or ice; (8) rending bodies it passes through; (9) destroying animals; (10) melting metals; (11) firing inflammable substances; (12) sulfurous smell. The electric fluid is attracted by points; we do not know whether this property is in lightning. But since they agree in all the particulars wherein we can already compare them, is it not probable they agree likewise in this? Let the experiment be made.

Franklin developed the conception of the large-scale separation of electric charge (positive and negative) within a



thunderstorm. As the Sun warms the Earth, a natural convection of warm air transports the heated moisture-laden air upwards. As the air expands and rises, it begins to cool until water begins condensing out of the moist air. The heat of vaporization given off by the condensing water drives the atmospheric "engine" even faster. As the process continues, heavy drops of rain fall and cool the air currents. In other words, a downdraft of cold air is generated. Within the thundercloud itself, an intense electrical current flows

for a few microseconds between positive and negative areas. The path of lightning discharge, an energy-enhanced beam of light, can travel up to 2 miles. The current, generating intense heat, expands the air in its vicinity extremely rapidly, thereby causing a shock wave or thunderclap.

Franklin Versus Newton's Point Masses

Approaching the question of light propagating in space from the standpoint of Leibniz and Huygens, Franklin totally rejected the theory of Newton that light was composed of point masses (little hard balls) moving in certain patterns. Leibniz and Huygens had both vigorously opposed the incoherence in Newton's theory, which incoherence is still embedded as a working assumption in much of quantum physics today. The hydrodynamic approach of Leibniz's School opposed any absolute discontinuity between particles and waves. Instead, scientific attention focused on the process of self-ordering in a flowing action, as is also appropriate for plasma physics today.

Given Franklin's explicit attacks on Newton's well-known theory, it was no mere coincidence that the Royal Society in London tried to suppress his influence. Franklin reported that Collinson had his papers "read in the Royal Society, where they were not at first thought worth so much notice as to be printed in their Transactions." In his *Autobiography*, Franklin noted, "One paper, which I wrote for Mr. Kinnersley, on the sameness of lightning with electricity, I sent to Dr. Mitchel, an acquaintance of mine, and one of the members also of that society [the Royal Society], who wrote me word that it had been read, but was laughed at by the connoisseurs."

In his 16th letter from Philadelphia, April 23, 1752, to Cadwallader Colden (read at the Royal Society on Nov. 11, 1756), Franklin wrote:

> I am not satisfied with the doctrine that supposes particles of matter, called light, continually driven off from the sun's surface, with a swiftness so prodigious! Must not the smallest particle conceivable, have with such a motion, a force exceeding that of a twenty-four pounder, discharged from a cannon? Must not the sun diminish exceedingly by such a waste of matter; and the planets, instead of drawing nearer to him, as some have feared, recede to greater distances through the lessened attraction. Yet these particles, with this amazing motion, will not drive before them, or remove, the least and lightest dust they meet with: And the sun, for aught we know, continues of his antient [sic] dimensions, and his attendants move in their antient orbits.

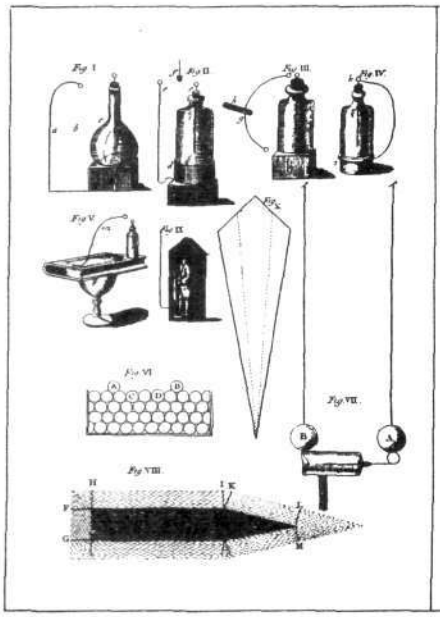
Franklin continues in a direct summary of Leibniz and Huygens' approach:

> May not all the phaenomena of light be more conveniently solved, by supposing universal space filled with a subtile elastic fluid, which, when at rest, is not visible, but whose vibrations affect that fine sense in the eye, as those of air do the grosser organs of the ear? We do not, in the case of sound, imagine that any sonorous particles are thrown off from a bell, for instance, and fly in strait lines to the ear; why must we believe that luminous particles leave the sun and proceed to the eye? Some diamonds, if rubbed, shine in the dark, without losing any part of their matter. I can make an electrical spark as big as the flame of a candle, much brighter, and, therefore, visible further; yet this is without fuel; and, I am persuaded, no part of the electrical fluid flies off in such case, to distant places, but all goes directly, and is to be found in the place to which I destine it. May not different degrees of the vibration of the above-mentioned universal medium, occasion the appearances of different colours? I think the electric fluid is always the same; yet I find that weaker and stronger sparks differ in apparent colour,

ELECTRICITY AS A FLUID

Facsimile of the title page of the fifth English edition of Franklin's book on electricity, along with a plate of the original illustrations.

Franklin's Fig. VII (at right) shows two balls suspended by silk threads from the ceiling. He wrote: "Apply the wire of a well-charged vial, held in your hand, to one of them, and it will receive from the wire a quantity of the electrical fluid; but will not imbibe it, being already full. The fluid therefore will flow round its surface, and form an electrical atmosphere. Bring A into contact with B, and half the electrical fluid is communicated, so that each has now an electrical atmosphere, and therefore they repel each other. . . ."



EXPERIMENTS
AND
OBSERVATIONS
ON
ELECTRICITY,
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PHILADELPHIA IN AMERICA,
BY
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some white, blue, purple, red; the strongest, white; weak ones red. Thus different degrees of vibration given to the air, produce the seven colours, yet the medium, air, is the same. . . .

Franklin closes his letter with an admission that what he has propounded are explicit "heretical" theories against the "orthodox doctrine" of Sir Isaac Newton:

It is well we are not, as poor Galileo was, subject to the Inquisition for Philosophical Heresy. My whispers against the orthodox doctrine, in private letters, would be dangerous; but your writing and printing would be highly criminal. As it is, you must expect some censure, but one Heretic will surely excuse another.

The Newtonian inquisition at the Royal Society was up against more than an attack from its American colonial flank. In the same year as Franklin's 16th letter, Leibniz's leading mathematical follower, Leonard Euler, published a scientific memorandum against Newton's theory of light, "Nova Theoria Lucis et Colorum," in the Berlin journal *Acta*.

In 1730, Euler (1707-1783) had become a professor of physics at the Leibnizian Academy of Sciences in St. Petersburg, Russia. Three years later, he succeeded Daniel Bernoulli in the chair of mathematics. Daniel, his brother Nicholas, and their father, Jean Bernoulli—himself a scientific collaborator of Leibniz—were the leading Leibnizian standard-bearers in geometry and physics after Leibniz's death in 1716. In his 1752 paper, Euler, in exactly the same fashion as Franklin, countered Newton's theory of light on the grounds that the Sun is not diminished by the "copious emission of material particles," lest the entire motion of planets and comets be totally disturbed. Twenty years later, Franklin's close scientific colleague and follower Joseph Priestley renewed Euler and Franklin's joint attack on Newton's theory of light in his 1772 work, "The History and Present State of Discoveries Relating to Vision, Light, and Colours."

The Newtonians Counterattack

The official Newtonian assault on Franklin began in 1766, three years after Priestley, at the suggestion of Franklin, published his book *The History and Present State of Electricity with Original Experiments*. Priestley's written evaluation, was put forward with a certain biting irony. It was "remarkable," he wrote, that Franklin's conception of the electrical fluid "should so much resemble the ether of Sir Isaac Newton in some respects, and yet differ from it so essentially in others."

After the circulation of Priestley's "History" and the publication of a widely promoted new fourth edition in English of Franklin's work, expanded and with notes, the standard-bearer of the Newtonian establishment, Bishop Horsley, openly attacked Franklin in an article in "Philosophic Transactions." This official Newtonian "authority," the editor of the only major collection of Newton's writings, titled his anti-Franklin article "Difficulties in the Newtonian Theory of Light, Considered and Removed." Horsley pompously asserted:

Dr. Franklin's first question is answered. A particle of matter, which is probably larger than any particle of light, moving with the velocity of light, has a force of motion, which, instead of exceeding the force of a twenty-four pounder discharged from a cannon, is infinitely less than that of the smallest shot dischargd from a pocket pistol, or less than any that art can create.

Franklin's lifelong war on the question of scientific method with the empiricist Newtonian faction in the hierarchy at the Royal Society in London came to a head in 1777. An anonymous Newtonian of the Royal Society published an open "Letter to Benjamin Franklin, LL.D., Fellow of the Royal Society: In Which his Pretensions to the Title of Natural Philosopher Are Considered." The vicious attack on Franklin, printed as a 25-page pamphlet in London, adopted a condescending tone toward the "self-taught American" who is not capable of "understanding Newtonian mathematics." The pamphlet lambasts Franklin for his too-great influence in organizing against Newton, and states frankly that it is trying to stop the vast popularity of Franklin's scientific works in England and America, precisely because they contained specific anti-Newtonian heresies. How venomous the Newtonians were can be seen in the following excerpts from the article:

O the vanity of human conceits! O philosophy, to what a phantom art thou reduced! O Newton, if any sublunary thing be worth thy notice, how must thou lament to see this nation gazing, with admiration, at Electricians feasting on turkeys killed by electrical shocks, and styling themselves Natural Philosophers, and their feasts philosophical banquets!. . .

If you had prepared yourself, by a proper course of mathematical study, for understanding Newton's reasoning, an attentive observation of the views he evidently had in making his experiments, must soon convince you, that your experiments were by no means calculated to establish Electricity as a philosophical principle. Any one may be convinced of this, who attends to Gravity, considered as a philosophical principle, and takes but a cursory view of the use to which Newton has applied it. . . .

It is so disagreeable to me to find fault, that I have endeavoured to keep your writings as much out of my sight as was in any measure consistent with my plan: This is the reason why I have dealt so much in generals, without references to particular passages of your book: but it will no doubt be expected, before I conclude, that I should give some specimen of your method of reasoning, expressed in your own words. Some people would pitch upon the most absurd parts of your writings for this purpose; those, where you are very much in the dark about light, and under terrible apprehensions lest the Sun should be burnt out, unless the Newtonian Theory of Light be overturned. . . .

As you are one of those self-taught philosophers, I am sufficiently sensible of the disadvantages which I labour under, in attempting to call in question your pretensions to the title of Natural Philosopher. . . .

Franklin's Concept of the Weather Cycle

In terms of fundamental scientific method, the Jesuit René Descartes did not represent any better alternative to the reductionist Newton, as Leibniz had so systematically proven. Not only was Franklin's approach to electricity developed in polemical opposition to the "dual substance friction theory" of Descartes's followers, but with respect to understanding the weather, Franklin's approach went directly counter to Decartes's then-hegemonic arcane theory. Descartes had published his "Meteorology," along with his "Optics" and "Geometry," as one of the three scientific essays accompanying his 1637 "Discourse on the Method for Rightly Directing One's Reason and Searching for Truth in the Sciences."

Franklin originated the conception of studying weather as a large-scale flowing energy cycle. The basis of the cycle was that air, warmed by the Sun, was forced upward by the cool, heavier air from the surrounding region. The movement of the air "currents" provided the energy for changing weather patterns. The essence of Franklin's approach was to conceptualize large-scale processes of the Earth and its atmosphere—air and sea currents, heating from the Sun, and so forth—as the interrelated aspects of one giant flowing "engine."

Franklin's classic hydrodynamic insight on large-scale weather patterns developed in the form of explaining his discovery of the origin of Northeast storms, as he wrote in a Feb. 13, 1749 letter to Jared Eliot from Philadelphia:

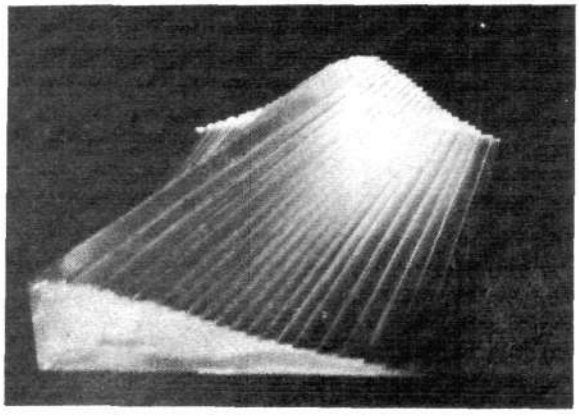
> You desire to know my Thoughts about the N.E. Storms beginning to Leeward. . . . As to the Reason of this, I can only give you my Conjectures. Suppose a great Tract of Country, Land and Sea, to wit Florida and the Bay of Mexico, to have clear Weather for several Days, and to be heated by the Sun and its Air thereby exceedingly rarefied; Suppose the Country North Eastward, As Pennsilvania, New England, Nova Scotia, Newfoundland, &c. to be at the same time cover'd with Clouds, and its Air chill'd and condens'd. The rarefied Air being lighter must rise, and the Dense Air next to it will press into its Place; that will be follow'd by the next denser Air, that by the next, and so on. Thus when I have a Fire in my Chimney, there is a Current of Air constantly flowing from the Door to the Chimney; but the beginning of the Motion was at the Chimney, where the air being rarefied by the Fire, rising, its Place was supply'd by the cooler Air that was next to it, and the Place of that by the next, and so on to the Door. So the

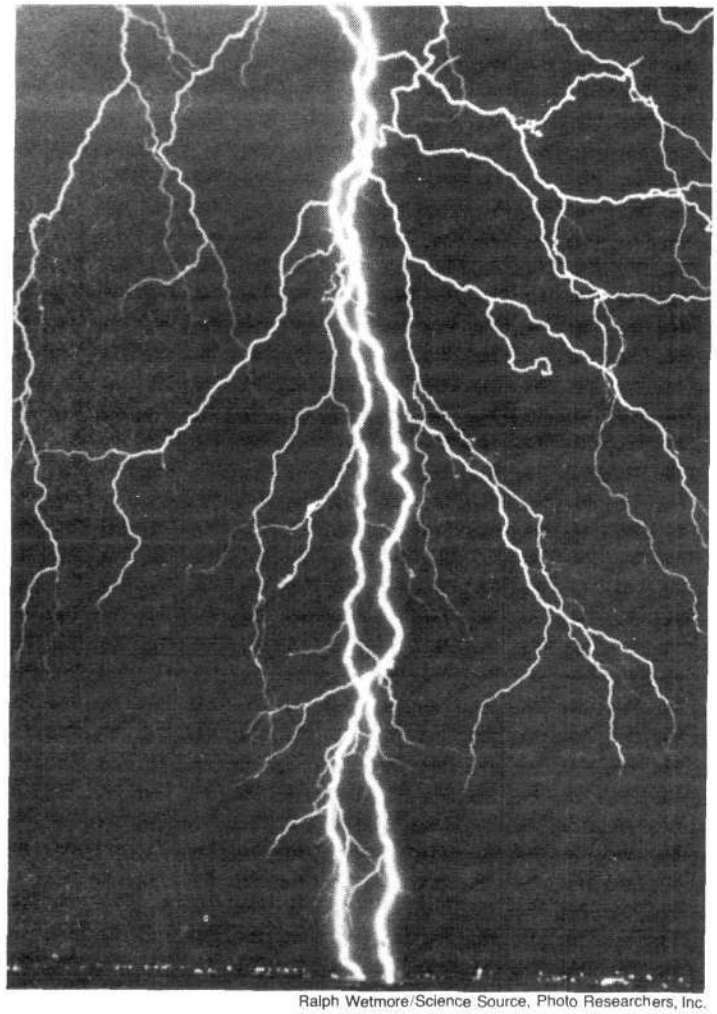
LIGHTNING AND SHOCKWAVES

Franklin demonstrated that electricity, light, heat, sound, and magnetism are part of a coherent physical process; namely, that electrical sparks generate heat and that electrically charged and coherently organized beams of light energy (lightning) generate sonic shock waves (thunder).

He wrote of his experiments on lightning and electricity, "In our small experiments we call this light and sound the electric spark and snap; but in the great operations of nature, the light is what we call lightning, *and the sound (produced at the same time, though generally arriving later at our ears than the light does to our eyes) is, with its echoes, called* thunder.

Below is a model in plastic of a Bernhard Riemann's 1859 wave theory of the way in which sonic booms could be generated. Right: Lightning over Tucson, Ariz.





Ralph Wetmore/Science Source, Photo Researchers, Inc.

> Water in a long Sluice or Mill Race, being stop'd by a Gate, is at Rest like the Air in a Calm; but as soon as you open the Gate at one end to let it out, the Water next the Gate begins first to move, that which is next to it follows; and so tho' the Water proceeds forward to the Gate, the Motion which began there runs backwards, if one may so speak, to the Upper End of the Race, where the Water is last in Motion. We have on this Continent a long Ridge of Mountains running from N east to S west; and the Coast runs the same Course. These may, perhaps, contribute towards the Direction [of the winds or at least influence] them in some Degree, [missing]. If these Conjectures do not [satisfy you, I wish] to have yours on the Subject.

Franklin's conception of studying large-scale weather phenomena from a hydrodynamic wave standpoint directly countered the "friction theory" elaborated in an involuted fashion in Descartes's "Meteorology." Descartes believed that the atmosphere was "composed of many small particles of various shapes and sizes, which are never so well arranged, nor so exactly joined together, that there do not remain many spaces around them," as he wrote in his "First Discourse" on "Meteorology":

> And I assume that these spaces are not empty, but are filled with that very fine material by means of which . . . the action of light is communicated. Then, in particular, I assume that the small particles of which water is composed are long, smooth, and slippery, like little eels, which are such that however they join and interlace, they are never thereby so knotted or hooked together that they cannot easily be separated; and on the other hand, I assume that nearly all particles of earth, as well as of air and most other bodies, have very irregular and rough shapes, so that they need be only slightly intertwined in order to become hooked and bound to each other, as are the various branches of bushes that grow together in a hedgerow. . . ."

Obviously, all "motion" in Descartes's overpopulated and densely packed universe generated friction. He advocated that it was a higher cloud falling down hard on a lower one that made the "sound" of thunder.

The Leibnizian Circle

The fundamental scientific polemics against both René Descartes and Sir Isaac Newton had been developed by Leibniz in the generation immediately before Franklin. Franklin had been introduced to the work of Leibniz at least in part through James Logan of Philadelphia.[5] Logan, who had established one of the best scientific libraries in the colonies, was one of the intellectual influences on Franklin and his circle of associates and was a staunch epistemological opponent of Thomas Hobbes, John Locke, and Isaac Newton. In terms of the controversial scientific issue of the day—whether Newton or Leibniz had first discovered the differential calculus—Logan unambiguously sided with Leibniz. "Tis certain the World was obliged only to Leibniz for the Publication of that method," Logan wrote.

The Study of Lightning Today

Today the subject of lightning and its associated shock-wave formation has significant implications for the beam defense program and plasma physics. In particular, the phenomena of ball lightning and bead lightning have been intensively studied in the West and in the Soviet Union.

Ball lightning is a luminous sphere the size of a grapefruit or orange with a lifetime of a few seconds. It is characterized by electron densities like those of a very high density plasma. The balls can pass through glass or other materials and travel on totally unpredictable bumblebee-type paths. Then, after less than 5 seconds they "decay" either silently or explosively. Ball lightning theories attribute the energy source either to an "external" or "internal" power source.

In bead lightning, the channel inside the lightning stroke breaks up into luminous fragments of about 10 meters each in length. It has been hypothesized that the breakup is similar to the pinch-effect instabilities that occur in high-energy plasmas.

Generally, lightning is observed as a high-current transient electric discharge—often branched—whose path length is measured in kilometers. The energy per unit length delivered to a lightning stroke has been calculated to be in the range of 10^5 joules per meter. The shock-wave phase of expansion lasts from 5 to 10 picoseconds. Using spectroscopic techniques, the temperature in the shock-wave phase has been measured to reach 30,000 degrees Kelvin. Various researchers have measured the energy radiated in the range of an average 500 to 900 joules per meter, thereby providing an energy radiated to energy input ratio of 0.007.

Using lightning spectroscopy, lightning temperatures and particle densities and pressures have been precisely measured. The light (radiation) is decomposed through "slit" and "slitless" instruments into various wavelengths and then analyzed and precisely recorded. As early as 1926, spectral data were compiled for wavelengths of 2,860 to 6,550 angstroms, including the first ultraviolet data. Between 1940 and 1960, spectral features were identified in wavelengths ranging from 2,800 to 9,100 angstroms, and more recent data extend the range to 11,000 angstroms.

Although direct evidence has not been discovered, to my knowledge, I strongly suspect that, before he wrote his 1752 letter on light as a wave, Franklin may have seen at least portions of the 1715-1716 Leibniz-Clarke correspondence with Leibniz's polemic that the universe does not conform to the "running down" of a clock, as Newton's theory proposes.

Leibniz had established an international network of scientific academies and correspondence circles, which served as a model for the Leibnizians in the American colonies. In

1700, Leibniz founded the Berlin *Akademie der Wissenschaften*, and in 1712, he gave Peter the Great a plan for a scientific academy at St. Petersburg, which was founded after the Czar's death. Between 1711 and 1714, he battled against Jesuit opposition to attempt to establish an academy in Vienna. The founding of Leibnizian institutions *de novo* was an attempt to outflank the Newtonian Inquisition, which had succeeded in pulling a coup at the Royal Society in London.

In autumn 1727, Franklin formed a modest American scientific association when, as he put it, he "united the majority of well-informed persons of my acquaintance into a club which was called the Junto." Sample discussion topics at the weekly meetings were "Is sound an entity or a body?" and "How may the phenomena of vapours be explained?" Franklin's Junto was the second scientific society in America. In 1681, Increase Mather had organized a group of men dedicated to "adding to the store of natural history." Franklin's personal debt to Cotton and Increase Mather is documented in a letter he wrote to Increase's son Samuel, May 12, 1784:

> When I was a boy, I met with a book, entitled "Essays to Do Good," which I think was written by your father. It had been so little regarded by a former possessor, that several leaves of it were torn out; but the remainder gave me such a turn of thinking, as to have an influence on my conduct through life; for I have always set a greater value on the character of the doer of good, than on any other kind of reputation; and if I have been, as you seem to think, a useful citizen, the public owes the advantage of it to that book."

The essence of Plato's notion of the Good, transmitted to Franklin by the Mathers and Leibniz, is encapsulated in the scientific spirit underlying his philosophic association, the Junto. Four years after Franklin's last meeting with Cotton Mather in 1724 he composed his Junto "Rules for a Club Established for Mutual Improvement," which began:

> Previous Question, To Be Answered At Every Meeting: "Have you read over these queries this morning in order to consider what you might have to offer the Junto touching any one of them?" viz. 1. Have you met anything in the author you last read, remarkable, or suitable to be communicated to the Junto? particularly in history, morality, poetry, physic, travels, mechanic arts, or other parts of knowledge. . . .
>
> Any person to be qualified [as a member of the Junto], to stand up, and lay his hand upon his breast, and be asked these questions, viz. 1. Have you any particular disrespect to any present members? Answer. I have not. 2. Do you sincerely declare, that you love mankind in general, of what profession or religion soever? Answer. I do. 3. Do you think any person ought to be harmed in his body, name or goods, for mere speculative opinions, or his external way of worship? Answer. No. 4. Do you love truth for truth's sake, and will you endeavor impartially to find and receive it yourself, and communicate it to others? Answer. Yes.

In 1731, Franklin and some of his Junto associates formed a subscription library, The Library Company of Philadelphia. The library's London agent was the botanist Peter Collinson (1694-1768), who later sent Franklin the various instruments for beginning his electrical experiments in the mid-1740s. Among the first order of books in 1732, The Library Company requisitioned works of conic sections, Euclid, astronomy, a five-volume mathematics history, Puffendorf's *Laws*, and various histories of philosophy and natural science.

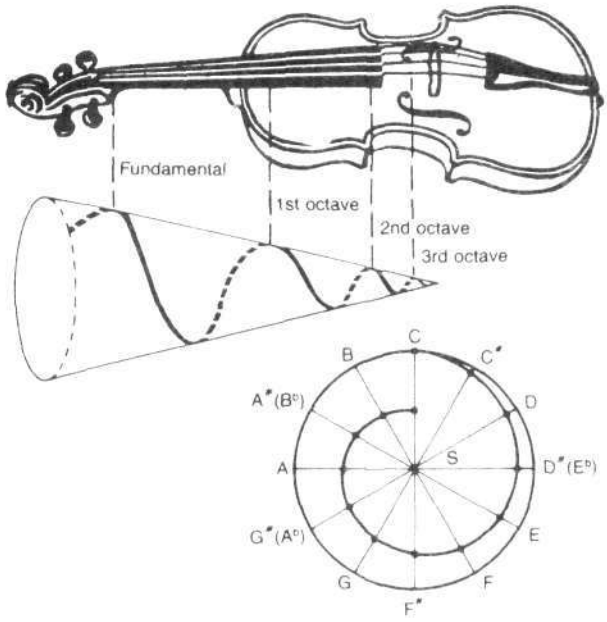
Later, in 1743, Franklin organized a more enduring Leibnizian association, the American Philosophical Society, after printing and circulating a founding program titled "A Proposal for Promoting Useful Knowledge Among the British Plantations in America."

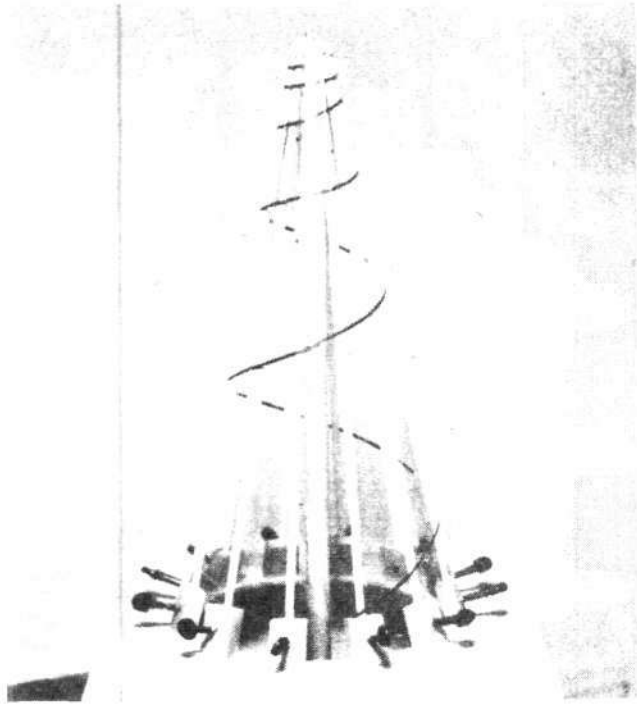
An International Research Plan

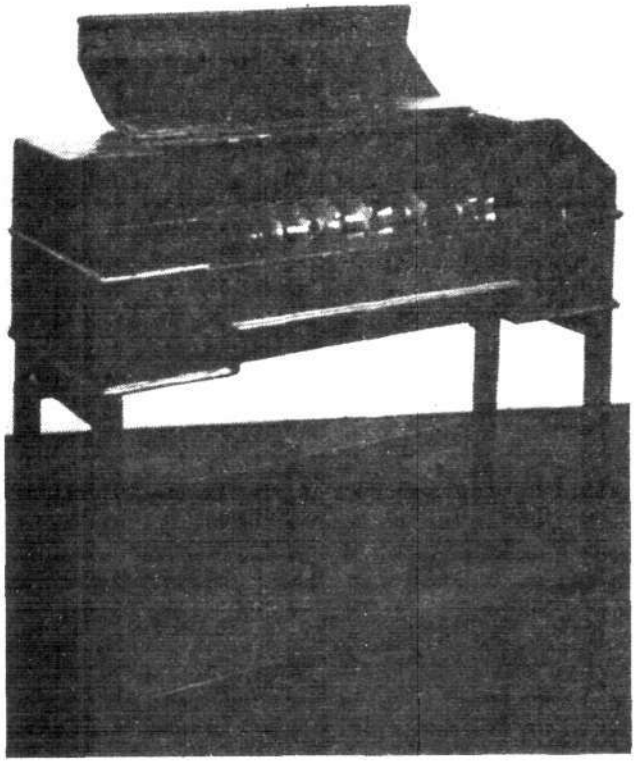
The overall plan for Leibniz's international academy movement was modeled on the memorandum his colleague Christiaan Huygens (1629-1695) had issued to Colbert in the late 17th century, when they collaborated in Paris. Huygens proposed that a scientific academy should conduct experiments on the general questions of power sources. He proposed research on a vacuum with a pump, how to determine the weight of the air, and study of the explosive force of gunpowder, the force of water, "the force and speed of the wind and uses made of it in navigation and machines [and] examine the force of percussion or the communication of motion in impact, of which I think I have been the first to give the true laws."

In addition to the experimental program, the Huygens memorandum to Colbert proposed the preparation of a history of the natural sciences:

> This history is composed of experiments and observations and is the sole method of arriving at the knowledge of the causes of all that is perceived in nature. As to learn the nature of weight, heat, cold, magnetic attraction, light colors, the particles which compose the atmosphere, water, fire, and all other bodies, the purpose of animal respiration, how metals, stones, and plants grow—all things of which little or nothing is yet known, although nothing in the world is more desireable to know. It would be necessary, by pursuing different subjects, some of which I have just named, to establish the chapters of this history and to accumulate under these heads all the observations and experiments relating to each one individually; it is not necessary to expend so much effort on recounting obscure and difficult experiments as on those which appear to be essential for the discovery of the object sought even though these are very ordinary. The usefulness of such a faithfully prepared history extends to the whole of mankind and to all ages to come, because aside from the use for various purposes which may be derived from particular experiments, the collection of all these experiments is a solid foundation for the construction of a natural philosophy in which it is essential to proceed from the knowledge of effects to the knowledge of causes. . . .







THE GEOMETRY OF THE WELL-TEMPERED SYSTEM

With stringed instruments successive octaves are obtained by successively halving the vibrating part of the string. The intervals between successive octaves on the string thus become progressively shorter. 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 can be seen by marking off the string lengths at vertical distances on a cone on which is drawn a spiral that with each winding around the cone moves up half the remaining distance toward the apex. In the well-tempered system, the octave is divided into 12 equal intervals. We construct the corresponding string lengths by dividing the circle at the base of the cone into 12 equal sections, then connecting 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.

At left is a glass harmonica designed by Franklin and constructed by Pietro Verri in Milan around 1771.

The conceptual basis of the mid-18th-century Franklin-Euler attack on Newton directly followed Huygens and Leibniz's own polemics against Newton's theory. Huygens had established the famous principle of the spreading of wave fronts, that "Each point in a wave front may be regarded as a source of secondary waves, and the position of the wavefront at a later time is determined by the envelope of these secondary waves at this time."

The electrohydrodynamic wave approach of the Leibniz-Huygens circle, in their understanding of physical processes, can be traced back to Leonardo da Vinci and Kepler, and forward to the Göttingen school of Gauss and Riemann.[6] Proceeding from the basis of Leonardo's hydrodynamic approach, the Leibnizians totally rejected Newton's mechanical laws for single particles and his gravitational "action-at-a-distance," which assumed a universe of separate particles of matter. Leibniz's famous attack on Newton's *Principia*, that it is "built upon miracles, and . . . occult qualities," speaks directly to this point.

In contrast to Newton's occultism, the circle of Leibniz and Huygens returned to the rational universe of Leonardo. In addition to the well-known Huygens principle for under-

standing the geometric spreading of wave fronts, the work was carried on by his and Leibniz's students. Leonard Euler, for example, investigated the mathematics of fluid flow, and developed the conception of the momentum of fluid motion as a functional relationship in a velocity-pressure field. All of the Bernoulli family also worked on this problem. Franklin's contemporary, Daniel Bernoulli (1700-1782), studied the relationship between fluid pressure and fluid velocity along the streamlines in a compressible fluid in his 1738 work, "Hydrodynamica."

Franklin focused upon the experimental side of these questions—studying large-scale atmospheric phenomena such as weather patterns, winds, storms, water phenomena and waves, and electric lightning. The culmination of the hydrodynamic approach to electricity, light, heat and magnetism came in the 19th-century developments of Gauss, the Webers, and Riemann, as described above.

Franklin's 1766 Trip to Germany

Franklin's thorough association with the Leibnizian scientific tradition is richly demonstrated by his 1766 trip to Germany, where he literally walked in the footsteps of Leibniz guided by the Göttingen mathematician Abraham Gotthelf Kästner and Rudolf Erich Raspe, the keeper of the Leibniz archives at Hannover. Franklin left England with his traveling companion, the medical researcher and physician Dr. John Pringle (1707-1782), on June 14, 1766, arriving in Hannover July 7. Two days later, Franklin was signed into the Royal Library "Guest Book" by Raspe, who had become the clerk at the Royal Library of Hannover in 1760, where he remained the keeper of the Leibniz archives until 1767.

The year before Franklin's arrival, Raspe had published a volume of Leibniz's previously unpublished, groundbreaking philosophic manuscripts with a preface by Kästner. The volume was jointly published in Amsterdam and Leipzig under a French title *Philosophic Works in Latin and French of the late Mr. Leibniz, recovered from his manuscripts which were conserved at the Royal Library at Hannover and published by Mr. Rud. Eric Raspe, With a Preface by Mr. Kästner, Professor in Mathematics at Göttingen*. Since Franklin had excellent command of French, it is virtually certain that he read Leibniz's work while in Germany with the two editors. When Franklin visited Göttingen, Kästner was involved in editing the multivolume collected works of Leibniz, the *Opera Omnia Leibnitii*, which Kästner and Raspe published in Geneva in 1768.

The centerpiece of the Raspe-Kästner volume was the publication for the very first time of Leibniz's monumental attack on John Locke, "The New Essays Concerning Human Understanding," which was written beginning in 1694 in French. When Locke died in 1704, Leibniz chose only to circulate his work on Locke in manuscript, and it was not

SOUND WAVES ARE ELECTROHYDRODYNAMIC

The hydrodynamic work of the Göttingen School provided the theoretical base for today's advanced technologies of laser and other directed energy beams. The fundamental achievements of the electrohydrodynamic wave tradition, in particular Karl Friedrich Gauss and Bernhard Riemann, were summarized recently by the economist Lyndon H. LaRouche, in a discussion of the lasing effect of bel canto singing:

"In all media, action is essentially electrohydrodynamic. The first characteristic of every medium in such respects is a well-defined rate of retarded potential of propagation of electrodynamic waves. In the case of projection of sound, the electrodynamic wave must organize the air-medium ahead of its movement into a state of induced self-transparency for propagation of the wave. The rate at which the air-medium can be assembled into the appropriate electrodynamic configuration of induced transparency for transmission of the wave is limited by the average rate of movability of the air molecules. In a perfect hydrodynamic medium, or an appropriate crystalline configuration of molecules, the rate of retarded potential would tend to be significantly greater than for air, for example.

"The empirical demonstration of the generation of shock waves by supersonic propagation of sound, as specified in Riemann's 1859 paper, proves that this analysis of sound-wave transmission is uniquely the correct one."

LLNL

Right: six of the twenty arms of the Shiva laser amplifier system at Lawrence Livermore National Laboratory.

published until Kästner and Raspe did so in 1765. In the "New Essays," written in the form of a dialogue, Leibniz called the champion of his own outlook "Theophilos," the "Lover of God," and immediately after he completed this work, he began composing the "Theodicy," which explored much of the same epistemological material. On the first pages of his work, Leibniz, identifying himself with Plato, lays out the basic scientific dispute on the question of *method*. He identifies Locke's attack on "innate ideas" as "Aristotle's tabula rasa":

> The question of the origin of our ideas and of our maxims is not preliminary in Philosophy, and we must have made great progress in order to solve it successfully. I think, however, that I can say that our ideas, even those of sensible things, come from within our own soul [*de nostre propre fonds*], of which view you can the better judge by what I have published upon the nature and connection of substances and what is called the union of the soul with the body. For I have found that these things had not been well understood. I am nowise in favor of Aristotle's *tabula rasa*; and there is something substantial in what Plato called *reminiscence*.

While Franklin was being given a guided tour of Leibniz's works in the Royal Library of Hannover he met Gerlach Adolf Freiherr v. Münchhausen (1688-1770), who in 1737 had founded the Georgia Augusta University at Göttingen. Münchhausen later wrote a letter to the faculty at Göttingen essentially telling them to open all doors for Franklin when he visited, which they did. The Göttingen Scientific Society organized a science festival evening in Franklin's honor, when he arrived. According to newspaper accounts Kästner, one of only four members of the Scientific Society in mathematics, presented a theoretical paper on the nature of electricity, no doubt to the delight of Franklin. The *Göttingischen Anzeigen* newspaper Sept. 13, 1766 reported that "the gathering of the Royal Society was more festive than usual." Franklin formally took his post as an honored member of the Scientific Society. Various papers were presented, experiments performed, and toasts made. When Franklin later wrote the outline sketch for his *Autobiography* he planned an entire section, now either lost or never written, which he titled "Journey into Germany, 1766,—Civilities received there. Göttingen Observations."

Franklin's travels through Germany were widely reported in the newspapers from Jena to Hannover. According to the printed recollections of one participant the science festival in Göttingen: "What Benjamin Franklin told us then would be a complete prophecy of the important events which followed"; namely, the war for American independence which began a decade later. This observer also reported that Franklin had announced that he would form an American scientific university in Philadelphia and therefore "came to study the inner functioning of our university."

Franklin's Theory of Music

Franklin's host at Göttingen, Kästner, also had played a key role in publishing the German edition of Kepler's works, a role that was extremely appropriate, because he himself demonstrated the universal coherence of the laws of the universe, with respect to both music and the heavens. Kästner was born in Leipzig in 1719, four years before J.S. Bach (1685-1750) settled there as the cantor of Thomas cathedral. When Kästner turned 18 in 1737, he left his study of law to study musical composition as Bach's personal student. It was through Bach's teaching of the science of musical composition that Kästner had his introduction to mathematical studies. Both Leibniz and Kepler had intensively pursued the study of the 24-key well-tempered musical system from the standpoint of its correspondence with the organization of the physical universe as a whole. In his *Mysterium Cosmographicum*, Kepler used the five regular Platonic solids to explain the orbits of the planets and their distances from the Sun. In the *Harmonies of the Spheres* he directly applied the geometric lawfulness of the heavens to the domain of music.

Franklin also explored the coherence between musical and physical laws in his own musical compositions and writings. German newspaper accounts of his 1766 tour, in fact, report that models of Franklin's invented instrument, the glass harmonica, were played for him in Hannover, Göttingen, and elsewhere as part of the festivities. Both Mozart and Beethoven composed music for Franklin's glass harmonica, which Franklin had designed, as he explained to the Italian scientist Giambatista Beccaria in 1761, very specifically:

> The advantages of this instrument are that its tones are incomparably sweet beyond those of any other; that they may be swelled and softened at pleasure by stronger or weaker pressure of the finger, and continued to any length; and that the instrument, being once well tuned, never again wants tuning [emphasis added].

In 1765, the year before his trip to Germany, Franklin wrote in a letter to Lord Kames:

> In common acceptation, indeed, only an aggreable *succession* of sound is called *melody*, and only the *coexistence* of agreeing sounds, *harmony*. But, since the memory is capable of retaining for some moments a perfect idea of the pitch of a past sound, so as to compare with it the pitch of a succeeding sound, and judge truly of their agreement or disagreement, there may and does arise from thence a sense of harmony between the present and past sounds equally pleasing with that between two present sounds. . . . Thirds are chiefly used, which are very pleasing concords. I use the word *emphatical* to distinguish those notes which have a stress laid on them in singing the tune, from the lighter connecting notes, that serve merely, like grammar articles, to tack the others together. That we have a most perfect idea of a sound just past, I might appeal to all acquainted with music, who know how easy it is to repeat a sound in the same pitch with one just heard. In tuning an instrument, a good ear can as easily determine that two strings are in unison by sounding them separately as by sounding them together; their dis-

agreement is also as easily, I believe I may say more easily and better distinguished, when sounded separately; for when sounded together, though you know by beating that one is higher than the other, you cannot tell which it is. I have ascribed to memory the ability of comparing the pitch of a present tone with that of one past. But, if there should be, as possibly there may be, something in the ear similar to what we find in the eye, that ability would not be entirely owning to memory. Possibly the vibrations given to the auditory nerves by a particular sound may actually continue some time after the cause of those vibrations is past, and the agreement or disagreement of a subsequent sound become by comparison with them more discernible.

Cultural Optimism

Franklin's overall scientific program was based upon a thoroughly far-reaching and culturally optimistic outlook, perhaps best expressed by his famous letter to Joseph Priestley Feb. 8, 1780:

> The rapid Progress *true* Science now makes, occasions my regretting sometimes that I was born too soon. It is impossible to imagine the Height to which may be carried, in a thousand years, the Power of Man over Matter. We may perhaps learn to deprive large Masses of their Gravity, and give them absolute Levity, for the sake of easy Transport. Agriculture may diminish its Labour and double its Produce; all Diseases may by sure means be prevented or cured, not excepting even that of Old Age, and our Lives lengthened at pleasure even beyond the antediluvian Standard.

When he was 81 years old, in 1785, Franklin wrote to his friend Ingenhousz in Passy, France:

> Rejoice with me, my dear Friend, that I am once more a Freeman: after Fifty Years Service in Public Affairs. And let me know soon if you will make me happy the little Remainder left me of my Life, by spending the Time with me in America. I have instruments if the Enemy did not destroy them all, and we will make Plenty of Experiments together.

Throughout his long life, the overall scientific focus of Franklin, in his quenchless thirst for scientific knowledge, was to further through experiment man's ability to understand and improve nature. Consequently, the principal areas of research were the energy, weather, and plant growth processes for the biosphere as a whole. His philosophic associates were responsible for numerous technological improvements in agricultural production methods. The researches of Joseph Priestley and his French colleagues around Lavoisier established the basis for "improving" the soil through fertilizers; his associate Linnaeus studied and classified plant growth patterns; and Priestley was the first to discover the basic scientific principles of photosynthesis, whereby green plants containing chlorophyll, use sunlight as a source of energy. In sum, the contribution of the Franklin networks as a whole gave us the understanding that life in the biosphere transforms radiant energy from the Sun, via a flow of energy, into biological work—a process that admits of Man's scientific intervention.Franklin's scientific pursuits were organized around increasing the energy throughput of the human economy through technology, or labor-saving inventions. Two years before his death, Franklin reiterated his creed of cultural optimism. I can envision no more immortal tribute to this wonderful man's scientific outlook than his own words in a letter to Rev. John Lathrop, Philadelphia, May 31, 1788:

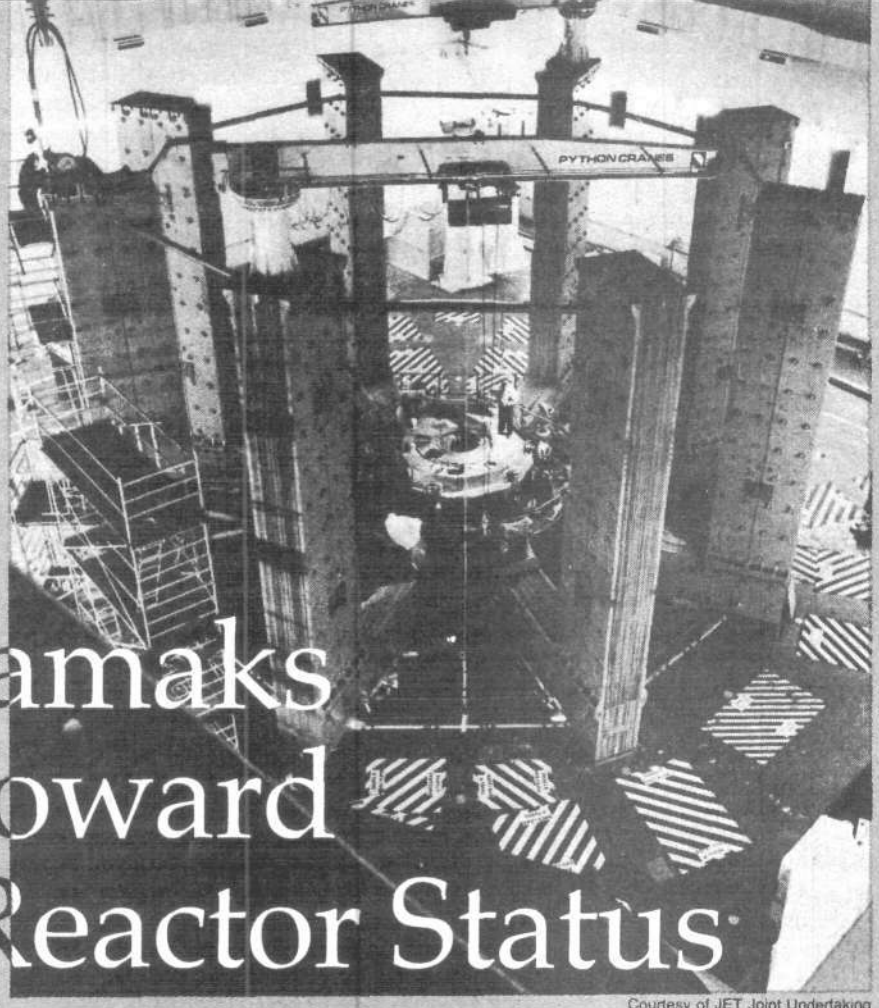
> . . .I have been long impressed with the same sentiments you so well express, of the growing felicity of mankind, from the improvements in philosophy, morals, politics, and even the conveniences of common living, by the invention and acquisition of new and useful utensils and instruments, that I have sometimes wished it had been my destiny to be born two or three centuries hence. For invention and improvement are prolific, and beget more of their kind. The present progress is rapid. Many of great importance, now unthought of, will before that period be produced; and then I might not only enjoy their advantages, but have my curiosity gratified in knowing what they are to be. I see a little absurdity in what I have just written, but it is to a friend, who will wink and let it pass, while I mention one reason more for such a wish, which is, that, if the art of physic shall be improved in proportion with other arts, we may then be able to avoid diseases, and live as long as the patriarchs in Genesis; to which I suppose we should make little objection. . . .

Warren J. Hamerman, an executive member of Lyndon LaRouche's philosophic association, is a founding member of the Fusion Energy Foundation. He writes and lectures frequently on the classical European scientific and cultural tradition. His published work includes studies of Leibniz, Pasteur, and Beethoven.

Notes

1. The task before the U.S. scientific community today of reviving the method of the hypothesis of the higher hypothesis has been emphasized specifically by economist Lyndon H. LaRouche. An elaboration of this point appears in his article "Why I Must Attack Albert Einstein," *Fusion*, July-August 1984, p. 41.
2. Jonathan Swift and the Leibniz tradition is the subject of a forthcoming book by Graham Lowry on the real roots of the American Revolution, to be published by the New Benjamin Franklin House .
3. An English translation by Uwe Parpart Henke of Riemann's paper "A Contribution to Electrodynamics" appears in the *International Journal of Fusion Energy*, Jan. 1985, p. 87.
4. The economist Lyndon LaRouche has most recently developed this concept, the "power of labor," as the centerpiece of a basic course in economics that includes a two and one-half hour videotape and an accompanying textbook, *So, You Wish to Learn All About Economics*, (New York: Benjamin Franklin Publishing House, 1984). Also, see the author's article "Leibniz's Approach to Geometry and Economic Science," in the American Almanac section of *New Solidarity* newspaper, Sept. 21, 1984.
5. Logan's introduction of Leibniz to Franklin has been established by Philip Valenti (unpublished research report).
6. Leibniz's commitment to the hydrodyamic approach is documented in "An Essay on the Causes of Celestial Motion." Leibniz here attributes to Kepler the working out of the relationship between the rotational action of the orbiting planets and their fluid motion through space. An article on this Leibniz work will appear in a future issue of *Fusion*.

The world's three largest tokamaks will demonstrate fusion energy breakeven in the next two years.



Courtesy of JET Joint Undertaking

JET, the world's largest tokamak, shown here in construction.

Big Tokamaks Move Toward Power Reactor Status

by Charles B. Stevens

Over the next two years, three large tokamak experiments will demonstrate for the first time the capacity for magnetic fusion energy generation, making the prospect for harnessing the unlimited energy potentials of nuclear fusion a reality. These machines will also reveal an entirely new physical regime for the first time, that of ignited and burning thermonuclear plasmas. The three devices—the Tokamak Fusion Test Reactor (TFTR) at the Princeton Plasma Physics Laboratory in New Jersey, the Joint European Torus (JET) at Culham Laboratory in England, and the JT-60 at Tokai in Japan—will open the road to the realization of commercial magnetic fusion electric power plants.

All three tokamaks will attain the physical conditions needed for energy breakeven; that is, the potential of producing more fusion energy than the energy consumed in the operation of the experiment. JET and TFTR have been designed to burn the most reactive fusion fuels (deuterium-tritium) and produce net energy. And major scientific advances in the past few years indicate that JET may be able to obtain full fusion ignition—a condition in which the fusion energy itself maintains the burning fuel at the hundred-million-degree Celsius fusion reaction temperature required to operate an economical commercial tokamak reactor. All three experiments will explore entirely new realms of plasma physics.

Ironically, just as the world magnetic fusion effort is demonstrating that energy-producing hydrogen plasmas can be created, budget cuts in the U.S. program have now catapulted that program two decades back in funding levels, pushing the United States from first place to third place in fusion technology, behind Japan and Western Europe. More significantly, U.S. magnetic fusion research is being gutted just as scientists are beginning to explore true fusion plasmas. The proposed funding cuts are primarily directed at curtailing and delaying research on the fusion plasmas that will be created for the first time in the TFTR.

The primary reason that the TFTR will obtain net-energy-producing hydrogen plasmas is its size; it has a maximum plasma volume of 35 cubic meters, more than twice the size of the previous-generation PLT tokamak at Princeton. Costing $314 million, the TFTR is the world's third largest magnetic fusion device, the JET and JT-60 being the first and second largest, respectively. The TFTR was originally scheduled to achieve energy breakeven and net energy generation within the coming year, but the U.S. budget cuts will delay this step for several years.

Scale Is a Crucial Factor

From almost every type of scientific measurement it has become increasingly evident that the size of a magnetic

plasma determines its operating capabilities. The reason for this is that small plasmas are almost transparent to X-ray radiation generated by plasma electrons and ions. This means that the plasma is not truly isolated from external factors; small plasmas are dominated by what should be only "edge" effects. With the larger machines like JET, JT-60, and TFTR, the edge effects are removed from the interior of the plasma and dominate only a thin layer of the outer skin of the plasma.

In other words, in previous experiments with smaller devices, the energy flow of the plasmas—hot, ionized gases—have been dominated by atomic radiation processes. This atomic radiation is created by nonhydrogen impurities—carbon, oxygen, and metal ions that derive from the vacuum chamber wall and the pumping system. In the large tokamaks, the plasma, which is confined and insulated by magnetic fields, will have its energy flow determined primarily by the interaction of the hydrogen plasma with the magnetic field.

The importance of scale has been seen most clearly in the extraordinarily good results achieved with low-temperature, ohmically (resistively) heated plasmas in JET and TFTR. It has also been indirectly seen in high-temperature plasmas on the largest, prior-generation tokamaks, where auxiliary heating has created what is called the H-regime, where the outer edge of the plasma is controlled for impurities. As auxiliary plasma-heating capabilities are added to TFTR, JT-60, and JET, these machines should also see the good results found in low-temperature, ohmically heated plasmas extended into the high-temperature, fusion regime.

Scientifically, almost all magnetic confinement schemes are not fully understood. The tokamak has achieved the best results to date and will certainly succeed in producing net energy fusion plasmas. But these large tokamaks also promise to illuminate the nature of true magnetic plasmas. As a result the science of magnetic plasmas will be greatly advanced across the board. And by penetrating this scientific frontier, entirely new possibilities for creating fusion plasmas and other applications will emerge.

Large Versus Small

One of the spurious excuses used by those advocating the castration of the U.S. fusion program is that the U.S. magnetic fusion effort has focused too much of its resources on large experiments like the TFTR and not enough on smaller, more "scientific" experiments. This argument, put forward by the President's science advisor Dr. George Keyworth, is similar to the suggestion that one should cut off one's head to increase blood flow to freezing hands and feet. Both large and small experiments are essential to the realization of economical fusion power.

The budget-cutting argument is also fallacious on its own terms. The large tokamak experiments are most scientific; they uniquely provide the size needed to enter the realm of true plasma dynamics—a capability that can be attained only with large plasma volumes. And, as discussed here, these large tokamaks are already achieving groundbreaking results.

Plasma volume, it should be emphasized, appears to be essential to approaching the sort of regimes in which mag-

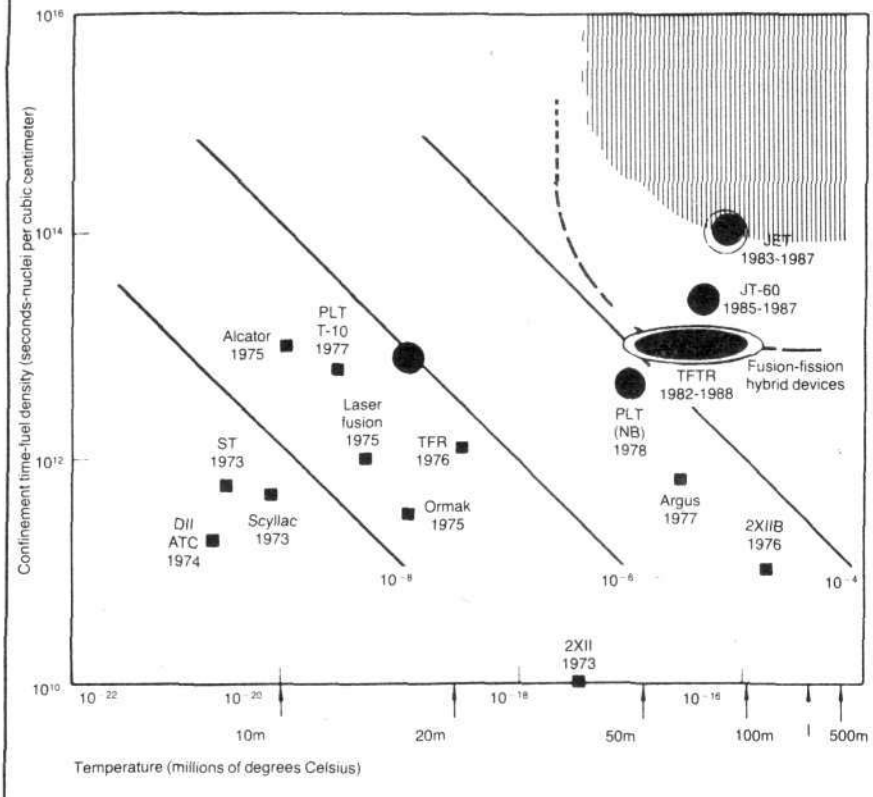


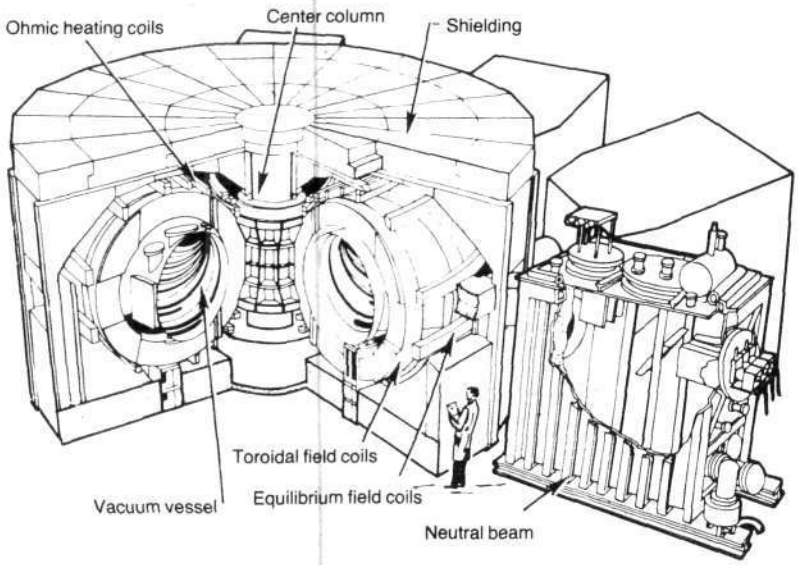
Figure 1
PERFORMANCE OF SELECTED FUSION EXPERIMENTS AND PROJECTED LARGE TOKAMAK PERFORMANCE

The Lawson product, confinement time times fuel density in seconds-nuclei per cubic centimeters is given along the vertical axis for several fusion devices and the three large tokamaks described here. Plasma temperature in millions of degrees Celsius is given on the horizontal axis. The diagonal lines indicate fusion energy gain. The hatched region in the upper right-hand corner indicates the area in which a pure fusion reactor must operate. The dashed line, also upper right, shows how these conditions are substantially lowered for fusion-fission hybrid reactors. Also shown are DII, ATC, ST, Ormak, Alcator A, PLT, and TFR, all previous generation tokamak experiments, and some results for laser fusion (Argus) and other types of fusion devices (the 2X IIB magnetic mirror).

Figure 2
SCHEMATIC OF THE TFTR TOKAMAK

The Tokamak Fusion Test Reactor, the largest construction project to date in the U.S. fusion program, became operational on Christmas Eve 1982. If not for the 1985 budget cuts, the TFTR would attain net-energy generation this year.

Shown are the various coil systems that produce the magnetic field configuration that spirals around the plasma in the tokamak, containing it.



netic confinement can be fully tested. The TFTR, which was first designed in 1974, has a volume of 35 cubic meters, while the much-later-designed JT-60 and JET have larger plasma volumes, 54 and 170 cubic meters, respectively. For JET, this could mean the difference of achieving ignition. Contrary to the propaganda coming from the Keyworth circles, the U.S. magnetic fusion program has not committed itself to build any new large tokamak in more than a decade, despite the provision of the 1980 Magnetic Fusion Energy Engineering Act, which mandated a commercial prototype reactor by the year 2000. There is no scientific reason for this failure to pursue the further development of the tokamak. Tokamaks have continued to achieve better and better results with each new device going well beyond its projected performance.

In addition, funding cutbacks over the past eight years have prevented the United States from pursuing important new opportunities with small experiments. For example, Dr. Bruno Coppi at the Massachusetts Institute of Technology developed the concept of small, high-field ignition tokamaks based on the amazing success of the small Alcator A tokamak at MIT. Although involving more risk, such innovative concepts provide the basis for leaps in scientific know-how. However, the zero-growth environment of the Carter years put the U.S. fusion effort in a deep freeze. The uncertainties of commitment forced fusion program managers into more and more conservative research planning.

The Successful Tokamak Design

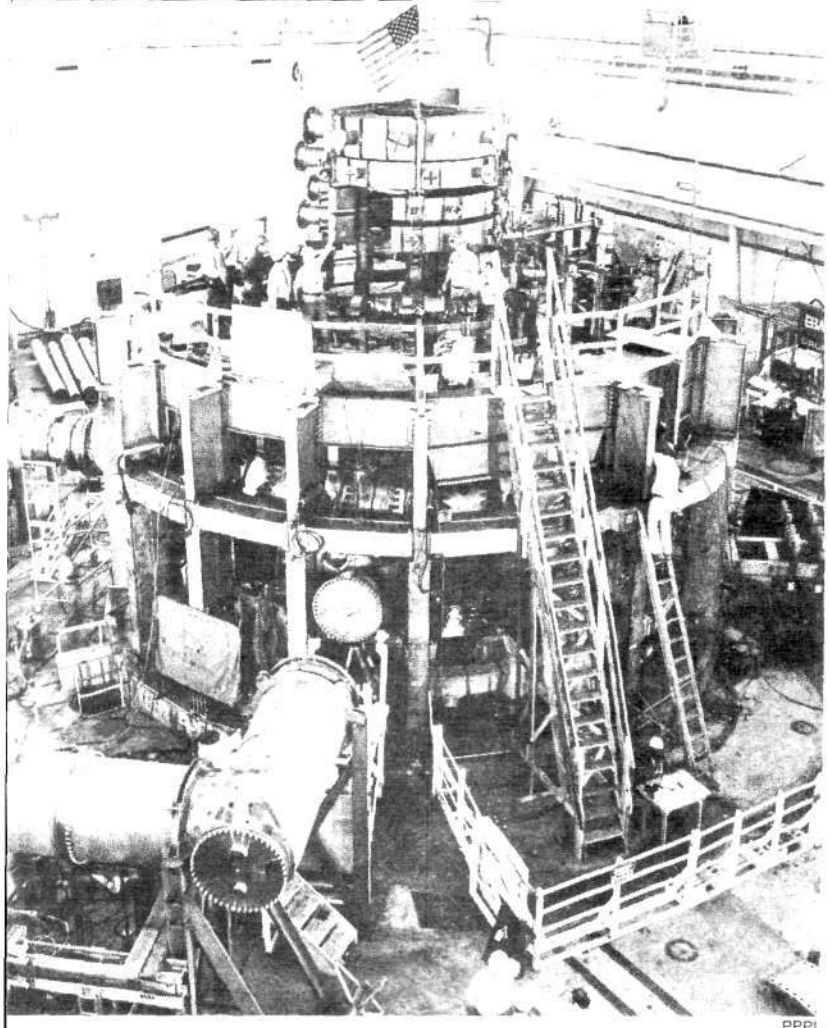
The tokamak is the most scientifically successful magnetic confinement design. Scores of tokamak experiments are currently being investigated throughout the world. But only the three discussed here, TFTR, JT-60, and JET, have the capabilities of going beyond breakeven energy conditions (Figure 1).

The basic design of a tokamak is shown in Figure 2. Hydrogen gas is puffed into the donut-shaped vacuum chamber. Constant electrical currents passing through the large coils circling this donut produce a toroidal magnetic field—toroidal meaning that the direction of the magnetic field force lines is parallel to the axis of the donut plasma column.

A second set of coils, the poloidal field coils, carry a varying current. This current variation induces an electric current within the donut of hydrogen gas, which does two things. First, it heats the gas because of the resistance of the gas to the flow of the electric current (this is called ohmic heating). As this current increases, the gas breaks down, or becomes ionized, and thus becomes a plasma. Second, the induced current generates a second magnetic field that is perpendicular to the externally generated toroidal field; that is, in the poloidal direction. (The toroidal direction is the long way around the torus and the poloidal is the short way around.) The toroidal and poloidal fields combine to form a single magnetic field configuration that spirals through the volume of the torus. This geometry is extremely important, because it is the spiral configuration that makes the interaction between the plasma and the magnetic field stable.

Until recently, it was believed that ohmic heating would not be sufficient to attain fusion temperatures. As noted above, as the plasma goes to higher, fusion-like temperatures, it becomes collisionless and the resistance to the flow of electricity is dramatically reduced. Because ohmic heating is in proportion to electrical resistance, this heating method becomes quite inefficient as fusion temperatures are approached. Therefore, auxiliary methods of heating magnetic plasmas have been developed, with neutral beam and electromagnetic wave heating shown to be the best.

However, the success of recent experiments has demonstrated that it may indeed be possible to attain fusion ignition with only ohmic heating. This is because the plasma energy confinement has been found to be much better than expected, actually increasing with increasing plasma density. And since the power density of fusion energy output increases with the square of the plasma density, these den-



PPPL

The TFTR was originally scheduled to achieve energy breakeven and net energy generation within the coming year, but the U.S. budget cuts will delay this step for several years.

ser, better confined tokamak plasmas could possibly bootstrap themselves to full ignition. That is, the fusion energy output, itself, could be sufficient at lower temperatures to provide enough heat to push the plasma to higher temperatures and full ignition.

A third set of external coils are vertical field coils, which produce a vertical magnetic field that is perpendicular to the plane of the torus. The vertical field prevents the plasma torus from simply expanding outward and also is used to keep the plasma well positioned within the vacuum chamber.

Because the poloidal field component of the tokamak is generated by an induced electrical current carried by the plasma and because this method of current generation must be transient (lasting only for a short time), the operation of the induction-driven tokamak must be pulsed. For scientific investigations, pulsed operation is of little concern, but for actual power plants, pulsed operation has a number of significant drawbacks and increased costs.

One of the major advances of the last several years is that electromagnetic wave heating has provided a means of generating nontransient plasma currents in tokamaks. This type of heating is often termed radiofrequency or rf because the range of frequencies utilized falls within that of radio waves to microwaves on the electromagnetic spectrum. It has been found that rf heating is quite efficient and does not disturb the stability of the plasma magnetic confinement. More important, when the rf is properly tuned and shaped it will also generate a plasma electric current. Thus, steady-state or near-steady-state continuous operation of tokamaks is a real possibility.

Other possibilities for steady-state current drive also exist, such as neutral-beam plasma-current generation or bootstrap currents generated by the fusion energy output. JET, JT-60, and TFTR will explore all these auxiliary methods of heating and current drive.

The table (page 45) shows the machine parameters of JET, TFTR, and JT-60. The three general parameters of plasma density, temperature, and energy confinement time for magnetic tokamak reactor-grade plasmas are, respectively, about 100 trillion nuclei per cubic centimeter, 10 keV (kiloelectron volts), and 1 second. The Lawson product, the product of the density times confinement time, would thus be about 100 trillion seconds-nuclei per cubic centimeter.

Fusion Ignition

A thermonuclear plasma becomes ignited when a sufficient portion of the fusion energy output is trapped and absorbed within the reacting plasma to balance the diffusion of thermal energy out from the plasma. For deuterium-tritium reactions, there are two fusion products, a neutron with an energy of 14 MeV and a helium nucleus (often called an alpha particle) with an energy of 3.5 MeV. Because the tokamak plasma is very diffuse—hundreds of thousands of times less dense then ordinary air—and because the neutron is electrically neutral and therefore does not interact with either the confining magnetic field or any ambient electric fields, there is no way of physically stopping or absorbing the neutron energy within the reacting plasma. Therefore, only the high-energy helium ion is a candidate for supplying energy to the reacting plasma.

The efficiency of trapping the alpha energy within the reacting plasma is determined by the size of the plasma and the intensity of the confining magnetic fields. Once these prerequisites are met, the plasma can attain full ignition if it is maintained for a sufficient time to allow the trapped alpha energy to build up to a point where it exceeds the rate of energy loss. Only JET appears to have all of the requirements for full ignition—large size, sufficiently large confining field, and long plasma pulse durations.

The U.S. TFTR: Progress Slowed by Budget Cuts

The $314 million TFTR began operation Dec. 24, 1982 at the Princeton Plasma Physics Laboratory with the objective of achieving reactor plasma parameters in the range of 10 keV temperatures, 100 trillion nuclei per cubic centimeter fuel densities, and 0.3 second plasma energy confinement times, in addition to fusion energy breakeven with D-T fueling. TFTR was designed to produce about 25 MW of fusion energy for 0.5 second, a fusion energy output about equal to the 25 MW of neutral beam heating needed to maintain the TFTR at fusion temperatures.

Already, TFTR has demonstrated better than the 0.3 second confinement time originally projected; 0.4 second energy confinement times have been attained at peak deuter-

ium densities of 60 trillion nuclei per cubic centimeter, which gives a Lawson product of 24 trillion seconds-nuclei per cubic centimeter, at a temperature of 2.3 keV. However, as noted, the U.S. fusion budget cuts will curtail the rate of progress on the TFTR.

Together with results from JET and the high-field Alcator tokamak, TFTR has shown that ohmically heated plasmas perform much better than expected. Even from a very simple standpoint it would appear to be the case that the rate of loss of plasma thermal energy should decrease with the increasing size of the tokamak; that is, the energy confinement time should increase with size. In fact, very detailed analyses projected that energy confinement time should increase with the square of the plasma size, for example, in proportion to the cross-sectional area of the plasma column. It turns out, however, that energy-confinement time scaling is much better and actually increases with the size *cubed*, for example, with the plasma volume.

In late 1984, 5 MW of neutral beam auxiliary heaters was added to the TFTR. In initial experimental runs, ion temperatures of about 4.5 keV were reached. In the coming year, the TFTR will be brought up to a full 27 MW of neutral beam heating, and up to 11 MW of additional rf wave heating will be added at a later point.

A third approach to auxiliary heating will also be tested on the TFTR—adiabatic plasma compression. Like all gases, when an insulated plasma is compressed its temperature increases. Already the TFTR has demonstrated that large plasma compressions can be stably achieved and maintained for up to 1 second.

Europe's JET: The World's Largest Tokamak

The Joint European Torus, which began operation in June 1983, is a project of the Western European Economic Community. Although its early stages of design were marred by infighting about its location, these political problems have been overcome and JET is on the way to being a tremendous success.

By far the world's largest fusion experiment, it has a plasma volume of 170 cubic meters and has already achieved an energy confinement time of up to 0.8 second. Current experiments are directed toward "cleaning up" the plasma, which appears to be the only potential barrier to JET's reaching ignition. Nonhydrogen impurity elements migrate into a magnetic plasma from gases released from the walls and pumps of the tokamak vacuum system. By heating the walls of the vacuum chamber with low-density discharges, many of these impurities can be removed.

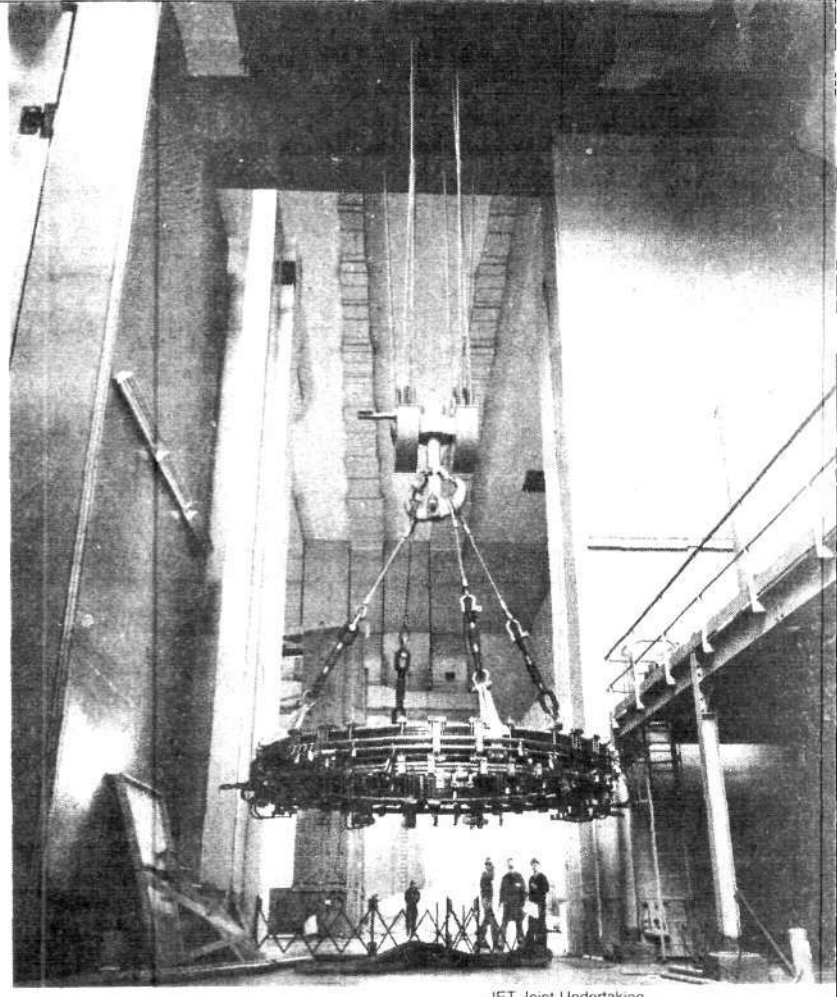
In the long run, moreover, recent experimental experience demonstrates that tokamaks can be cleaned up and JET should therefore be able to reach full ignition when it is brought up to full performance in the coming years.

Japan's JT-60: Going for Commercial Power

Perhaps the main advantage of the JT-60 is political; the Japanese are determined to develop a commercial reactor before the turn of the century—and to export tokamaks.

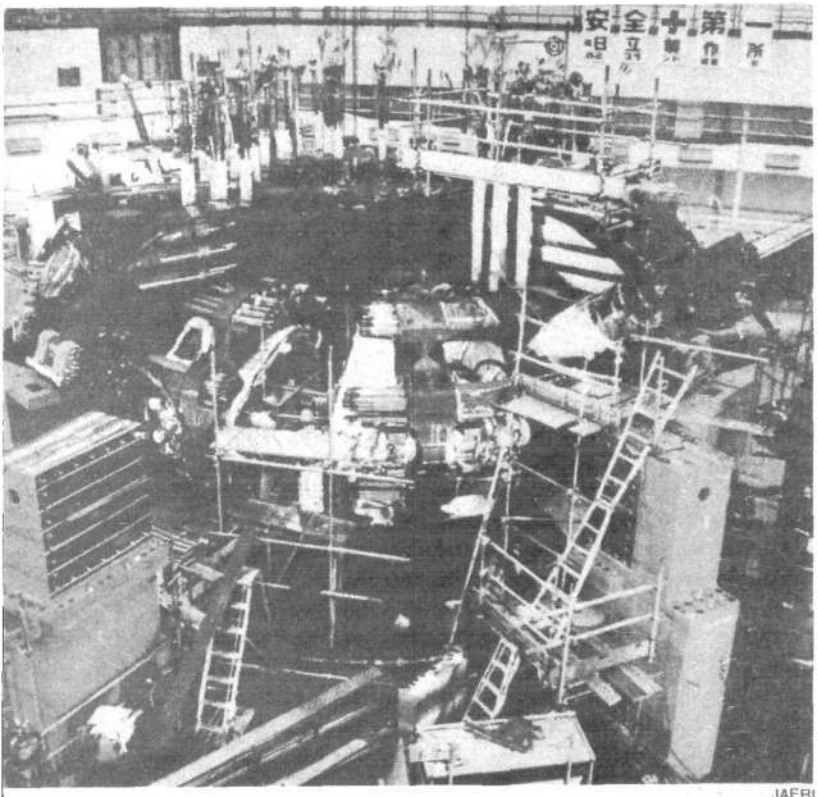
Initial operation of JT-60 has been advanced from April to March 1985. Although JT-60 does not have the capability of actually burning D-T fusion fuel—it will be limited to simple hydrogen and deuterium gas—it does have a number of unique advantages over JET and TFTR. For example, only JT-60 has a magnetic divertor system for cleaning up plasmas during operation. This built-in system, also called a magnetic limiter, consists of a carefully designed "hole" in the outer layer of the magnetic bottle, through which the outer edge of plasma is scraped off into an auxiliary chamber, thus removing impurities. This divertor could also prove crucial for attaining maximum energy confinement times during high-temperature operation.

JT-60 should also be able to more easily access the H-mode of better energy confinment. When higher-temperature neutral-beam auxiliary heating was first demonstrated, it was noted that the energy confinement times were lower compared to those achieved with lower-temperature ohmically heated plasmas. Over the past several years, though, the West German Asdex tokamak experiment demonstrated that if the physical parameters of the outer plasma edge are maintained within a certain range, then the energy confinement time for neutral-beam-heated plasmas becomes like that found in ohmically heated plasmas. This mode of operation is called the H-mode, and it has been extended to a number of other tokamaks including the Doublet III in San Diego, which is a joint U.S.-Japan project, and the Princeton PBX tokamak. All three of these machines



JET Joint Undertaking

One of JET's poloidal field coils being transported into the Torus Hall at Culham Laboratory.



JAERI

Japan has made the political commitment to be number one in fusion. The JT-60, shown here in construction, will be on line ahead of schedule.

have magnetic divertors that provide a means for controlling the physical parameters of the outer edge.

Theoretical investigations of the H-mode indicate that JET and TFTR should also be able to attain this regime. And because H-mode types of energy confinement time are beyond those originally projected for these large tokamaks to achieve successful full performance, if these devices reach the H-mode, they will be able to perform much better than originally predicted.

JT-60 is also designed to achieve a higher plasma beta, which is important in terms of reactor economics. Plasma beta is the measure of the efficiency by which the magnetic field confines a fusion plasma. Technically, plasma beta is equal to the ratio of the plasma gas pressure to the "pressure" of the magnetic field, in percentage terms. Roughly speaking the magnetic field pressure is proportional to the square of the magnetic field strength. High betas, ranging from 10 percent to 100 percent, mean that the magnetic field is quite efficient. Tokamaks generally operate with betas of less than 1 percent. For commercial reactors, minimum betas in the range of 4 to 5 percent are required. Higher betas would greatly decrease reactor capital costs per unit energy output.

Recent experiments on the Princeton PBX tokamak have attained betas of 5.3 percent, which betters the previous record of Doublet III of 4.5 percent. The JT-60 has been designed to achieve higher betas with 4 percent being the targeted value. Continuing research could provide the means to attain even higher values on actual JT-60 experiments.

Future Operating Plans

All three large tokamaks have similar future operating plans with the devices available for plasma experiments about 50 percent of the year in the first year and increased to 60-70 percent in the next two years. Down time will be used for scheduled maintenance and system upgrades, such as the addition of scientific diagnostics, auxiliary heating devices, and radiation shielding for full DT runs.

In terms of the paths that these three machines will take to full performance, however, there are significant differences. TFTR and JET will undergo upgrades in modes with numerous, relatively short, scheduled down periods. JT-60, on the other hand, will take a small number of long shutdowns to upgrade in large steps. This difference involves the way in which these machines have been built and qualified. JT-60 is designed not simply to be an experiment, but to provide the context in which an industrial base for fusion technology for power reactors can be created. Therefore, JT-60 abides by a quite rigorous acceptance-testing procedure and the machine will become available for experimentation only when full engineering testing is completed. In other words, only after all equipment has demonstrated that it can operate to full capacity will the device be made available to researchers.

In contrast, with the TFTR, machine parameters are pushed to their limits only as part of a slowly evolving experimental program. Magnets, induction coils, and so on, will not be brought up to full strength until after many experiments are carried out at a lower rating. JET stands somewhere between TFTR and JT-60 in this respect.

As for day-to-day operating procedures, TFTR and JET will employ a traditional daily cycle that incorporates alternating periods of plasma experiments with discharge cleaning. JT-60, however, will use a new approach in which plasmas will be run for a period of up to eight days, preceded by three days of discharge cleaning and followed by three days of inspection and maintenance.

Implications for Tokamak Reactors

Scientifically, there is little doubt that a power-producing tokamak fusion plasma can be achieved. The outstanding question is whether the actual physical performance can be optimized to minimize the technological difficulties and improve the economic performance of power reactors. Existing experiments strongly indicate that there are indeed numerous paths to better performance which these large tokamaks will have the capabilities of exploring. Therefore, these scientific issues will have an indirect and major impact on technology, engineering, and economics of potential tokamak power plants. They will also have a much broader impact on the general science of fusion plasmas. The most important questions that will be explored by these machines are energy-confinement time scaling, plasma heating, plasma density and fueling, and plasma beta.

Energy-confinement time scaling. The question here is how does the energy confinement of hot plasmas by magnetic fields change as the parameters of the tokamak are

varied; for example, the size, the shape (various cross-sectional geometries for the plasma column), the plasma temperature and density and their spatial distribution within the tokamak, impurity levels, plasma current levels, magnetic field intensity, and so on.

The outlook here is quite optimistic. Empirically, energy-confinement time scaling improves as the experiments approach parameters required for power plants. And from the analysis of these past results there is even a substantial basis for projecting that there will be a leap in further improvements on the large tokamaks. This is because these devices are sufficiently large to produce plasmas that are dominated by internal effects as opposed to external ones.

Plasma heating. Most issues in plasma heating in practical terms have been resolved. What remains to be seen is if these auxiliary heating systems can also be utilized to improve other aspects of fusion plasma operation. For example, neutral beams and rf heating could also generate plasma electric currents. Rf can be used to control the distribution of temperature within the plasma since the electromagnetic waves could be "tuned" into specific portions of the plasma. And, in fact, it may be possible to tune the deposition of rf such that it can be used to clean the plasma of certain impurity elements. From the evidence so far, the interaction of the plasma with rf heating promises to be one of the most fruitful areas for new scientific advances in tokamak experiments.

Parameters of the Large Tokamaks

Device	TFTR	JET	JT-60
First plasma	Dec. 1982	June 1983	Apr. 1985
Major radius (meters)	2.55	2.96	3.0
Half-width (meters)	0.85	1.25	0.95
Ellipticity	1.0	1.0-1.6	1.0
Toroidal field (Tesla)	5.2	3.5	4.5
TF coil conductor	Copper	Copper	Copper
Working gas	H D-T	H D-T	H
Plasma current (Megaamps)	2.5-3.0	4.8	2.7
Discharge duration (sec)	1.0-3.0	10-20	5-10
Neutral beam power (MW)	27	16	20-30
Beam pulse length (sec)	0.7-2	10	10
Neutral beam energy (keV)	120.D	80.H-160.D	100.H
RF power (MW)	ICRH 8	ICRH 30	IHRH 8
	LHRH 3		LCHR 3
Fueling	gas puff, pellet injection	gas puff	gas puff
Volume (cubic meters)	35	170	54
Impurity control	gettering	wall cond.	magnetic limiter, wall cond.

The plasma half-width gives the radius of the plasma column. The JET plasma column has an elliptical cross-section with a horizontal half-width of 1.25 meters and a vertical half-width of 2.1 meters. TFTR and JT-60 have circular cross-sections. ICRH stands for ion cyclotron resonance heating; LHRH for lower hybrid resonance heating.

In nonignition, net-energy-producing regimes it is possible to achieve the maximum fusion energy output per unit auxiliary heating input through so-called beam-plasma fusion reactions. This regime is of interest for low-power output plasmas that could be used to breed nuclear fission fuel for nuclear power plants. This regime will be explored on the TFTR with its 27 MW of neutral beam injection.

Plasma density and fueling. Tokamaks have always produced sufficiently dense plasmas for power reactor regimes. In 1974, the MIT high-field Alcator broke all records by increasing the operating density from 100 trillion to 1,000 trillion nuclei per cubic centimeter. TFTR, JT-60, and JET are not designed to explore these high-density regimes, but the densities that they have attained and will attain are more than sufficient.

All three big tokamaks will explore high-density current drive. Until recently, rf current drive experiments have been limited to low-density regimes, insufficient to produce full-power fusion plasmas. But recent results on the Alcator and Princeton Large Torus (PLT) have shown that higher-density plasmas can also support rf current drive.

In terms of fueling, plasma pellet injection techniques have been developed and successfully tested on a number of tokamaks. This method of injecting more hydrogen fuel into tokamaks proved to be of crucial importance for the MIT Alcator C to attain its full operational capabilities. TFTR will be the primary testbed for further tests of this method of fueling. JET and JT-60 utilize gas puff systems.

Plasma beta. Although none of these large tokamaks is designed to explore the limits of plasma beta, they will provide some useful experimental regimes. This is particularly true of the TFTR when the plasma compression method of heating is utilized.

Scientific Implications

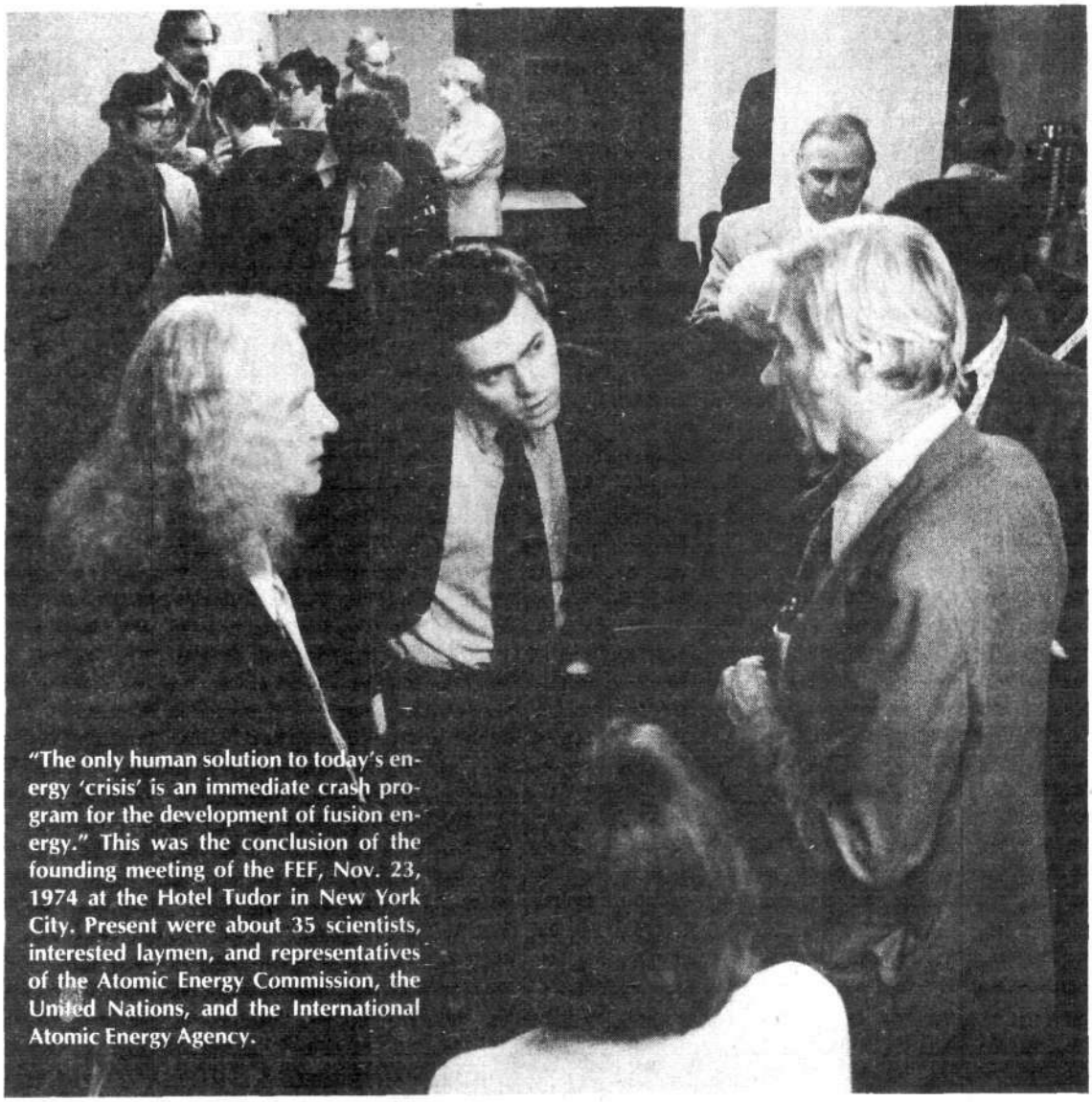
Plasmas are not uniform states of matter. In fact, they have a wide variety of distinct regimes, just as ordinary matter takes a wide range of forms, as for example, the various geometries found in crystals. These plasma regimes will have many applications to industry in addition to the simple one of electric power generation.

For example, it is possible to directly transform plasma thermal energy into electricity or to use it to generate microwaves. In fact, plasma is the ideal medium for energy transformation, because it can operate at much higher energy flux densities and efficiencies than any other medium. This is crucial for industrial applications because the productivity of a manufacturing process is primarily determined by the maximum energy flux density that can be applied to the material to be transformed and the wavelength and internal configuration of that energy. Since plasmas provide the most efficient regime for transforming energy into various forms and wavelengths and for concentrating energy, these large tokamaks could provide essential data for making entirely new industrial processes possible. In fact this has already occurred with the TRW Plasma Separation Process for separation of nuclear isotopes.

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

The Fusion Energy Foundation

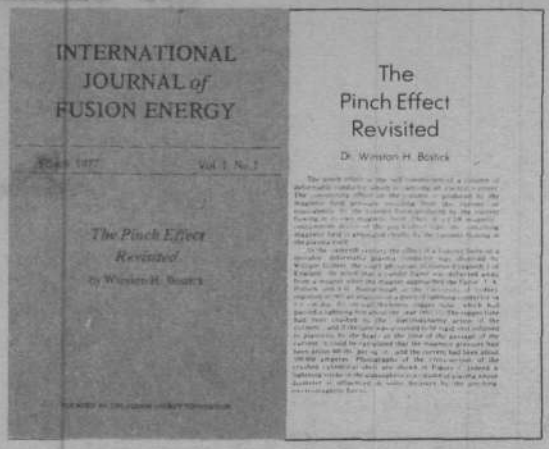
10 Years of Fighting for Progress

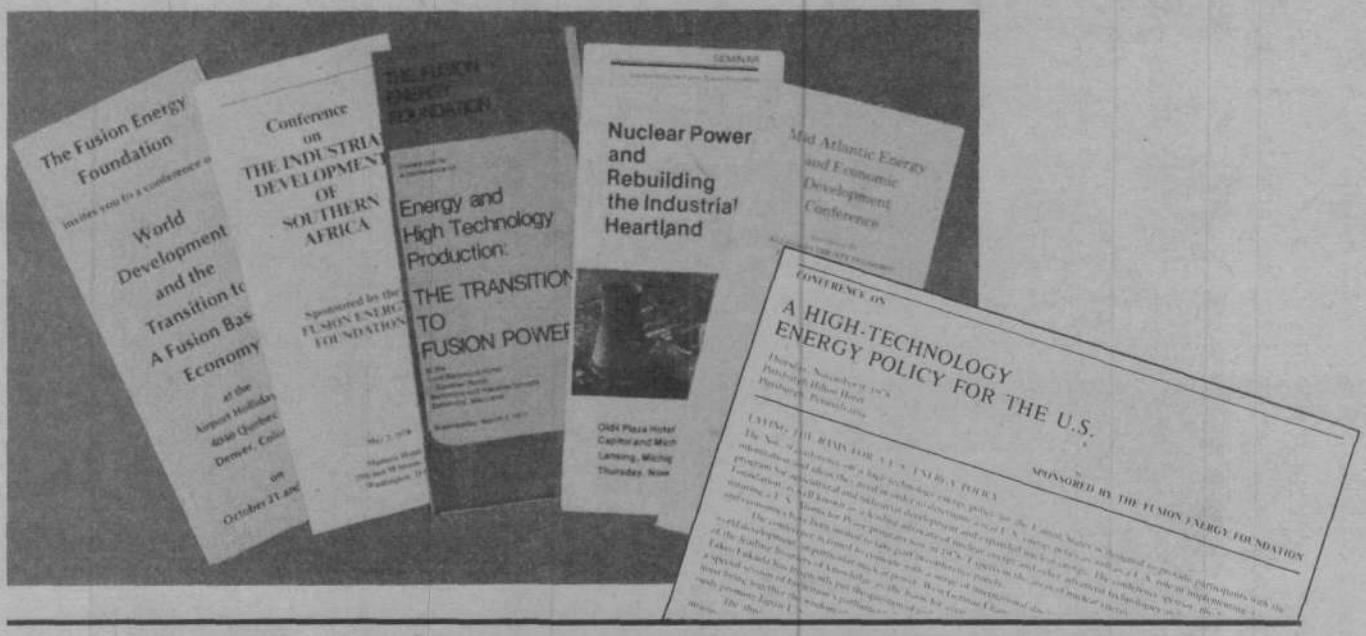


"The only human solution to today's energy 'crisis' is an immediate crash program for the development of fusion energy." This was the conclusion of the founding meeting of the FEF, Nov. 23, 1974 at the Hotel Tudor in New York City. Present were about 35 scientists, interested laymen, and representatives of the Atomic Energy Commission, the United Nations, and the International Atomic Energy Agency.

Above: Charles B. Stevens (center), FEF director of fusion engineering, at the founding meeting talking informally with Dr. Robert Moon (left) and Dr. Winston Bostick, both members of the initial scientific advisory board.

In early 1975, the FEF began to sponsor conferences promoting fusion energy, nuclear power, and industrial development in major cities around the country, and by spring 1975, a bi-monthly FEF newsletter circulated to a few hundred subscribers. A theoretical journal, the *International Journal of Fusion Energy*, made its debut in March 1977, featuring Winston Bostick's discussion of plasma filaments—the self-ordered structures in fusion plasmas that many scientists said could not exist. Dr. Morris Levitt was the FEF's first executive director.





In July-August 1977, the FEF launched *Fusion* as a monthly magazine. The first issue featured presentations from the founding meeting of the FEF biological sciences section at Columbia University in New York, at which 200 biologists, mathematicians, physicists, and engineers discussed the need to take up the achievements of Riemann and Cantor and apply them to biological processes.

The FEF News section in the first issue reported how Energy Secretary James Schlesinger had waged a campaign to intimidate participants at an April 1977 conference on energy and technological development in Pittsburgh. The FEF obtained a temporary restraining order against such harassment, and 120 people attended the conference in a city that President Carter had selected as a model to set the pace for his deindustrialization and conservation policies.

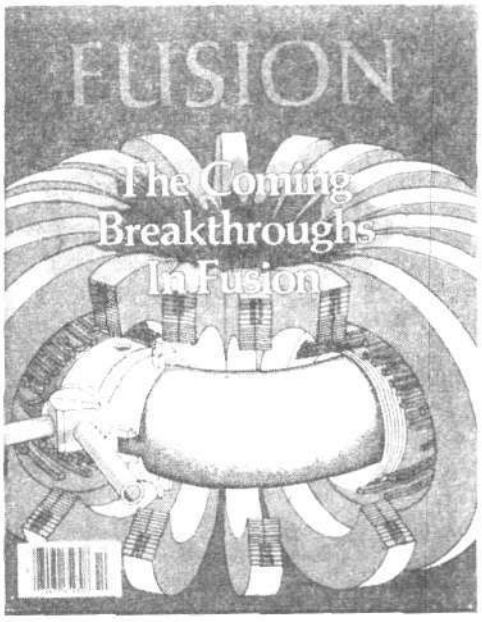
Conference on Nonlinearity Launches FEF Biological Sciences Division

As early as 1977, the FEF advocated beam defense research. This pamphlet reported on how far in advance the Soviets were in beam research, and a cartoon in *Fusion* suggested one of the reasons that the United States lagged behind.

"So you see Mr. President, there's no such thing as the E-beam."

The FEF campaigns for nuclear power, industrial development, advanced science and technology, and against the Malthusian ideas of the environmentalists quickly became international and *Fusion* magazine was initiated as a quarterly in German, French, Spanish, Italian, and Swedish.

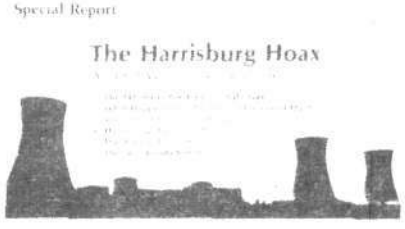
(A) Nuclear power, yes! reads the buttons of FEF organizers in Sweden shortly before the March 1980 referendum on nuclear development there. (B) Cecilia Soto de Estévez, director of the Mexican Association for Fusion Energy, shows visitors the fusion technology display at a 1981 industrial fair in the state of Sonora. (C) Mayor Seib (at podium) joins Helga Zepp LaRouche (left) at a 1981 mass meeting in West Germany to support the Biblis nuclear plant.



Above: John Clarke, associate director of the DOE Office of Fusion Energy, speaking at the FEF's annual meeting in 1978.

When the Princeton Large Torus reached record tokamak temperatures, upwards of 60 million degrees, during summer 1978, the FEF made sure that this news became world headlines instead of being kept in Energy Secretary James Schlesinger's closet. Pressure from the FEF forced the DOE to break its blackout with a press conference. The FEF followed up with a special *Fusion* issue on "The Coming Breakthroughs in Fusion" to let the world know the importance of the research result. At the same time that Schlesinger was downplaying fusion, he nixed a $1 billion proposal from the Japanese to jointly develop fusion. Schlesinger's alternative? Coal liquefaction.

Above: The Fusion booth at the Houston airport.



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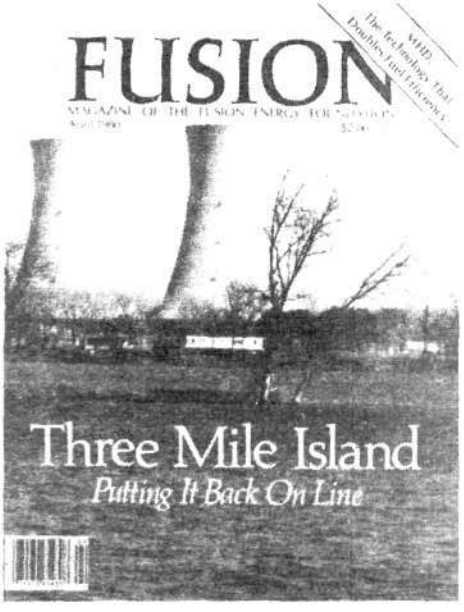


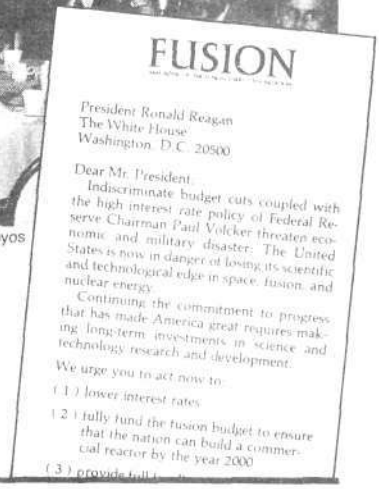
The Three Mile Island incident in March 1979 marked a turning point for the nuclear industry and for the FEF, which led an aggressive fight to expand the U.S. nuclear industry and debunk the propaganda of the environmentalists. *Fusion* organizers became a familiar sight at airports around the country, and the picket sign "Feed Jane Fonda to the Whales" became American history. *Fusion* sales reached 200,000 as it became the nation's only pronuclear science magazine.

Carlos de Hoyos

The FEF won the Freedoms Foundation George Washington medal for its *Fusion* magazine series exposing possible sabotage at Three Mile Island. Jon Gilbertson (right), then FEF nuclear engineering director, holding the medal at the award ceremony in June 1980. With him (from left) are Dr. Morris Levitt, then FEF executive director; Robert W. Miller, president of the Freedoms Foundation; and Marjorie Mazel Hecht, managing editor of *Fusion*.

When President Carter signed the Magnetic Fusion Energy Engineering Act into law Oct. 7, 1980, it provided the potential for the United States to launch another Apollo Project, this time to move the economy into the 21st century with an unlimited energy source and uncountable technology spinoffs. The law specified an engineering reactor to be built by 1990 and a commercial prototype by the year 2000. The FEF had waged a vigorous eight-month educational campaign to make the "McCormack bill"—known for its chief sponsor, Washington Rep. Mike McCormack—a reality.

Carlos de Hoyos



FUSION

President Ronald Reagan
The White House
Washington, D.C. 20500

Dear Mr. President,

Indiscriminate budget cuts coupled with the high interest rate policy of Federal Reserve Chairman Paul Volcker threaten economic and military disaster. The United States is now in danger of losing its scientific and technological edge in space, fusion, and nuclear energy.

Continuing the commitment to progress that has made America great requires making long-term investments in science and technology research and development.

We urge you to act now to:

(1.) lower interest rates.

(2.) fully fund the fusion budget to ensure that the nation can build a commercial reactor by the year 2000.

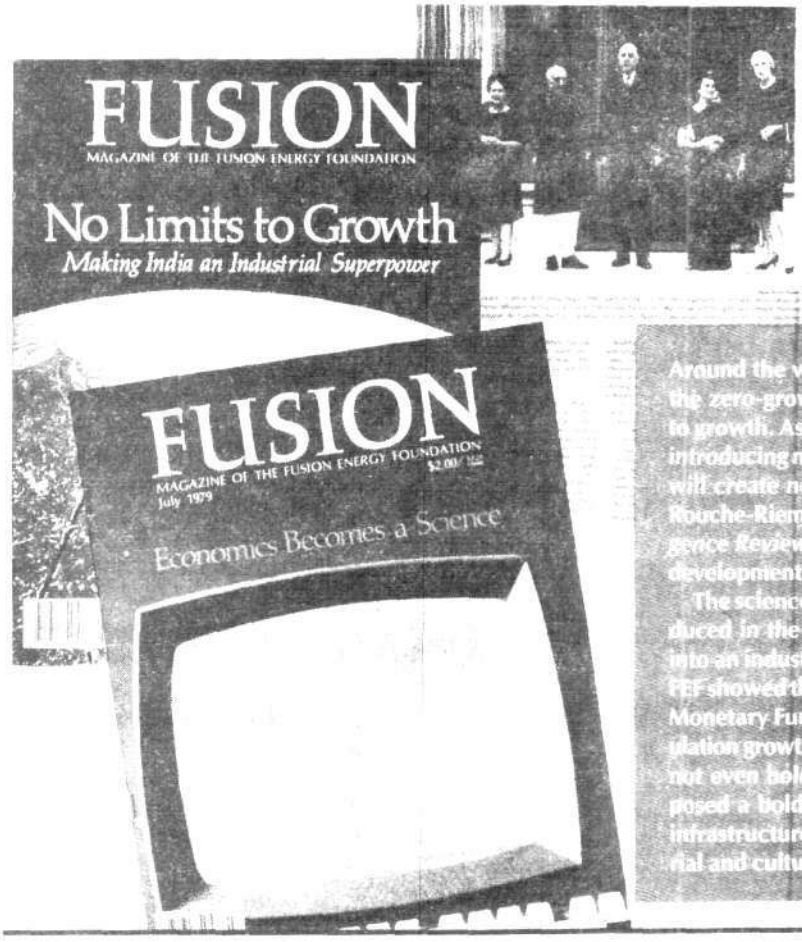
(3.) provide full [illegible]

Above: Rep. McCormack addresses a May 1981 FEF seminar in Washington, D.C., on how the science budget cuts threaten national security. Right: One of the thousands of postcards fusion supporters sent to President Reagan urging him to implement the 1980 fusion law.

Carlos de Hoyos

Above: Dr. Gottlieb at the podium. Seated at left is FEF research director Uwe Parpart Henke.

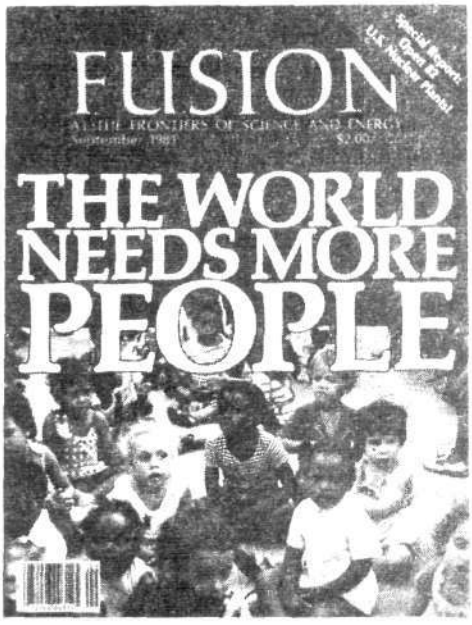
More than 350 fusion supporters gathered at a banquet sponsored by the FEF in February 1981 to honor Dr. Melvin Gottlieb, who had recently retired as the director of the Princeton Plasma Physics Laboratory. On hand to recount the history of the fusion program and Gottlieb's pioneer role were three generations of fusion scientists—including Gottlieb's college physics teacher, Dr. Robert Moon, and one of Gottlieb's former graduate students, Dr. William Ellis, then director of the Mirror Systems Division at the DOE Office of Fusion Energy.



Around the world, the FEF countered the gloom and doom of the zero-growthers by demonstrating that there are no limits to growth. As long as economies operate with a science driver, introducing new technologies into industry at a rapid rate, they will create new resources. The FEF jointly developed (with a) LaRouche-Riemann economic model with the *Executive Intelligence Review* magazine and used the model to design specific development strategies for several countries.

The science behind the LaRouche-Riemann model was introduced in the July 1979 *Fusion*. A 40-year plan to make India into an industrial superpower was presented in May 1980. The FEF showed that Malthus and his successors at the International Monetary Fund and the World Bank were wrong: Cutting population growth and barring investment in high technology would not even hold the miserable status quo. Instead, the FEF proposed a bold program in investment in high technology and infrastructure and a vast upgrading of the population's material and cultural level to transform India.

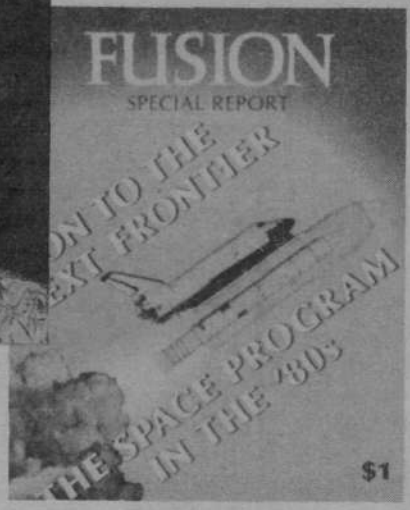
The Fusion feature was reprinted in Japanese in the popular science magazine Cosmos 82. Inset: FEF research director Uwe Parpart Henke (at podium) debated Nicholas Yost, one of the principal architects of the Carter administration's Global 2000 Report, before an audience of diplomats, government officials, and university professors. Yost stated, "We have to choose between despair, hopelessness, and total extinction," while Henke documented why "a newborn child is the principal asset of the human race, not a threat to the existence of the living."



With its September 1981 *Fusion* cover proclaiming "The World Needs More People," the FEF took center stage in attacking the Carter administration's *Global 2000 Report*. The critique made headlines around the world.

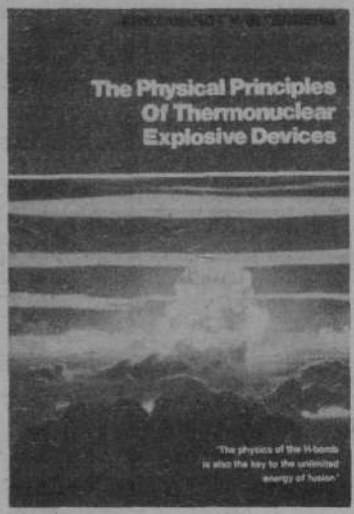
Stuart K. Lewis

Above: Marsha Freeman, Fusion's Washington editor, with astronaut Crippen.



With the successful flight of the Columbia Space Shuttle in April 1981, the FEF opened a renewed campaign for space development. *Fusion* published an exclusive interview with astronaut Robert Crippen, pilot of the first Shuttle flight, and issued a special report "On to the Next Frontier: The Space Program in the '80s." The report outlined an aggressive NASA program including a manned space station, colonization of the Moon and Mars, and accelerated planetary exploration. "The final issue is, where are we going with our civilization?. . . We are talking about the movement of civilization into space," said Sen. Harrison Schmitt in his introduction to the report. The details of how to do this were elaborated in the December 1981 *Fusion* in a cover story by renowned space scientist Krafft Ehricke on colonizing and industrializing the Moon.

In August 1981, the FEF published a book by fusion scientist Friedwardt Winterberg demystifying the science of the H-bomb and describing the basic physical principles upon which the most concentrated energy source—inertial confinement fusion—as well as the most destructive weapon are based. As Winterberg says in his introduction to *The Physical Principles of Thermonuclear Explosive Devices*: "there are no secrets surrounding thermonuclear explosive devices. . . all the basic physics is accessible in the open, published scientific literature. . . ."



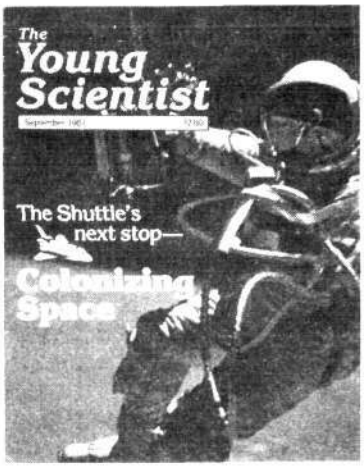
Stuart K. Lewis

Busemann chats with Carol White, then FEF education director.

Carlos de Hoyos

Above: Adolf Busemann at the podium. "I am very pleased to sit here today and hear that my ideas from many decades ago are still working and doing more than I ever would have thought about," he said with characteristic modesty and humor. He briefly described his early work at Ludwig Prandtl's institute at Göttingen in the mid-1920s on supersonic flows and his prediction of the behavior of crossing Mach waves during high speed flight. With him (from left) are Dr. Krafft Ehricke, Mrs. Ingeborg Ehricke, fusion scientist Dr. Friedwardt Winterberg, and plasma physicist Dr. William Grossman.

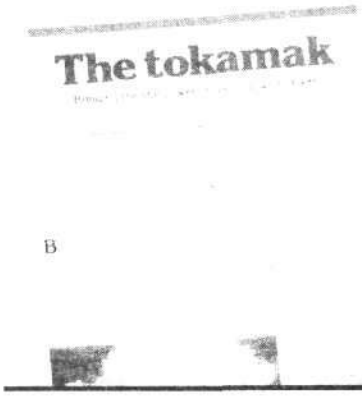
In November 1981, the FEF brought together an outstanding group of scientists at an awards dinner to honor Dr. Adolf Busemann, a pioneer in aerodynamics and one of the most outstanding exponents of Bernhard Riemann's hydrodynamic method in this century. The FEF tribute to Busemann in his 80th year was both a celebration of the classical tradition in science that Busemann represents and a call to renew the commitment to restore excellence in American science education.

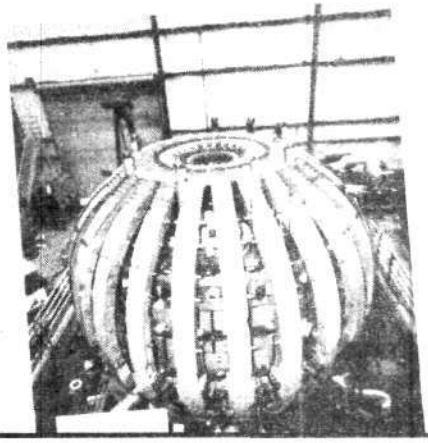


One of the weapons the FEF used in the war against scientific illiteracy was a new magazine, *The Young Scientist*, which is now incorporated into *Fusion*. The magazine got rave reviews—except from the ultraliberal environmentalists who thought it was "biased" to teach children that progress and growth were good.

Stuart K. Lewis

Above: Two New York junior high school students, Michael Masterov (left) and Yaroslav Shoikhet, who, inspired by the first issue, built a model tokamak and won first prize in the national SEER science competition sponsored by the National Energy Foundation.





Bardwell proposes anti-freeze

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"Stopping the nuclear technology would put a stop to the main chance we have for preventing nuclear war, which is energy development."
—Steven Bardwell
Fusion Magazine

Left: The Seattle Daily *at Washington University featured the FEF campaign against the freeze.*

NDPC POLICY DISCUSSION MEMORANDUM

Only Beam-Weapons Could Bring to an End The Kissingerian Age of Mutual Thermonuclear Terror:

A Proposed Modern Military Policy of the United States

By Lyndon Hermyle LaRouche, Jr.

NDPC Advisory Committee · New York City · March 1982

Above: LaRouche's March 1982 pamphlet on beam weapons.

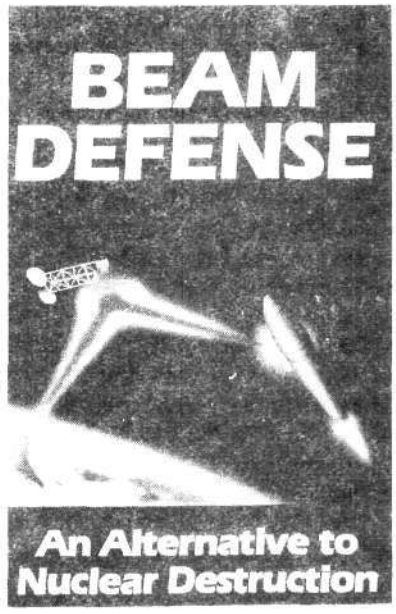
More than a year before President Reagan made his historic March 23, 1983 speech proposing the development of new technologies to overturn the era of Mutual Assured Destruction, the FEF, led by board member Lyndon H. LaRouche, Jr, had been advocating a crash program to develop directed energy beam technologies, and the FEF wrote proposed legislation to carry out this new Apollo program. The FEF also waged a vigorous organizing campaign against the nuclear freeze movement.

While much of Washington and the scientific community was stunned by the President's speech, and the press immediately began to ridicule it as "Star Wars," the FEF quickly mobilized to educate the nation about beam defense. FEF executive director Paul Gallagher appeared on CBS national television news supporting the President's proposal, and showing graphics drawn by the FEF depicting what beam weapons are. The FEF launched a national campaign with scores of media interviews and debates on the subject, plus a major conference in Washington April 13 that drew more than 600 people. Additional conferences were held in all the capital cities of Western Europe, involving many scientists and military representatives.

Stuart K. Lewis

Top right: An Associated Press story featuring Uwe Parpart Henke. Inset: Paul Gallagher interviewed at the FEF office by CBS TV. Above: Steven Bardwell (at microphone) debates anti-beam-spokesmen Richard Garwin (left) and John Parmentola. The event was sponsored in April 1983 by the N.Y. chapter of the American Institute of Aeronautics and Astronautics.

Directed Energy Beam Weapons Technologies Can End the Era of Mutual Thermonuclear Terror



In October 1983, Aero Publishers released the FEF's *Beam Defense: An Alternative to Nuclear Destruction*, the first popular book on the subject. *Beam Defense*, which has also been published in Japanese by Jiji Press, won the top award of the Aviation/Space Writers Association in May 1984.

FUSION ASIA

sia Can Lead
rld Economic Revival

Top: LaRouche (center) and Henke visit the High-Energy Physics Laboratory at Tsukuba City in Japan. FEF's theoretical publications have influenced the development of Japan's laser fusion program, in particular. Dr. Chiyoe Yamanaka, head of the Institute for Laser Engineering at Osaka University, is on the scientific advisory board of Fusion *and* Fusion Asia. *Above: Thai communications minister Samak Sundaravej speaking at an October 1983 conference on the development of the Pacific and Indian Ocean Basins. With him (from left) are Uwe Parpart Henke, Lyndon H. LaRouche, and FEF coordinator in Thailand, Pakdee Tanapura.*

An Interview with Dr. Robert J. Moon

Founding Member of FEF Talks About His 55 Years in Nuclear Science

Dr. Robert J. Moon, professor emeritus at the University of Chicago, is a founding member of the Fusion Energy Foundation, a veteran of the Manhattan Project, and a pioneer in frontier areas of nuclear science for the past 55 years. This is the first in a series of interviews with him.

* * *

Question: You've been a member of the Fusion Energy Foundation since its founding 10 years ago in November 1974. What interested you in the FEF?

When I was invited to be one of the founding members, there were essentially four points that attracted me to what the foundation was setting out to accomplish. First, I wanted to bring before the public worldwide the fact that energy is a key ingredient in the well-being of any society and that we had to increase our energy resources in order to expand our populations.

Second, energy from combustion had reached a state of equilibrium; combustion requires oxygen and oxygen comes from plants—leaves, blades of grass, and whatnot—that in the presence of sunlight convert the CO_2 back into oxygen and make chlorophyll in the plants. We had reached an equilibrium there. To continue to use more oxygen for combustion would only do one thing—increase the carbon dioxide content of the atmosphere. And since we need oxygen as human beings, this would suffocate us. It is necessary to develop the more advanced technologies of fission and fusion in order to generate spectral energy beyond that of the Sun that would convert the excess CO_2 through photosynthesis into food-producing plants.

Third, we wanted to encourage a greater exchange of ideas on advanced nuclear energy—fission and fusion—among those engaged in research in these fields.

The fourth point, very important, is that we wanted to encourage new ideas and an understanding of phenomena on the frontiers of science, especially fusion energy and related processes.

Question: You are still very much involved in these last two points, since you just began to serve as the editor-in-chief of the *International Journal of Fusion Energy*, IJFE. The journal has set out in an expanded format to aid in the exchange of ideas and new concepts not just in fusion and plasma physics, but also in directed-energy technologies and biophysics. I think you have said that we need a revolution in science today.

Yes. In these times, it is essential that articles in the journal are of such a nature that they bring about the birth of new concepts. That would be very unlikely to occur with the referee system of judging papers for acceptance that is now in use in most scientific journals. The referees always base their reviews on what is known in physics, biology, or biophysics as it stands today; but often there is a greater understanding, new interpretations, new explanations for scientific phenomena that should become known and discussed. It is the IJFE editorial policy to give authors with a

Dr. Moon speaking on the need for fusion at the founding meeting of the FEF, Nov. 23, 1974.

new concept a chance to defend their ideas and theses before acceptance for publication. And the journal has expanded to include new areas such as biophysics.

Question: The first issue of the IJFE in its expanded format, January 1985, has a few examples of the kinds of articles that are very important and yet did not make it into some of the conventional physics, biology, biophysics, and medical journals.

That's right. And instead of the referee system, the journal has an alternative method wherein the editors meet with the authors to give them a chance to defend their own theses. After an exchange of ideas over a period of two or three days, the editors then decide on that basis whether the paper is really breaking new ground on the frontier of science—not based on the established field, but based on whether the paper seems somewhat probable beyond the bounds of existing fields in which the new concepts are being developed.

Question: One of the main articles in this issue that makes that point is Winston Bostick's piece on the morphology of the electron.

Yes, I think that Bostick's filamentary model of the electron is an excellent one. Classical physics has made the structure of the electron spherical, that is to say, a rigid, massless sphere covered uniformly with a massless electronic charge, with all the rest mass of the electron generated by the energy contained in the electric field from the surface of the sphere out to infinity. That meant that the electron exists from the surface of the sphere out to infinity! And when in motion, a magnetic field was generated perpendicular to the electric field and the velocity of the electron (these are vector quantities). This additional mass due to the energy of the magnetic field, plus the rest mass, approaches infinity as the velocity of the electron approaches the velocity of light. This model yielded the classical relativistic increase of mass as a function of velocity.

Yet this classical model of the electron was not very congruous with the general nature of things, as something that extended throughout the entire universe; in other words, its mass was not localized.

Winston Bostick describes the electron as right-handed and left-handed screws joined together to make a torus that's been twisted a couple of times and has a charge circulating in it. This filamentary model then produces all the measurable qualities that an electron is supposed to have, and does it in a very amazing way. I think it is a concept that could very well prove useful.

Question: What effect do you think the electron article will have on the physics community?

It's hard to say. Since the state of physics is such that they have gone as far as they can with the classical structure of the electron, the quantum mechanical structure, and the wave mechanical one, I think they really should turn to a structure of the sort that Bostick describes for further insight into the nature of the electron. It seems that Bostick's model describes all known properties of the electron in one model and this concept may possibly lead to the discovery of the yet unknown nature of the electron.

Question: This is really some of the first material in physics in years, since the era of Heisenberg and Einstein and so on, that deals with basic ideas about the physical world in a fundamental way.

That's so true. And this kind of thinking has needed to be done. A great deal of the things that are so necessary for science consist of not only looking forward to the future but also referring backwards to what has happened in the past, so as in that way to get a better idea of the nature of the physical world.

Question: I think that the article by Erich Bagge of Kiel University also fits this description; it contradicts so much of what is going on today in high-energy physics, because he shows clearly that neutrinos do not exist.

That's right. Bagge has shown that neutrinos are not needed in order to describe the beta-ray spectrum and the energy balance in the reactions he studied. To date no free neutrino has been isolated. It's a very small particle, according to the theory, and it has a very tiny cross section of 10^{-44} square centimeters. It's so tiny that it could even pass through the Earth and not be detected!

"We're living in an age in which energy is key. For more people we need more energy. This means controlled fusion. Otherwise we get into a problem; people say, 'well, let's solve it by cutting down the world population.' But that's no solution. . . . It means you lose all that creativity. This is a really exciting, challenging time, and there's much ahead."

—Robert Moon
addressing the founding meeting of the FEF

Question: So as the neutrino is usually described, it's essentially undetectable. I think you mention in your editor's note in the journal that you would need 10^{18} meters of lead to catch even half of the neutrinos postulated.

The only way that scientists have tried to detect it is indirectly; but that is not very satisfactory. They've tried to use the antineutrino to detect it, and yet they don't know if the antineutrino exists! The neutrino is still a particle with zero charge in the minds of scientists, but recently it seems to have a slight mass . . . less than 42 electron volts, approximately 1/10,000 times the mass of the electron.

Question: It's like using a ghost to find another ghost—

Or rather, to find an anti-ghost—whatever that is! There are several particles in particle physics, some of which we can describe and for which we have experimental data. For example, the three types of heavy electrons, the various leptons as they are called. Some of these supposedly involve neutrinos in their reactions; but still we have not

really found a free neutrino, and we don't have any way to find one, because it doesn't ionize, or react mechanically or electrically with matter.

I think Bagge has shown, that in electron-positron pair production by means of gamma rays, all the energy can be accounted for without the neutrino. This has been the enigma even back in the early 1930s. Where is that missing energy in the beta-ray decay of the nucleus, since all the electrons produced don't come out of the energy of the reaction? The neutrino was invented to take care of that missing energy.

Question: When was the neutrino invented?

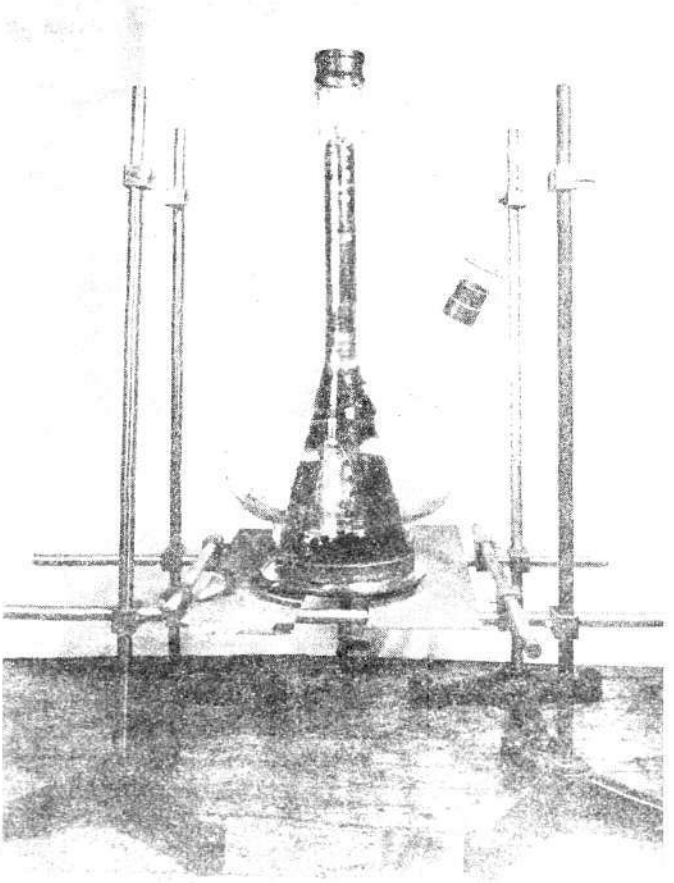
It was invented by Pauli in 1927, and then it was elaborated upon by Fermi in 1932. He set up some mathematics that could show some of the properties that a neutrino could have, none of which were measurable. Anyway, this gave most physicists a way to satisfy themselves theoretically that a neutrino must exist, because here there exists a theory that says so. So we have looked for the neutrino all these years and it's never been found free.

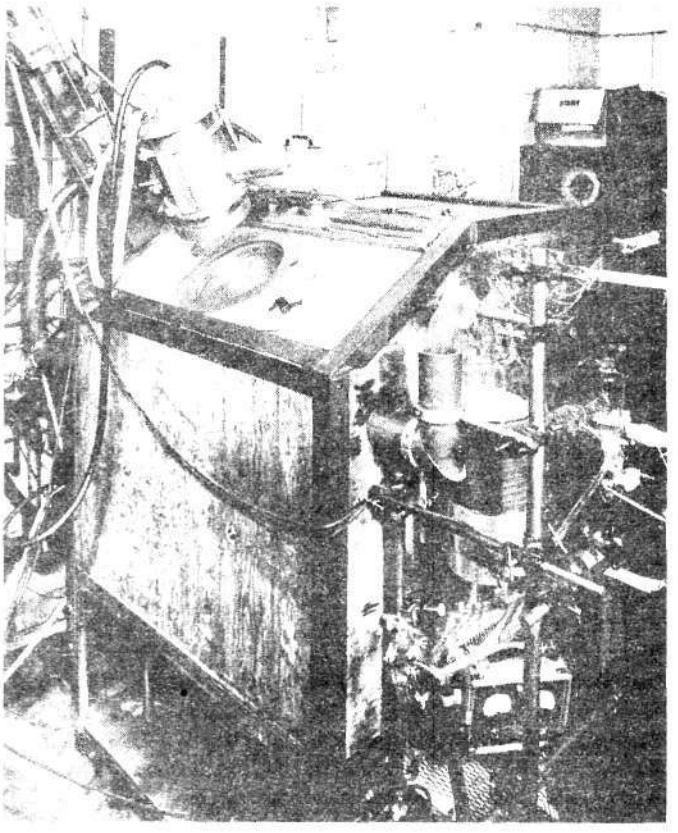
Question: That's nearly 60 years of not finding a neutrino, but developing more and more theory about what it must look like, as derived from some particles that have nine new types of quantum numbers such as charm, color, strangeness, and so on. I think in your editor's note, you likened this to the epicycles of Ptolemy. I guess those epicycles were around for many, many years, before thinkers like Kepler and Copernicus were able to end the epicycles.

And that was very difficult, to change men's minds around to thinking about epicycles in another way—that we on Earth were not the center of things, but the Sun is, and that we revolve about the Sun instead.

Question: I know this won't be the first time that you have contributed to changing men's minds about how the world works. You've accomplished a number of firsts throughout your career. In 1930, I think, you were probably the first person who suggested a doctoral thesis on how to create fusion power as a graduate student at the University of Chicago. And I know you were the first to build the scanning X-ray system that led to the CAT scanner, the first to discover the correct cathode surface for a high-current electron gun, the first to design and build an effective cyclotron, and a whole host of other things. You were also the editor-in-chief of the first few issues of *The Bulletin of Atomic Scientists*, before it turned antinuclear, so for that reason the present *Bulletin* leaves you out of its history. Would you like to tell us a bit about some of these things?

In my undergraduate work at Southwest Missouri State College, I had two very good professors, one in physics, Prof. A.P. Temple, and another in chemistry, Prof. Robert W. Martin, who allowed me to use all the equipment—including new and unused—that was in the storeroom. I was able to do a lot of fundamental experiments with that. In exchange for this privilege, I had to demonstrate all this before a lot of other classes. At the time I read all the articles describing the possibility of fusion energy, and it seemed to me that this was the energy for the so-called millennium that was to come, the thousand years of peace and pros-





perity. Back then, they were talking about its arrival by the end of the century.

Question: This was even before fission was discovered and proved.

Right, it certainly was. And so, when I was just a youngster of 19, I came to the University of Chicago and I presented a proposal on creating fusion energy in the laboratory to the physics department. But they weren't at all interested in nuclear energy. They said the energy is there but it will never come out; all has been done that can be done. As far as they were concerned, the books were closed

But there was one professor at Chicago, William Draper Harkins, a physical chemist, who had written several papers which I had read on the structure of nuclei, and the particles that should be in the nucleus, and so on. He took me on as a thesis student. "We just have a small amount of equipment for the things you want to do," he said, "but it's very important to construct some of the equipment we don't have in order to do your thesis work." So I went ahead and built the first Geiger counter on the campus. It had a recycling binary recorder that printed out in decimal numbers instead of digital numbers. Also I developed a scale of 10 (a recycling binary), in order to go from the binary system to the decimal system in counting the number of particles out of a radioactive reaction.

Above: Moon viewing the scanning X-ray system he designed. Shown are the control panel, storage system, and viewing kinescope. Top left: Partial assembly of target glass enclosure and gun anode support. Bottom left: Scanning X-ray assembly. Outer box is shield of 1/2-inch lead. Vacuum pumps are exterior to box on right. CaF_2 single crystal housing and photo multiplier tube are at the upper left.

While I built the equipment for the nuclear work, I did another thesis on the study of surface structures by means of slow electrons (less than 50 electron volts energy). Then I got involved in building the cyclotron. You know, we built the best cyclotron in the world, right in the middle of the Great Depression! And it cost $30,000, including my salary and the salary of my associates, as well as the material costs, the model magnets for design of the cyclotron—everything. This model magnet had quite a history. It was borrowed by universities all over the country to help other people build cyclotrons.

We had to make a lot of the equipment ourselves. We designed the transformers and built them, and one of our students helped design the vacuum tubes for the push-pull amplifier of the final stage. These tubes were continuously pumped vacuum tubes with the properly shaped water-cooled grids. These were capable of generating about 100 kilowatts, and it could go up to 200 kilowatts of radio frequency power—10 megacycles—to drive the "dees" of our cyclotron. "Dees" was the name given to the accelerating electrodes, which were like a pill box cut in half, an open "D" shape. So we had a good healthy beam of 150 microamperes of deuterons.

Let me tell you, too, that a man like Fermi didn't get into nuclear physics until the neutron was discovered in 1932. In 1932, people like Fermi came into the field, because here was a particle that could go into the nucleus of the atom; they were bombarding everything, every element, with neutrons. At the time, the most prevalent neutron source was a radium-beryllium source, where alpha particles hit beryllium and the nuclear action that followed produced neutrons. The cyclotron could be used as a prolific source of neutrons.

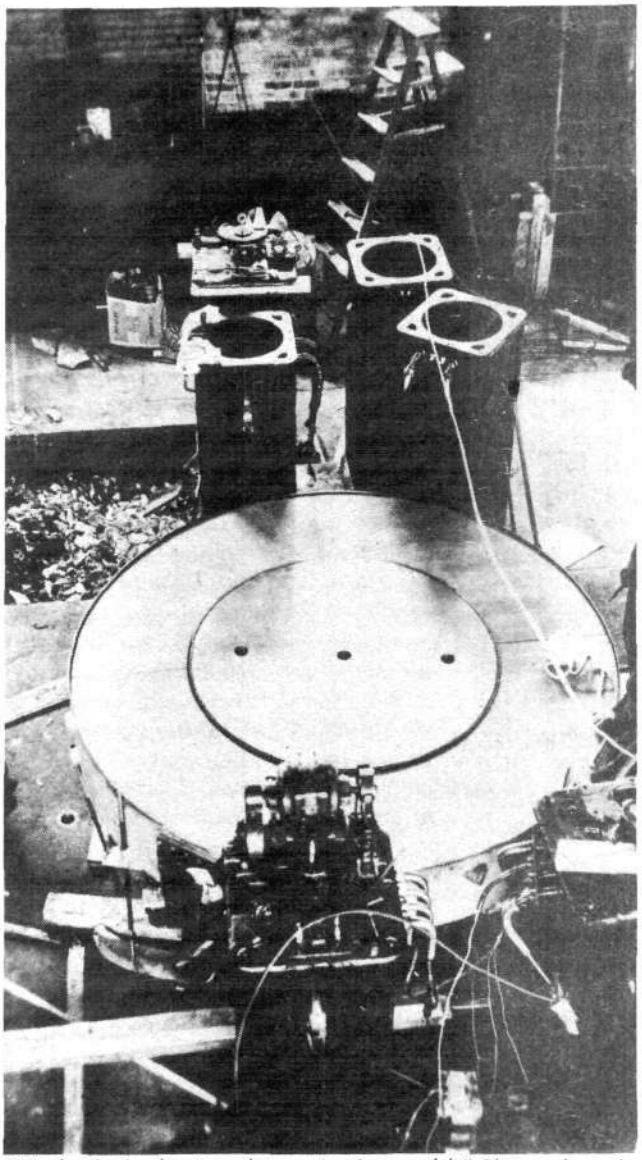
Historically, it took a long time to discover the neutron—two years after one of the fundamental experiments was done—for them to find out what the particular radiation was that was coming out of the radium-beryllium source. A block of paraffin was bombarded with this radiation and it was discovered that protons were coming out the other side. Well, anyone who's played billiards knows that if a ball is hit head-on by another one of the same mass, it stops and the other billiard ball goes on. Therefore, this strange nonionizing radiation must have had the same mass as the proton, but zero charge. It was knocking the protons out of the paraffin like one billiard ball hitting another one head on.

J. Chadwick, in England, put all of this information together and did some other experiments, and showed that what was coming out—this strange radiation—was a neutron, in fact. That marked a turning point in many physicists'

minds, for here was a particle that could enter the nucleus without being repelled by the nuclear charge.

Question: This was in 1932?

Yes. And that was when Fermi entered the field of nuclear physics. Then we went through a period from 1932 to 1938, six years, of just bombarding everything with neutrons, including uranium. And Fermi worked on uranium, and found the products of neutron bombardment were highly radioactive—a neutron was being added to a uranium nucleus followed by one or more electrons being given off. And the same type of nuclear reactions was taking place with the new-product nuclei, and thus transuranic elements—elements with a greater nuclear charge—were being produced.



"We built the best cyclotron in the world." Shown here is the cyclotron core (50 inches diameter) as the magnet and coils were being assembled.

Question: Was Fermi working at the University of Chicago at the time?

He was in Italy and he came over to this country to give some summer courses at the University of Chicago, and he had a lot of fun in teaching the courses, particularly in regard to nuclear reactions, with a jovial spirit and frequent use of his pocket slide-rule. Then he would go back to Italy. But as time went on, the Nazi movement and the fascist movement began growing. They always wanted Fermi, who was already very well known, and the King to sit on the stand with Mussolini when he spoke, and Fermi didn't like that. So when things got kind of tough in about 1937, he came over to this country with some of his colleagues and stayed. He joined the University of Chicago faculty and others from his group went to the University of California. . . .

Now, the interesting thing was that in these experiments bombarding uranium, there was some fission going on, unknown to Fermi's group, for fission hadn't been discovered yet. Fermi had said, "Oh, we're getting transuranic elements," and he published several papers with that interpretation. He was awarded the Nobel Prize for having done all this wonderful work in discovering "transuranic elements." Well, some of the product nuclei were transuranic, but the majority of product nuclei he was seeing was the result of the fission of uranium, which produces fission products, roughly one-half the mass of uranium, that are highly radioactive. There were many other things for which Fermi could have been awarded the Nobel Prize; however, the Nobel Prize committee happened to choose an erroneous part of his research.

At any rate, the first to know about fission in this country was the Chemistry Department of the University of Chicago. Aristede von Grösse was on our staff, and he had gone over to Germany. He learned of some very significant chemical research. He met with Otto Hahn and Leo Strassman, who were not very well known at the time. They were bombarding uranium with neutrons and studying the chemical properties of what was produced by the bombardment—working on a lab bench about eight feet long. They said to von Grösse: "Look, there are no transuranic elements that we can find. The majority of these elements that are produced from uranium-bombarded neutrons are in the middle of the periodic table. The only thing that we can say about this is that it seems as though the uranium atom is splitting in half!"

And so von Grösse came back with that information, and we had several meetings in the chemistry department, particularly among the physical chemists. We couldn't believe it unless we did the experiments, so we did every kind of experiment. Physicists were really slow to pick up on it, because they thought, "Well, all these people in chemistry, they don't know what they're doing!" They said this because what we were finding was contrary to their philosophy.

Anyway, in six months, the world over, the world community of scientists realized that uranium did fall apart and it did produce about 250 million electron volts per fission of uranium and about two very high energy neutrons.

Reagan Slashes U.S. Fusion Budget

When President Reagan sent his fiscal year 1986 budget to Capitol Hill Feb. 4, no one was expecting great increases in the energy, space, or science programs because a balance-the-budget atmosphere prevailed. There was no question in anyone's mind, however, that the President would insist on increased funding for his Strategic Defense Initiative. Yet, while the $3.8 billion SDI request is more than double the fiscal year 1985 level, the deep cuts the President requested in the magnetic and laser fusion programs and the NASA space-station project sacrifice the scientific research and infrastructure development that is key to the beam defense program.

The President is getting bad advice from his science adviser, the budget office, and his economic advisers. The SDI will be greatly handicapped without research in plasma physics and technology development in the magnetic and inertial fusion programs.

The civilian space program, the nation's greatest technology driver for growth, is also slated for real cuts. The space station, which the President designated to be built within a decade, is needed as soon as possible; it could and should be built by 1992. It will provide industry, foreign nations, and the military with a testing ground for crucial new technologies, a repair facility for spacecraft of all kinds, and an opportunity to extend the frontiers of space science and exploration.

The President cannot capitulate to budget cutters and have his beam-weapon defense program at the same time.

Fusion Dismantled

For the past three years, Dr. George Keyworth, the President's science adviser, has been in charge of policymaking for the magnetic fusion program. Despite the fact that Congress nearly unanimously passed a law in 1980 committing this nation to an Apollo-style effort to demonstrate commercial fusion power by the turn of the century, Keyworth dictated that the program remain in the "basic research" phase.

The administration did ask for a modest increase in the magnetic fusion program for fiscal year 1985. The Congress would not agree to spend almost a half billion dollars on a "research project." Last year, therefore, the fusion budget was cut back to $437 million from a request of $483 million.

This time, the administration took the knife to the fusion budget itself, and is requesting $390 million. At that level, current experiments cannot continue on schedule, achievement of energy breakeven will be postponed—perhaps indefinitely—and construction programs will probably be terminated.

Since 1977, the magnetic fusion budget has not even kept up with inflation. At more than $300 million in 1977, by 1985 the funding was only about $200 million in 1977 dollars. The current cut, if not restored by Congress, will shrink fusion research back to the level of the early 1970s, and the United States will relinquish its unchallenged leadership in the field.

In inertial confinement fusion, the picture is even worse. The fiscal year 1986 funding level for laser and electron-beam development has been cut by $100 million to $70 million. Crucial science programs at universities will be sacrificed, and even if the SDI office does fund some of the work dropped from the fusion budget, civilian plasma physics research and power reactor development will be eliminated.

—Marsha Freeman

Oncogene Research

Continued from page 23

surfaces. Normal resting state cells do not have these receptors, but abnormal leukemic cells have thousands per cell. Dr. Thomas Waldman, head of the Metabolism Branch of the Institute, has developed an antibody to the TCGF receptor that prevents most of the TCGF from stimulating the cells to grow. A patient who was given this treatment has lived 12 months so far.

The use of monoclonal antibodies, antibodies grown in bacteria using gene splicing, has been extended to administering them directly into the lymph system to target cancer metastases, which frequently spread through the lymph ducts to distant lymph nodes. Dr. John Weinstein at the Laboratory of Mathematical Biology of the Institute has shown the potential to use radioactive-tracer-associated antibodies to track distant metastases, and is studying the use of antibody-toxin combinations for treating such metastases.

In a related development, Dr. Jeffrey Schlom at the Institute Laboratory of Tumor Immunology and Biology developed an antibody that reacts with a protein that is found in 85 percent of human colon cancers and 50 percent of breast cancers. The antibody, called B72.3, has not reacted to any normal tissues so far tested. Schlom showed that this antibody, combined with radioactive tracers, can successfully identify tumors in mice, and is now testing this system in humans.

The mode of cancer invasion is another possible site for therapeutic intervention. Dr. Lance Liotta of the Institute's Laboratory of Pathology focused on a key protein, laminin, present in normal connective tissue and blood-vessel walls, which cancer cells bind to in order to penetrate through these tissues in the process of local invasion and distant metastatic spread. Liotta isolated the cancer cell surface-binding site for attaching to this protein. He then made fragments of the laminin molecule and injected them into animals with cancer; these fragments bound to the cancer cells and prevented them from binding to the animal's laminin, stopping the process of metastasis.

How to Make a Leyden Jar

by David Cherry

Benjamin Franklin used a Leyden jar, which stores and releases electric charge, to do many basic experiments with electricity. In his book *Experiments and Observations on Electricity* he describes these experiments, and 230 years later the concepts he developed there are still important elements of electrical theory. The Leyden jar is the first version of an electric capacitor or condenser.

Here's how to build and charge a Leyden jar.

The materials you will need are:

- a peanut butter jar or other wide-mouth jar, or a laboratory beaker*
- a piece of cork (a wine bottle cork is good)
- several inches of wire—a piece of coat hanger or a large paper clip bent out straight
- several standard paper clips
- a piece of cardboard
- aluminum foil
- tape
- a discarded phonograph record
- a piece of wool or a woolen sweater
- a bar of paraffin wax or two small bars of soap
- silk thread

Remove any label attached to the jar. When the jar is clean and dry, tape a strip of aluminum foil several inches wide all the way around the outside of the jar, and another strip around the inside of the jar. Take care to get the foil as close to the surface of the jar as possible. To tape the bottom edge on the inside of the jar, put each bit of tape lightly on the end of a pencil; then lower it into place.

Now push the piece of wire through the cork and bend each end of the wire into a hook. If the cork does not fill the mouth of the jar, cut a circle of cardboard large enough to cover the jar, and then cut a hole in the middle of the cardboard just large enough to hold the cork securely. The cork will not pick up moisture in the air, but the cardboard will, which makes the cardboard a conductor (except in very dry weather).

Next, make a chain of several paper clips and tape one end of the chain to the foil inside the jar. Turn the jar upside down so that the chain will hang out. Then catch the free end of the chain with one of the hooks of the cardboard lid and set the apparatus upright.

Form a small ball of aluminum foil around the hook that sticks up from the cork. This ball will help the Leyden jar hold its charge, for the same reason that a pointed lightning rod draws off lightning better than a blunt one. (Benjamin Franklin discovered this, too.)

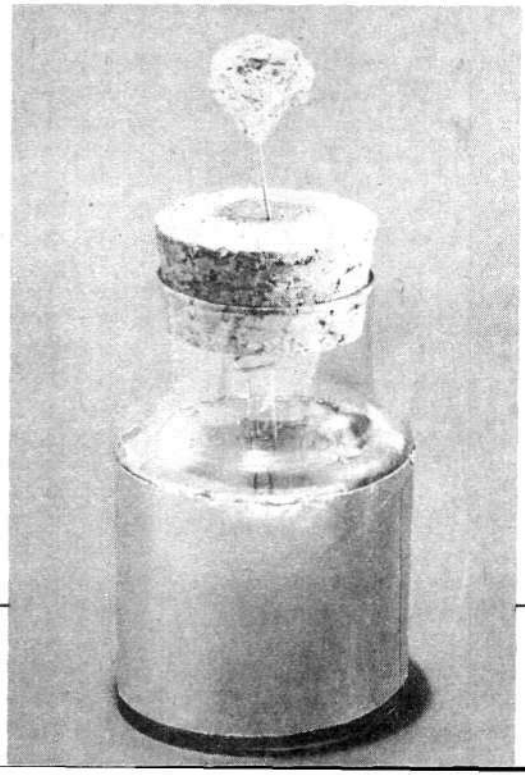
Charging the Jar

To charge the Leyden jar, you should place it on a good electrical insulator. A piece of paraffin wax, a sheet of plastic, or a formica table top will do. Now, rub the piece of wool over the surface of the discarded record. With vigorous rubbing, the record will develop a good static electric charge.

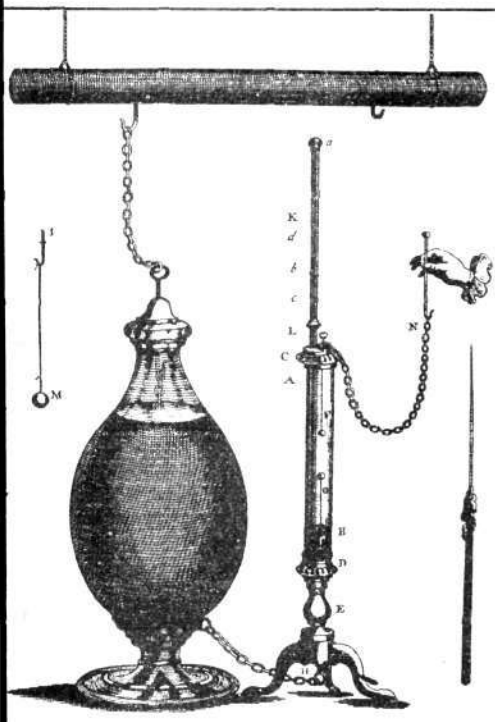
Next, while holding the record between two slabs of paraffin wax or between two small bars of soap (in dry weather, two blocks of wood will do), touch the record to the ball of foil. Touch several places on the record to the ball. You will have to experiment to know how many times to repeat the rubbing and touching to build up a charge on the jar.

To discharge the jar, put your thumb on the outside strip of foil and touch a finger to the ball. If you have a small charge, you will see a spark when you touch the ball. If you have a larger charge, you will also get a shock. If you build up an even larger charge, discharge it using an insulated piece of wire instead of your fingers to touch the ball.

You can measure the charge you build up in the jar using an *electroscope*, a device that detects electric charge. (Building an electroscope was the subject of the Experiments column in the November-December 1981 issue of *The Young Scientist*, page 15). If you have an electroscope, tape one end of a wire to the outside strip of foil and attach the other end to your electroscope. As you add to the charge on the jar, the leaves of your electroscope should measure it.



The Leyden jar is a capacitor or condenser that stores electrical charge. The charge is stored on the inner surface of the glass and induces an opposite charge on the outer surface. The glass is a dielectric; that is, a charge cannot pass through it until a certain high level of charge has accumulated. The purpose of the inner and outer layers of foil is to conduct and distribute the charges over the two surfaces of the glass.



Franklin's Leyden jar. A chain on the ring atop the jar runs to a large rod of polished ebony, which was charged by rubbing. At right is a device to demonstrate that electrical discharges produce heat. When the wand (N) is touched to the top of the jar, a sufficient charge will cause a spark across the gap from F to G inside the vertical tube. When the temperature rises inside the tube, it registers on the thermometer (K). At left, a ball of cork suspended from a silk thread, to demonstrate the presence of charge on the Leyden jar.

Franklin's Experiments

You can also reproduce two of Benjamin Franklin's experiments.

Franklin showed that the inside and outside of the charged jar carried opposite charges. To do this he used a very small cork attached to the end of a silk thread. (Silk will not readily absorb moisture from the air.) You can do this experiment using a bit of cork or Styrofoam tied with thread. Holding the thread, lower the cork to touch the ball atop your charged jar. It will be attracted and then repelled.

What is happening? The cork is attracted by the charge, and takes on some of it. But then it is carrying the same kind of charge as the ball, and like charges repel each other.

Now, lower the cork to the outside foil around the jar. Is the cork atrracted or repelled? If, indeed, the outside of the jar were of a charge opposite to the inside of the jar, the cork should be attracted; if it were of the same charge as the inside, it should be repelled.

Franklin was able to show that the opposite charges accumulate on the inner and outer surfaces of the glass, and not on the conductors (the foil strips), which only conduct and distribute the charges over the glass. To do this experiment, remove the inner foil and fill the jar with water. The water will conduct the current as the foil did. Dissolving some salt in the water will improve its conductivity.

Franklin charged the first jar, then poured the water out into another jar. Which jar now had the charge? Was the charge carried in the water? No—the original jar remained charged.

To show this, you must be able to remove the water without discharging the jar in the process. If the water spreads across the lip of the jar, you will lose the charge. Also, you should not touch the outside foil of the jar; touch only the glass. You could remove the water with a straw or a siphon of the kind used for emptying aquariums. Now discharge the jar with a thumb on the outside foil and forefinger at or just inside the lip.

The Leyden jar will not work as well (or perhaps not at all) on moist days. It will lose its charge to the moisture in the air and never build up enough to produce a spark.

Note

*If you cannot get a peanut butter jar to work, try the experiment using a laboratory beaker. Laboratory glass is borosilicate glass, which seems to work better for small charges.

Also, because the laboratory glass is thinner, the two strips of foil are closer together, which may be necessary for smaller charges. Your science teacher may have a beaker, or you can purchase one from a laboratory supply store.

You can order a 250-milliliter beaker by mail by sending a check or money order for $3.25 to Chem Lab Supplies, 13814 Inglewood Ave., Hawthorne, California 90250.

Krafft Ehricke

Continued from page 9

volves the use of the lunar soil as a fluid. (The word comes from *harena*, sand, in Latin.) The soil could then be used in place of liquid fluids on Earth, in applications such as the cooling of nuclear power plants.

Harenodynamic braking has been proposed by Ehricke for a lunar slide lander, a transport vehicle that would land on a sand runway, using small blades to deflect and eject the sand, thus braking the vehicle. Ehricke's method does not require propellant for retrothrusting, as does conventional braking for landing on the Moon, such as that of the Apollo Lunar Module. Also, the slide lander would not release gas in the lunar environment, which allows the possibility of keeping it gas-free for astronomical observing.

Ehricke developed hundreds of ideas over his career that mankind will need to conquer space—techniques for disposing of highly toxic and long-lived nuclear fuel waste in space; using mirrors in Earth orbit to increase agricultural productivity and modify the weather; and small single-mission space stations that would be in different orbits for specific missions, to name just a few.

At his death, Ehricke was completing a book called *The Seventh Continent: Industrialization and Settlement of the Moon*, which the FEF is now involved in publishing. For the tens of thousands of people who can carry his work further, and for the millions of Americans and others worldwide who do not believe there are limits to growth, either physical or philosophical, Ehricke's work will be essential in carrying out what he defined as the extraterrestrial imperative—man's mission to create a more open world to enrich future civilization.

—Marsha Freeman

Nuclear Winter

Continued from page 19

mally small they were straight lines. Weierstrauss constructed a function that is continuous everywhere but differentiable nowhere; it is nowhere linear.

Infinitesimals

A Weierstrauss function has no smallest scale. If you magnified the graph of the function, it would be just as intricate no matter how much you magnified it (Figure 2) and the function is self-similar throughout all levels of scale. Leonardo da Vinci's water studies are suggestive of such differentiation.

Does such a function exist in nature? Recent work has shown that the so-called Brownian motion of air molecules is most simply described by a Weierstrauss function. M.V. Berry and Z.V. Lewis discuss this—though from a backward, statistical standpoint. A Weierstrauss function, they write, "is a model for the distance traveled along an axis in time *t* by a particle moving in infinitesimal steps which are equally likely to be backwards or forwards."[7]

Human hearing is one of many examples of how infinitesimal action can affect a large-scale process. The movement of the eardrum on the order of the diameter of a hydrogen atom coincides with the perception of sound. In addition, Georg von Bekesy argues that during ordinary conversation, the amplitude of the movement of the basilar membrane of the inner ear was about the radius of the hydrogen atom.[8] Recent work indicates that a basilar membrane movement on the order of 1 picometer (1 trillionth of a meter) correlates with sensation, thus confirming von Bekesy's hypothesis.[9]

If scale of resolution were the only criterion by which to judge models, this result would put weather modelers a factor of 10^{15} away from lawful processes.

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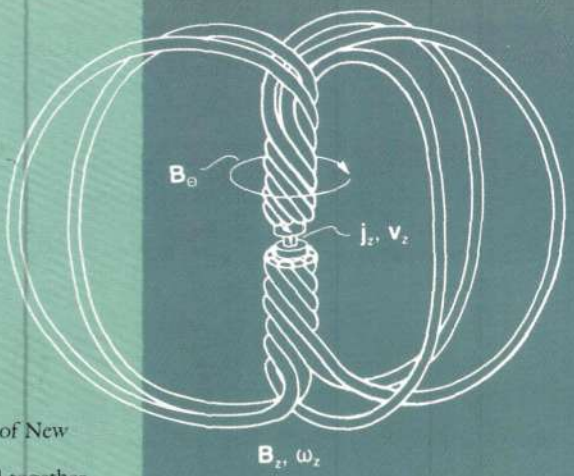

The Morphology of the Electron

by **Winston H. Bostick,** Stevens Institute of Technology and University of New Mexico

A new model of the electron as right-handed and left-handed screws joined together to make a filamentary torus that's been twisted a couple of times and has a charge circulating in it . . . replaces the contradictory hard ball of Newton, bringing quantum theory back into the family of classical physics.

Missing Energies at the Pair Production by Gamma Quanta

by **Erich R. Bagge,** Institute for Pure and Applied Nuclear Physics, University of Kiel, West Germany

A theory of beta decay without neutrinos.

The Relation between Angular Momentum and Star Formation in Spiral Galaxies

by **L. Carrasco and A. Serrano,** Institute of Astronomy, University of Mexico

Star formation takes place in galaxies at places of low specific angular momentum, suggesting that structure at one level is dependent on differentiation at lower levels.

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by **James Frazer,** Houston Medical Center, M.D. Anderson Hospital

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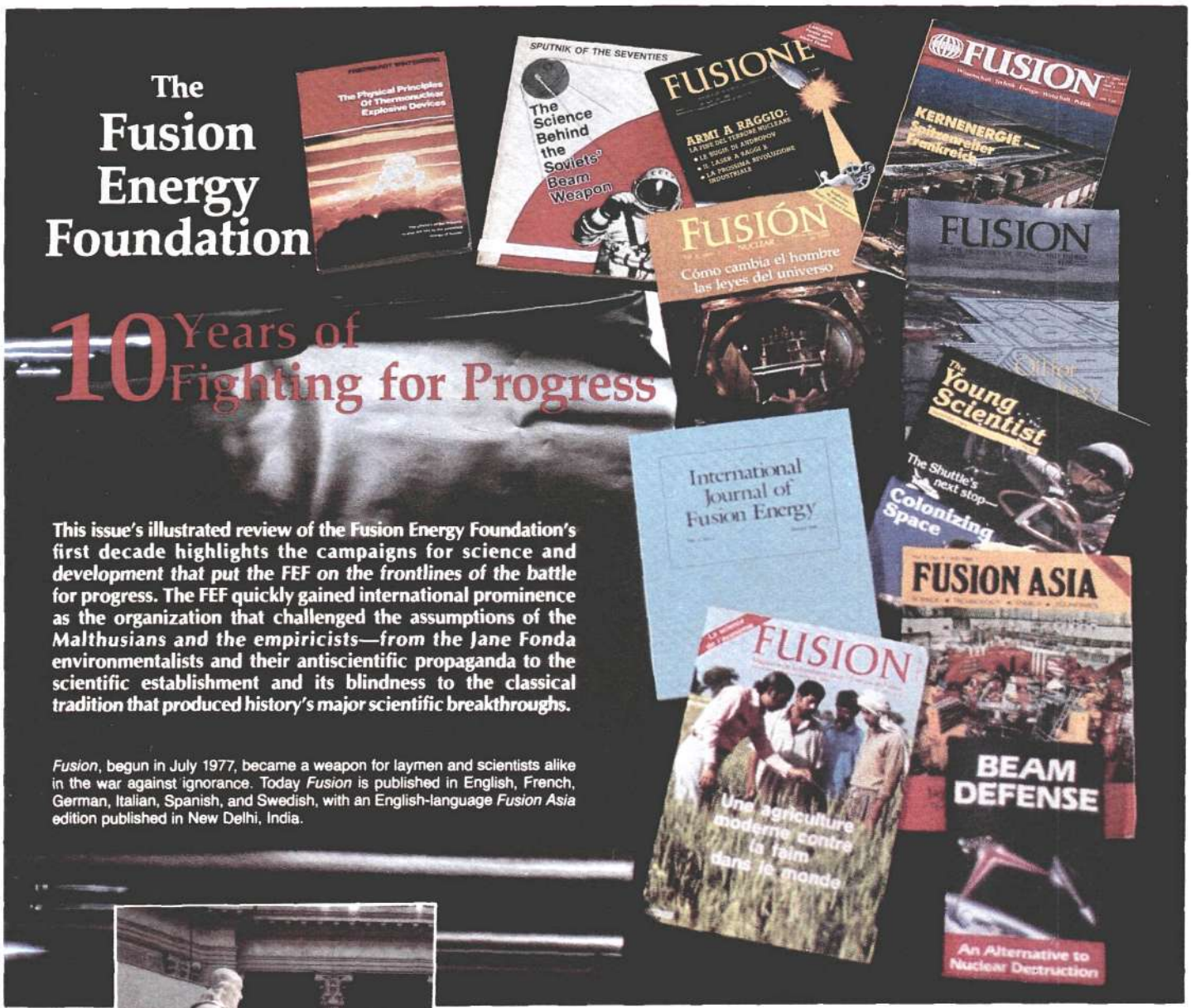

This issue's illustrated review of the Fusion Energy Foundation's first decade highlights the campaigns for science and development that put the FEF on the frontlines of the battle for progress. The FEF quickly gained international prominence as the organization that challenged the assumptions of the Malthusians and the empiricists—from the Jane Fonda environmentalists and their antiscientific propaganda to the scientific establishment and its blindness to the classical tradition that produced history's major scientific breakthroughs.

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Stuart Lewis

Virginia Baier

"The rapid Progress true Science now makes, occasions my regretting sometimes that I was born too soon. It is impossible to imagine the Height to which may be carried, in a thousand years, the Power of Man over Matter."

Franklin, Leibniz, and the Göttingen School:
The Forgotten Origins of American Science

Most Americans have no idea that Benjamin Franklin and the foundations of American science are rooted in the German classical tradition. Also unknown is the fight that Franklin waged for the Leibniz-Huygens approach and against Isaac Newton's "orthodox doctrine." In our lead feature, Warren J. Hamerman reviews Franklin's scientific work and his ties to the Leibnizian circle and the Göttingen University hydrodynamic school. A revival of this tradition is necessary today if America is to make a scientific-technological revolution.