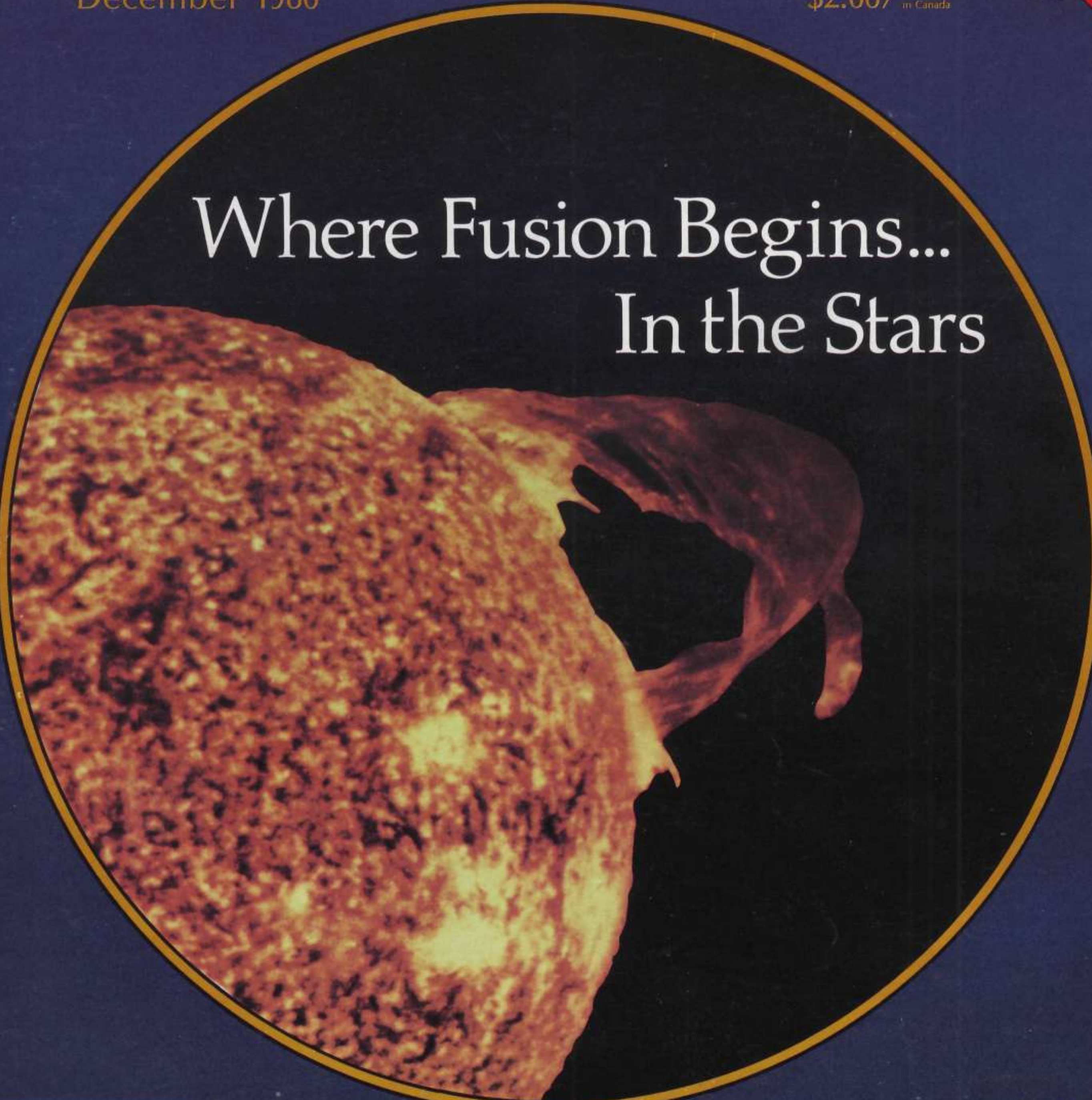
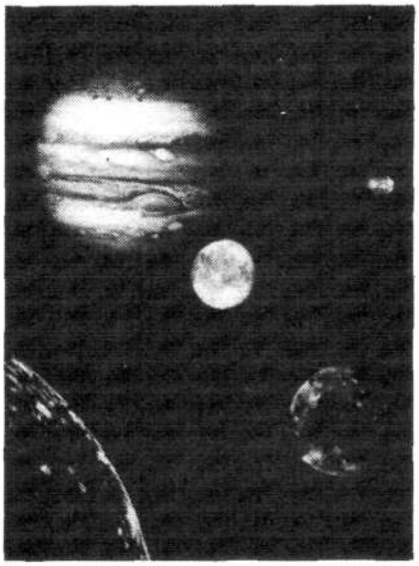
FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION
December 1980
$2.00/ $2.25 in Canada

Holiday Bonus for Subscribers
Premier Issue of The Young Scientist
See page 3



Fusion and the Frontiers of Astrophysics

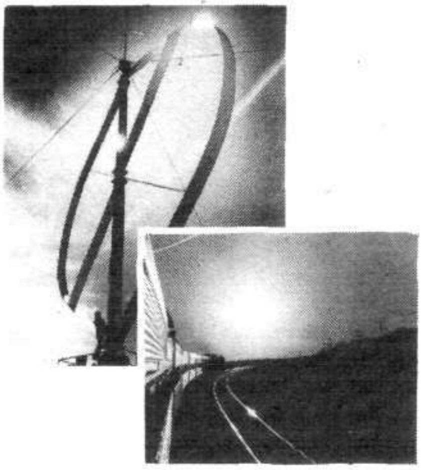


Jupiter and its moons, one of the many worlds NASA has opened up to us. See page 29.

Features

Fusion and the Frontiers of Astrophysics

News



Sunset versus sunrise industries: This issue's special report shows why the administration's reindustrialization plan is really deindustrialization. *See page 14.*

Departments

From the Editor's Desk

The Young Scientist

The December *Fusion* has more than the usual good news on issues we're involved with. The McCormack fusion bill is on the president's desk, Maine residents voted a hefty "yes" for nuclear power, the Senate voted to send nuclear fuel to India (where the FEF has been making news), and the Fusion Energy Foundation has launched its new magazine for children—*The Young Scientist*.

We are sending the premier issue of *The Young Scientist* to every *Fusion* subscriber as a holiday bonus, and we hope that you'll be as excited as we are at the prospect of bringing news and features of the frontiers of science to 10 to 14 year olds. We intend to expand *The Young Scientist* in number of pages and frequency of issue and to make it into a best seller that will help educate young scientists to be the thinkers and discoverers of the 21st century.

Fusion *Washington news editor Marsha Freeman with Rep. Mike McCormack on Capitol Hill.*

Coming up in January is a firsthand report on Mexican development by FEF research director Uwe Parpart with his color photographs of Mexico's high-technology agriculture and petrochemical industry.

Marjorie Mazel Hecht

Marjorie Mazel Hecht
Managing Editor

FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION

Vol. 4, No. 2 ISSN 0148-0537
December 1980 USPS 437-370

FUSION is published monthly by the Fusion Energy Foundation, Suite 2404, 888 Seventh Ave., New York, N.Y. 10019, Tel. (212) 265-3749. Dedicated to providing accurate and comprehensive information on advanced energy technologies and policies, FUSION is committed to restoring American scientific and technological leadership. FUSION coverage of the frontiers of science focuses on the self-developing qualities of the physical universe in such areas as plasma physics—the basis for fusion power—as well as biology and microphysics, and includes groundbreaking studies of the historical development of science and technology.

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

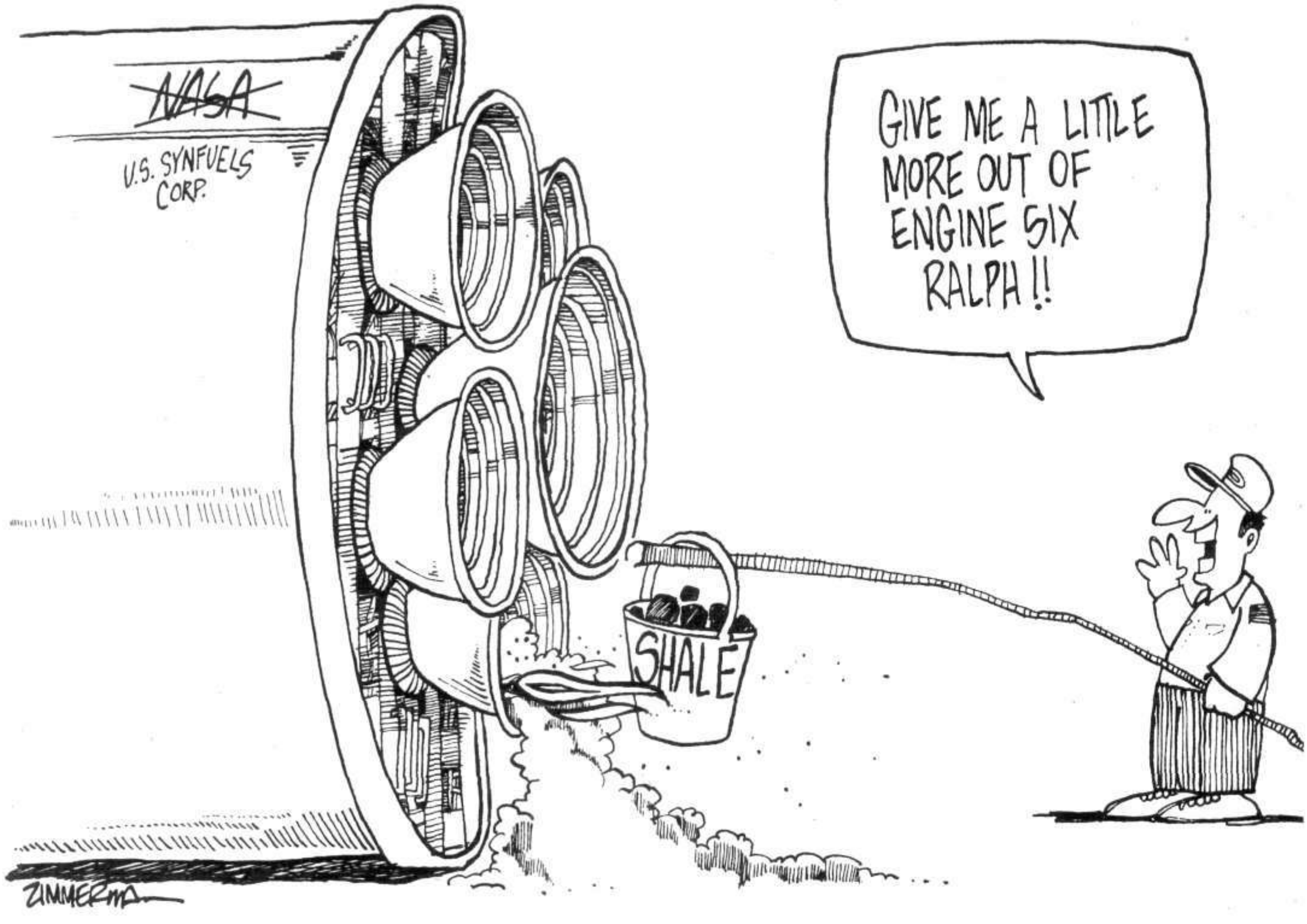
Subscriptions by mail are $20 for 12 issues or $38 for 24 issues in the USA; $25 for 12 issues in Canada. Airmail subscriptions to other countries are $40 for 12 issues.

Address all correspondence to FUSION, Fusion Energy Foundation, Suite 2404, 888 Seventh Ave., New York, N.Y. 10019.

Second class postage is paid at New York, N.Y. and at additional mailing offices.

Advertising Representatives

FUSION's national advertising representative is Patricia Van Thof, *Fusion*, 888 Seventh Ave., Suite 2404, N.Y.C. 10019, (212) 265-3749; East Coast advertising representative is Warren Smith and Associates, 38 Hull Rd., Box 754, Bernardsville, N.J. 07924, (201) 221-0184; European advertising representative is Karl-Heinz Holz, Pf. 3329, 62 Wiesbaden, West Germany, Telephone (06121) 440277.



Space and Fusion: Partners in Progress

We have long supported upgrading both the U.S. fusion and space programs, yet preparation of this issue of *Fusion* has impressed on us even more emphatically the close scientific connection between the two programs. Both involve the development of new technologies and materials, the discovery of new raw-material resources, and the comprehension of fundamental energy-generating processes. Furthermore, the space effort has provided unique insights into the fusion process, and during the 1960s and 1970s nuclear power and fusion were active areas of space propulsion research.

It is time to reinstate and upgrade this fruitful relationship. The fusion program will need substantial resources to achieve the goal of a fusion reactor by the end of the century, as mandated in the McCormack bill for an Apollo-style fusion program. At the same time, the scientific core of the space program and its manned missions must be rebuilt from its present downgraded condition.

Of course, this is not the present wisdom determining U.S. policy. It is argued by present policymakers that basic science is a luxury that the nation can no longer afford. Instead, science and technology are to be put at the disposal of new national priorities for "reindustrialization," such as costly and inefficient synthetic fuels.

Such a policy cannot work even in the short term because it guts basic industry and continues the phase-out of nuclear power. In the long term, however, it is exactly the opposite of the required policy. The right kind of policy has two principal objectives: first, to achieve the scientific and technological advances and commercialization of the high-technology devices and processes that provide an abundant, relatively cheap resource base, and a highly productive and growing economy; second, to train a new generation of young scientists that is capable of achieving yet more advanced breakthroughs and of training its own successors.

Space and fusion research are the cutting edge for the R&D program that can achieve these twin objectives.

The Role of Fundamental Science

The importance of the indicated types of scientific breakthroughs is well illustrated by a look back at the history of "space science." The great achievement by Johannes Kepler (described in this issue) in determining the underlying harmonies and invariant features of planetary and solar system motion posed another, even more profound problem: how to calculate the path length and dynamics of a trajectory whose curvature is constantly varying. That problem opened the door to two of the most important developments in mathematics: namely, Leibniz's invention of the calculus and, later, the whole new analytic universe of elliptic functions.

These developments were the key to the solution of whole new classes of physical problems and the generation of whole new fields of mathematics. In short, they were a perfect example of how research directed to solving a crucial scientific problem increases man's more general ability to comprehend and control the lawful ordering of the universe.

The investigation of fusion in the cosmos, in earth-based laboratories, and now in space-centered research facilities is the same kind of scientific frontier today. If we accept the challenge to aim that high scientifically, we will create the conditions for achieving the breakthroughs in mathematical physics that are just over the horizon. And that will also provide the best possible situation for solving our more immediate problems of economic recovery, military security, and educational renaissance.

Off the Launching Pad:
The Young Scientist Magazine

Much lip service is paid to the proposition that the nation's most precious resource is its youth. That resource, however, has been treated worse than any other national asset over the past decade. It is not necessary to itemize the effects of the collapse of education and the infusion of antiscientific ideology and drugs into the schools; the results speak for themselves.

The point is to do something positive now to prepare our youth to help make the scientific breakthroughs of tomorrow. Therefore, the Fusion Energy Foundation is proud to announce the launching of its new magazine for youngsters aged 10 to 14, *The Young Scientist*.

Just as *Fusion* is the magazine whose philosophy is progress, *The Young Scientist* will present all the exciting scientific advances that can make a new era of progress and abundance possible.

We are sending the first issue to every *Fusion* subscriber and FEF member with this issue of *Fusion*. If you agree that it meets a vital need, and that every youngster in your schools should be a *Young Scientist* reader, subscribe now and then contact us for information on bulk distribution.

The Lightning Rod

My dear friends,

I am sometimes accused, in rather energetic tones, of being altogether too willing to poke fun in this space at those of our citizens who style themselves "environmentalists." These are serious persons, I am told, with ideas and projects that ought to be taken seriously.

It was with such admonitions ringing in my mind that I set out recently, in the spirit of free enquiry, to explore the highways and byways of an environmentalist establishment known as a "windfarm." Here is a report on my investigations, presented in as sober and serious a fashion as my human nature permits me to assay.

I arrived at the windfarm, located on an acre or two of a New England field, in early autumn. I observed a crowd of some two dozen persons touring the field, on which were placed 10 or so varieties of windpower devices. The purpose of the windfarm appeared to be to disseminate the virtues of "natural windpower" as "our energy future" to as many persons as were willing to pay the price of admission, about that of a first-run movie. At least such was the orientation indicated by the windfarm's proprietor, a middle-aged man attired in a gentleman planter's hat and bluejeans, who was serving as tour guide.

I joined the tour in front of an irrigation device described by our guide as "very useful in the Third World." It was markedly different from other windmills on the property by reason of the fact that the "blades" designed to catch the wind consisted of several large cotton sails. The well-pumping machinery to which the

Continued on page 6

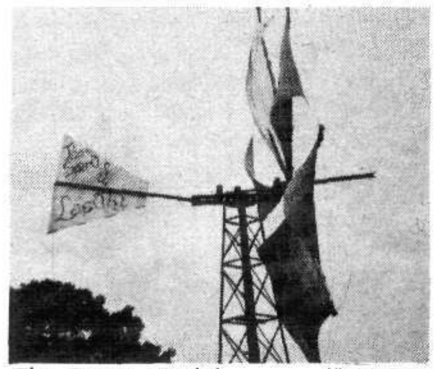
The Lightning Rod

Continued from page 5

windmill was rigged up appeared to be operating satisfactorily; at the end of a hose steady pulses of water were spewing out into a tomato patch.

Our guide explained that this device was invented at the close of the Second World War on Crete, and was manufactured out of scrap metal consisting of the remains of German tanks. He did not otherwise suggest that military occupation was a useful precondition for national use of such a "Cretan windmill."

Next we paused in front of a variety of far more modern looking windpower devices, currently manufactured in the United States, also designed to generate mechanical or electrical power. In addition to shutting themselves on and off according



The Cretan Model Virginia Baier

to the speed of the wind, they self-adjusted for maximum efficiency according to wind velocity. The one described by our guide as "the Model-T of the industry," to be used by homeowners to sell power to public utilities, retails for $5,000.

Another, described as "the Cadillac of windmills," was a strictly mechanical device that, our guide informed us, was "invented by a distinguished professor at MIT who hates electricity." I must interrupt this purely objective report here to confess that for personal reasons, that statement filled me with a certain sadness.

Our next stop was the Dempster windmill, introduced by our guide as "the windmill that won the West" and the only windpower device manufactured continuously in the United

Continued on page 71

Letters

Magnetic Liners

To the Editor:

As a layman, I do not completely understand the problems inherent in nuclear fusion. However, it seems that one of them is containing a plasma in a magnetic field. That is, a charged particle tends to jump from one line of flux density to the next.

Consider, then, a collapsing magnetic field originating from the center of a sphere. The inward collapse of the magnetic field should cause the particles of plasma to be swept inward or at least held stationary in their outward drift.

I don't have the math or sufficient physics to know if the idea is a good one. . . .

Timothy W. DeVille
Hollywood, Calif.

The Editor Replies

The idea that you expressed in your letter is not only a good one, but is the basis for a major research effort in magnetic fusion called the liner approach, reviewed in the March-April 1979 issue of *Fusion*. The most significant part of the U.S. program along the lines of the magnetic liner compression systems was killed at that time, although the Soviets maintain an effort on a very large scale. Recently, L. Rudakov, the Soviet electron beam fusion researcher, proposed to use his machine for "driving" fast magnetic liner implosions.

The basic idea of the magnetic liner approach is that you get a tremendous increase in a magnetic field's strength if you enclose it in a metal sphere, or more usually a cylinder, and then implode the sphere. The collapsing liner traps the magnetic field and compresses it as it implodes. If a plasma is placed in the interior of the liner, the collapsing magnetic field compresses the plasma and heats it to fusion temperatures and high densities at which it burns up quickly. It has recently been proposed that the radiation output from such a liner-imploded thermonuclear plasma be used to drive an inertial fusion target implosion.

Use of a "superconducting" liner was investigated by Maisonnier [*Nuovo Cimento* 42: 332 (1966)] and found not to be practical—although I have not investigated this possibility in detail. Other articles on liners are: R.A. Gerwain and R.C. Malone, *Nuclear Fusion*, 19: 155 (1979), No. 2; and J.G. Linhart, *Nuclear Fusion*, 13: 321 (1973).

Charles B. Stevens
Fusion Technology Editor

Environmentalism & Dope(s)

To the Editor:

The photo on page 7 [Aug. 1980] of "part of the 'Direct Action at Seabrook' contingent at a 'legalize marijuana' rally" would suggest that all who oppose the Seabrook nuclear plant are no more than foggy minded potheads and, as if the photo is not enough, the editorial reply which it accompanies leaves no doubt that you wish the readership to equate antinuclear with simple-minded, drug-induced radicalism. . . .

Alfred P. Gorman
Charlotte, N.C.

The Editor Replies

The starting point for all debate on environmental issues is the environmentalist belief that man and nature exist in a delicate balance or equilibrium that is constantly threatened by human activity and the concomitant belief that nature, free of mankind, is purity and bliss. This view denies the most advanced force for the continued evolution of the biosphere, that of human mind. It is the quality of *reason* that allows for the ever-increasing escape from the enslaving primitive subsistence modes of life to the enjoyment of more human, that is, more reasoned, levels.

Although there are decent and well-meaning individuals active in the environmentalist movement, the fundamental premise of environmentalism, by denying the basis of the qualitatively unique contributions of human activity, places these people into a camp where the mind-destroying qualities of drug-use, rock music, and sexual perversity cohere with a bestialized world outlook.

This coherence extends to funding. For example, the Playboy Foundation funds NORML, the pot-smokers lobbying group, and the American Friends Service Committee, which has been a leading organizing group for antinuclear activities. The former head of NORML, Keith Stroup, filed a suit to prevent the U.S. State Department from funding Mexico's program to eradicate marijuana, with the very active assistance of the antinuclear group Friends of the Earth.

Furthermore, AFSC has continuously funded a group called Movement for a New Society, which was founded by the Quaker Action Project.

State court records in New Hampshire show that more than 90 percent of the several hundred Pennsylvania residents arrested at the 1977 Seabrook antinuclear action listed their address as one of the Movement for a New Society communes.

Dr. Richard Pollak
Biology News Editor

Public 'Fear'

To the Editor:

Jon Gilbertson's article, "Who's Afraid of Nuclear Waste?" in the August *Fusion* is very informative. I might add a word as to the so-called public fear of nuclear power plants: The nuclear plants at North Anna, Virginia, pipe their hot water into a lake about one-and-a-half miles from the plants. There are marinas and private beaches for boating and swimming close to the plants' water exit area and apparently the boating and swimming public do not consider the water "dangerous."

Herbert Eby
Barboursville, Va.

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Letters

Continued from page 7

The Whole Picture

To the Editor:

I would like some forms for gift subscriptions of *Fusion* in November. . . . I particularly liked the article on bioethics in the magazine I saw [July 1980]—the best I've seen yet on that subject. Keep branching out into all areas of science like that . . . and tying it back to politics and theology. Excellent! That's what sold me on getting your magazine—a writer who can see the whole picture.

Cheryl L. Farr
Phoenix, Ariz.

No Nonsense On the No-Nukes

To the Editor:

As a senior physics major at the Illinois Institute of Technology, your magazine has impressed me for its no-nonsense reporting on the no-nukes movement and the politics behind it. As a future research scientist in the field of photon-induced inertial confinement fusion I greatly enjoyed Charles B. Stevens's article on tandem mirror fusion reactors. Although it did not read like an excerpt out of *Physical Review Letters* or even *Physics Today*, it was very informative about the latest developments in this approach to fusion energy.

From my own experience, having worked for a large Chicago-area electronics firm the last three years, I can safely state that the vast majority of the technologically educated people in America today agree with your assessment of nuclear power.

As a working scientist I abhor politics, but I feel I can no longer sit back and watch a small group of narrow-minded fanatics try to destroy my future career and lifestyle. . . . I feel that I could provide support by organizing pro-nuclear-power groups in Chicago-area universities.

Charles T. Booher
Chicago, Ill.

Who's Funding Whom?

To the Editor:

As a subscriber to *Fusion*, I have enjoyed your articles describing the "wars" going on between the nuclear energy forces—in which I put myself—and the antinuclear forces.

I have been surprised that you have not mentioned that the federal government itself is funding the antinuclear forces. For example:

The Federal Trade Commission funds the Nader groups, Union of Concerned Scientists, Friends of the Earth, the Sierra Club, the Environmental Defense Fund, and the Natural Resources Defense Council. ACTION funds the Association of Community Organizations for Reform Now (ACORN); the Midwest Academy, a school for training young radicals in terrorism; and PIRG. The Department of Energy funds Environmental Action, whose founder is Denis Hayes, now director of the Solar Energy Research Institute in Golden, Colorado, although he is not a scientist. DOE also funds ACORN, and the Farm Labor Research Projects. The White House Office of Consumer Affairs funds the Association of State Utility Consumer Advocates. The Consumers Services Administration funds People's Organization for Washington Energy Resources (POWER), which has no members but sends professional rioters to utility rate hearings and power plants.

The above is not a complete list because such organizations are springing up like mushrooms to get in on the gravy trains.

Sydney U. Barnes
Fort Pierce, Fla.

Hyperinflationary Collapse

To the Editor:

. . . I am frequently put off by your references to the so-called LaRouche-Riemann economic model, as though this were God's own answer to all our problems. Two items from your July issue should, at the very least, instill a bit of caution.

First, there is the report on the "Riemannian Economics Seminar" on page 71. In this report Parpart is quoted as predicting a hyperinflationary collapse of the American economy within three to six months. . . .

Second, Parpart's failure (my prediction) is hardly surprising. Bardwell's article on computer science correctly notes on page 43 that the LaRouche-Riemann model is under development, that the model is an "attempt" to solve a very complex problem, and that the attempt is, in fact, pushing the very limits of mathematical knowledge and available computational capability. The problem is closely related to the basic problems of pattern recognition generally. The fact is that we do not have the mathematics for solving—or for recognizing a solution to—those problems involving relationships between dissimilar systems. A related field, and one whose negative aspects should concern you greatly, is that called "technology assessment."

Clinton J. Chamberlain
Hayes, Virginia

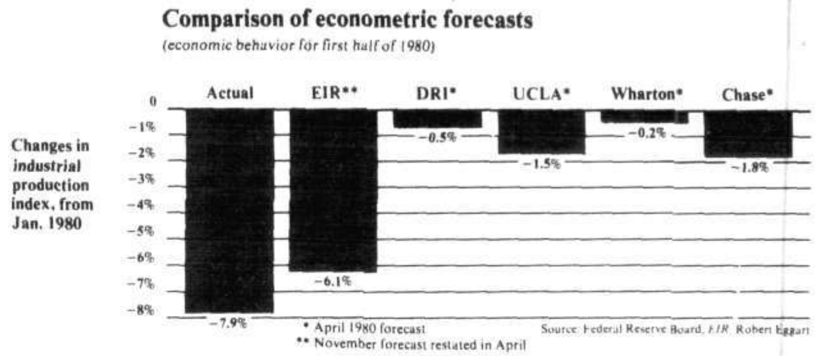
The Editor Replies

Although it is correct to emphasize that the LaRouche-Riemann model is under continuing development, one shouldn't underestimate the fundamental superiority of the model to the conventional econometric models.

These models are regularly wrong in their predictions because they have axiomatic flaws built into them. In essence, they churn out predictions based on correlations with the past performance of the economy—a futile endeavor in a period of unprecedented rises in the price of energy, sharp swings in monetary policy, and the cumulative buildup of obsolescence in plant and equipment.

The LaRouche-Riemann model, on the other hand, was specifically designed to take into account such economic discontinuities. It treats the economy as a physical system and examines the causal relations among tangible economic inputs over time.

The most notable success of the model to date was in correctly predicting the effects of the October 1979



This figure is from "Why the EIR model beat Wall Street's 1980 predictions," the Executive Intelligence Review, *Sept. 2, 1980, p. 18. The EIR jointly developed the LaRouche-Riemann model with the Fusion Energy Foundation and markets it. DRI stands for Data Resources, Inc.*

credit tightening measures on the economy [see accompanying figure]. As early as last November, the model predicted that the measures of Federal Reserve head Volcker would throw the economy into a deep and prolonged recession, which would hit the hardest in the first half of 1980.

The largest econometric houses were still predicting a mild recession as late as last April—while the industrial production index was in the middle of its steepest plunge in postwar economic history.

Are you claiming that the announced shutdown of one-third of U.S. basic industry and the recent surge of inflation in basic consumer goods (18 percent) is not a "hyperinflationary collapse"?

Lydia Schulman
Energy News Editor

Fusion Breakthrough

To the Editor:

I just read that the House passed a bill to have a commercial fusion power plant in operation before the year 2000. I want to know if there will be a fusion rocket operational in the 1990s.

In the world of space exploration, when will we have a lunar base? Will there be a manned mission to Mars before the year 2000?

Continued on page 88

Suzanne Klebe/NSIPS
'Mr. Fusion': Rep. Mike McCormack

McCormack Bill Passes Senate, Ready for Presidential Signature

The passage by the U.S. Senate Sept. 23 of the Fusion Energy Research, Development, and Demonstration Act of 1980 (HR 6308) is an important milestone toward turning the nation's energy policy back onto a path of high-technology growth. Congressional sources now expect the bill to be on President Carter's desk by Oct. 1 and to be signed into law by the president before the Nov. 4 election.

Known as the McCormack fusion bill after its House sponsor, Washington Democrat Mike McCormack, the bill had passed the House by a landslide vote of 365 to 7 Aug. 25. In a voice vote the Senate passed McCormack's HR 6308, along with the specific recommendations of Senator Paul Tsongas, the Massachusetts Democrat who sponsored the Senate version of the bill. The House then voted to accept the Tsongas provisions Sept. 24.

The historic bill calls for a national commitment to a 20-year plan to bring magnetic fusion to the demonstration stage by the turn of the century. It mandates an increase in the fusion budget by 25 percent in fiscal year 1982 and another 25 percent in fiscal 1983. The bill authorizes a program plan to be developed by the Department of Energy and submitted to Congress to demonstrate the engineering feasibility of fusion by no later than 1990 and commercial feasibility within the next decade. A new national laboratory will be established to develop the Fusion Engineering Device.

See Washington section for details.

SENATE VOTES TO ALLOW NUCLEAR FUEL SHIPMENT TO INDIA

The U.S. Senate voted 48 to 46 Sept. 23 to uphold President Carter's decision to permit the first of two overdue shipments of enriched uranium fuel to India for its American-built nuclear power station at Tarapur. The president had earlier waived the 1978 law banning the sale of nuclear fuel to nations not signatories to the Nuclear Nonproliferation Treaty. The administration lobbied heavily to win the Senate vote, observers said, because President Carter had personally promised the Indian government during his January 1977 visit to India that the fuel would be supplied to Tarapur.

NUCLEAR POWER SCORES VICTORY IN MAINE

Maine voters turned out heavily for the state's nuclear power referendum Sept. 23 and voted 60 percent to 40 percent to keep the Maine Yankee, the state's only nuclear plant, up and running.

U.S. AGRICULTURE MECHANIZATION UNDER ATTACK

Sources report that the Science and Education Administration of the U.S. Department of Agriculture has drawn up a "Redirection Plan" ordering federal work stopped and funds withdrawn from mechanization projects for apples, citrus fruits, and lettuce—areas that are among the major sectors of labor-intensive employment in the farm economy. The policy of terminating federal funding for agricultural research that displaces workers from stoop-labor jobs was put forward in January by Agriculture Secretary Bob Bergland.

FEF, AMEF SPONSOR CONFERENCE ON MEXICAN INDUSTRIALIZATION

Salvador Lozano/NSIPS
Uwe Parpart talks with reporters.

The Mexican Association of Fusion Energy (AMEF) and the U.S. Fusion Energy Foundation jointly hosted a conference on the LaRouche-Riemann economic model and its application to Mexican development in Mexico City Sept. 18. In the opening presentation, FEF director of research Uwe Parpart denounced the misconception that Mexico is "growing too fast" and emphasized that Mexico must be allowed to invest its oil wealth in an in-depth agricultural and industrial development program.

Other presentations were made by Dr. Steven Bardwell, FEF director of plasma physics, and Cecilia Soto-Estévez and Patricio Estévez, executive directors of AMEF. The seminar was attended by officials of Mexico's planning and budget and industrial development ministries.

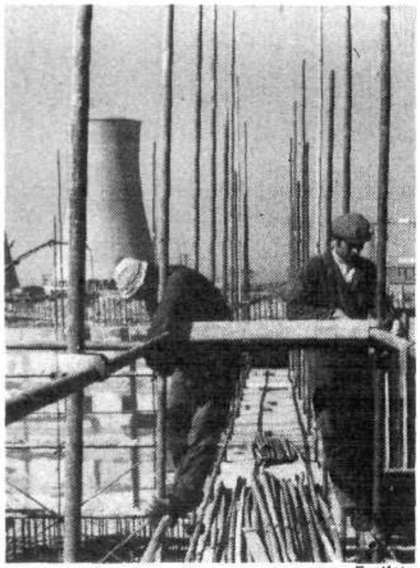
A press conference held by Parpart on industrializing Mexico received prominent same-day coverage in eight of the country's leading dailies. *El Sol de Mexico* called the LaRouche-Riemann model "the most advanced method of economic analysis in the world." *Excelsior,* which is read throughout Latin America's capital cities, headlined its article with a quotation from Parpart: "IMF and BID [Inter-American Development Bank] seek to control investment in the developing countries; they want to trap them in the dangers of production of a single export."

The January issue of *Fusion* will carry coverage of the conference and of Parpart's tour of Mexico's oil facilities.

CZECHOSLOVAKIA MOVES UP NUCLEAR ENERGY TIMETABLE

The government of Czechoslovakia has announced that it is stepping up the country's already ambitious nuclear power program. The new target is to have 33 percent of Czechoslovakia's energy needs supplied by nuclear power by 1990, compared with the present 5 percent. From now on, one-third of the country's industrial investment will go toward developing energy resources, with the emphasis on the nuclear sector.

The definitive choice to concentrate on nuclear will bring to an end the era of constructing coal-burning plants, government sources indicate. The new energy program will also entail a partial reorganization of the economy, with an expansion of the steel and engineering sectors planned.



Eastfoto

Construction on the Czech V-2 nuclear plant in western Slovakia.

FEF TO GIVE ENERGY TECHNOLOGY AWARDS

Dr. Dvorkovitz and Associates, sponsors of the "TechEx" international technology-transfer exhibitions, and the Fusion Energy Foundation announced Sept. 30 the establishment of the "Fusion Energy Foundation Energy Technology Awards" as an annual feature of the TechEx shows.

The awards will be presented for the first time at the 1981 TechEx exhibitions in Atlanta, Georgia; Vienna, Austria; and Columbo, Sri Lanka. The Energy Technology Awards will recognize "the greatest potential advance in the *productivity* of energy generation and use for society, of a technological improvement or process under development." The same criteria will apply for technologies or processes under development for use in advanced or underdeveloped countries.

Dr. Morris Levitt, executive director of the foundation, announced that the foundation is recruiting an international panel of judges from experts in the energy processes and technologies field to judge the awards, and he urged industry, private inventors, research labs, and governments to attend and join in the competition. The deadline for entries is Jan. 1, 1981. For more information, contact the FEF, 888 Seventh Ave., New York, N.Y. 10019.

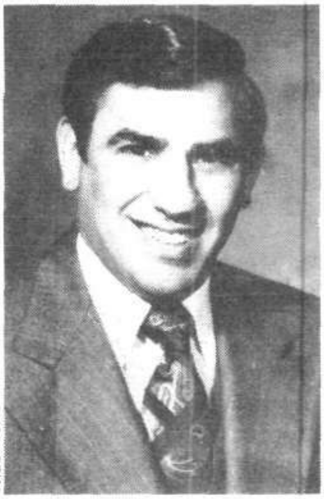
LOUSEWORT LAURELS TO WASHINGTON POST

The Lousewort Laurels for December go to the *Washington Post* for its editorial Sept. 25 interpreting the Maine nuclear referendum not as a pronuclear victory but as "*evidence of at least a deep and widespread concern over the safety of nuclear power and whether its long-term problems especially the handling of radioactive waste can ever be satisfactorily solved. . . .*"

The *Post* notes that the pronuclear forces "were jubilant claiming a great victory for nuclear power and claiming the outcome a strong vote of confidence in the technology," but then editorializes: "But was it really?" What it "really" was, according to the *Post*'s logic, was voters merely voting in their economic self-interest.

Viewpoint

Nuclear Energy and Economic Stability



by Robert A. Georgine

The availability of jobs and the opportunity for our citizens to enjoy a decent standard of living depend on this country's continuing economic vitality. Prosperity and an expanding economy cannot be provided unless an ample supply of reasonably priced domestic energy is assured.

Lack of sufficient energy strikes especially hard at the employment opportunities of those in the middle and lower income groups. It has been estimated that 59 percent of all the energy used in the United States is used in work activities of persons with family incomes of less than $16,000. In order to avoid serious electric shortages in the coming decades and avoid the hardships which would result, I am convinced that nuclear energy must play a major role in meeting our future energy demand.

I reject the arguments of those advocating a shutdown of this technology. Even with Three Mile Island, nuclear is an energy source with a remarkably good safety record after nearly a quarter of a century of commercial operation. Despite the fact that no one was killed or injured at Three Mile Island, it was a very serious industrial accident and we must continue to improve the technology.

But, we can't abandon an electrical supply that provides this nation with as much energy as the entire U.S. refinery capacity in residual oil—the type used to make electricity. If we had to import that oil, it would cost the nation an additional $6 billion a year. We can't abandon an electric source that provides nearly half of all the electricity in the Northeast and which, in fact, literally kept the lights from going out during the coal strike and winter freeze of 1977–78.

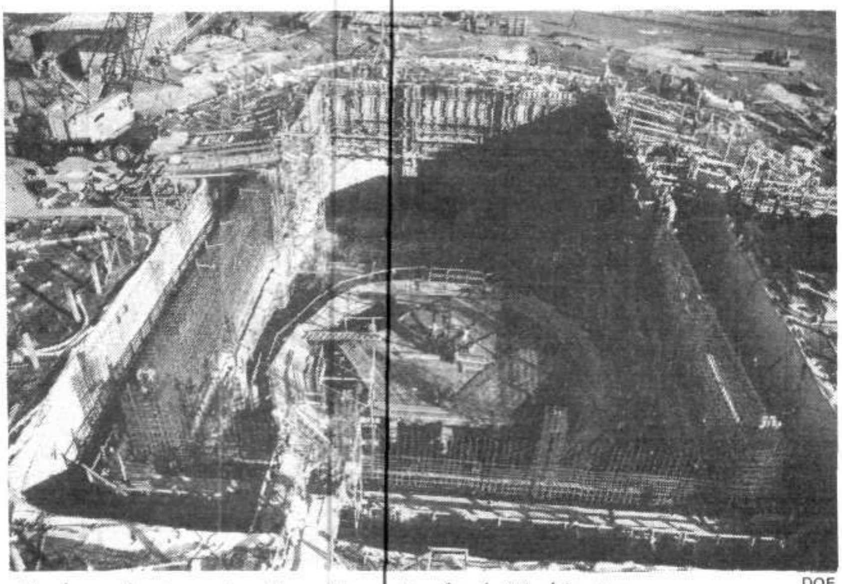
National Economic Research Associates of New York says if no new nuclear plants were permitted to go into operation, consumers would pay an extra $119 billion for all the electricity consumed between now and the year 2000. This economic consulting firm also reports that oil imports would be increased by roughly one million barrels per day during the 1980s and by 3 million barrels per day in the year 2000. Even if it were possible, the price of abandoning nuclear power is unacceptably high. We must take the lessons from Three Mile Island, apply the necessary improvements, and move ahead.

We must somehow come to grips with the risks and benefits posed by all energy sources and then make our judgments. If we are stampeded into abandoning a proven technology or regulating it irrationally with nothing to replace the energy it produces, we are risking serious shortfalls in the decades to come.

The American workforce has been growing at twice the rate of the U.S. population as a whole in recent years. In order to provide the jobs that are needed for a full employment economy it is imperative that we continue to expand domestic energy resources.

Our economic welfare and the promise of upward economic mobility that has so long fueled the American dream depends on economic growth. All this will require not less, but more energy.

Robert A. Georgine is president of the Building and Construction Trades Department, AFL-CIO, and its 17 affiliated international unions, representing 4.5 million members. A version of this Viewpoint appeared in the Sept. 1980 issue of Labor Action News *in Massachusetts.*

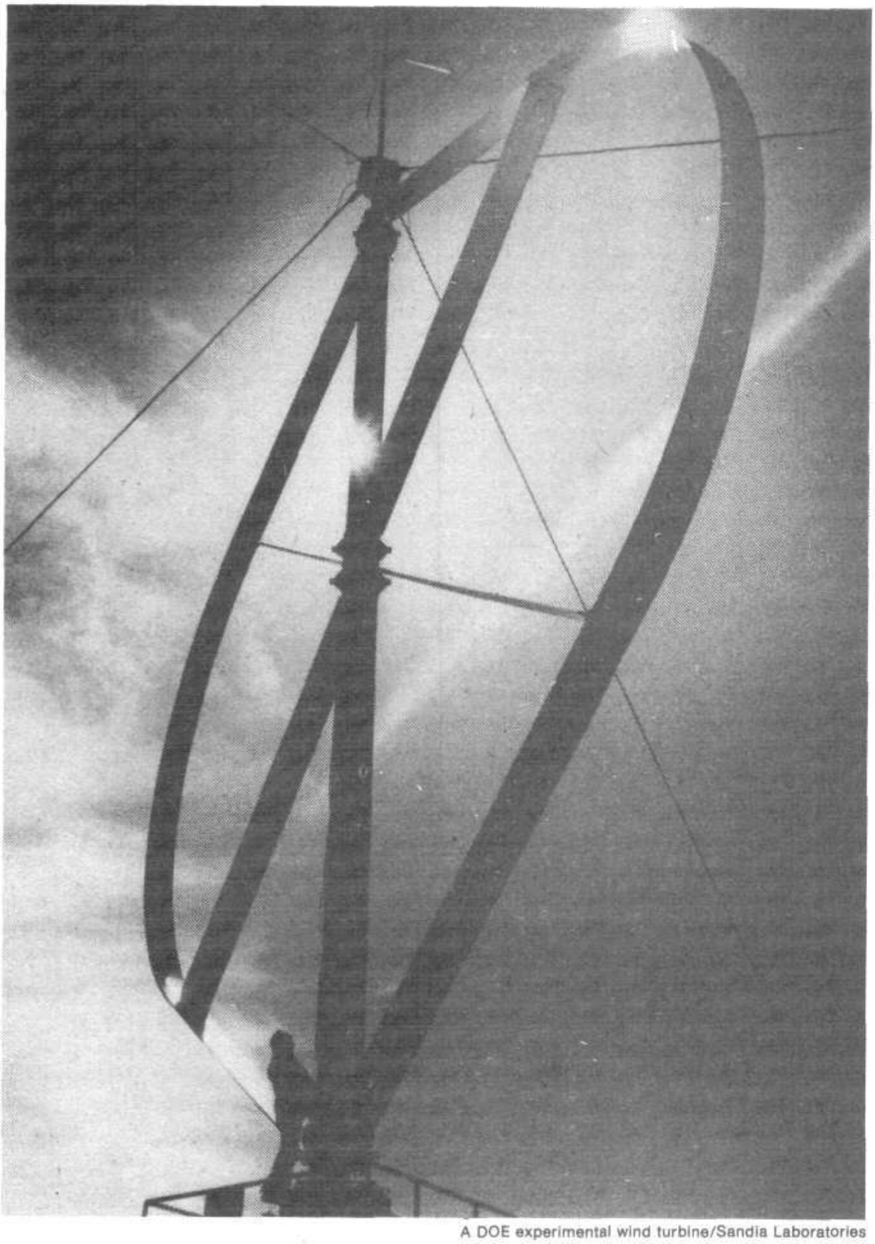


Nuclear plant construction site at Hanford, Washington.

Sunrise, Sunset

The White House D~~R~~eindustrialization Plan

by Lydia Schulman



A DOE experimental wind turbine/Sandia Laboratories

The so-called sunrise industries—such as solar power and synthetic fuels—are costly and inefficient, the opposite of what is needed to restart the economy.

The Economic Renewal Program issued by the White House Aug. 28 is a classic case of Orwellian doublespeak: a set of proposals purporting to do one thing that would actually accomplish the opposite. Billed as the administration's program for reindustrializing America, in actuality the program would dismantle large portions of the nation's high-technology industrial and agricultural sectors.

In each of the three main areas discussed—energy, basic industry, and transportation—President Carter opted for backward-looking technologies and "rationalization"—a euphemism for deliberate shutdowns of capacity. The president's plan emphasized:

- replacing imported oil with coal and oil-shale-derived synthetic fuels, while ignoring nuclear fission and the development of fusion energy,
- rationalizing the so-called sunset industries like auto and steel, and
- deregulating the railroads and other modes of transportation.

It would be a mistake to dismiss these stale proposals as a nonprogram, however, because there is a definite coherence to them—albeit a pernicious one. By institutionalizing energy prices at a level at least double today's world oil price, the shift to synthetic fuels will force cutbacks throughout the "sunset" industries and transportation sector; accelerate the abandonment of tens of thousands of miles of rail track in the farm belts; force stringent cutbacks in living standards; and exacerbate the already pronounced tendency in the economy to substitute low-skilled labor for energy and capital.

Synthetic Fuels

The centerpiece of the new "reindustrialization" strategy is the same energy program floated by President Carter in early 1977, which emphasizes inefficient synthetic fuels production. The new twist is that the United States, the world's leading exporter of nuclear reactors through the mid-1970s, is now to become the leading steam coal exporter.

Title I of the omnibus Energy Security Act of 1980, signed into law last summer, has already created a mammoth U.S. Synthetic Fuels Corporation, with $88 billion in funding allocated for the next decade. The mandated goal of this public corporation is to subsidize the creation of a major new synthetic fuels industry, which will be producing 500,000 barrels per day (bbl/d) of synfuels by 1987 and at least 2 million bbl/d by 1992. The United States currently imports between 5 million and 7 million bbl/d of petroleum.

The ultimate cost to the U.S. economy of this synthetic fuels industry will be a lot more than the taxpayers' first $88 billion. All of the synthetic fuel processes under development—chiefly coal gasification and liquefaction and the extraction of oil from oil shale—are inefficient and high cost. For example, in the process of hydrogenating coal to produce a liquid fuel, between one-third and one-half of the coal's energy content is lost. Therefore, any proposal to replace imported oil used to generate electric power with coal synthetics will minimally double the cost of delivered electricity.

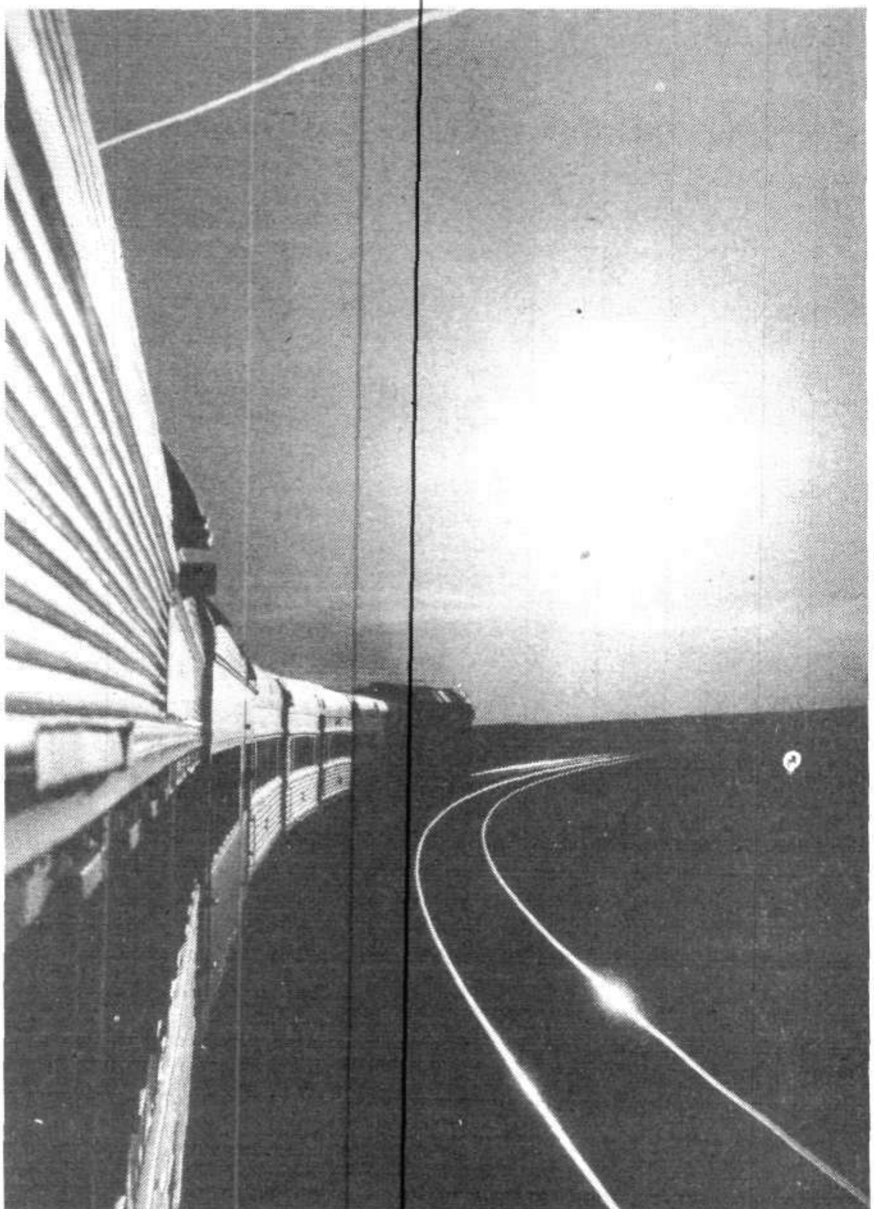
This rule of thumb bears out in all of the projections of per barrel price for synfuels. A recent study by the Office of Technology Assessment of Congress on oil shale technologies, which are considered the most economical of the synfuel processes, calculated that "syncrude"—a mix of crude shale oil and hydrogen—would have to be priced at $62 a barrel in 1979 dollars to guarantee a 15 percent rate of return on investment. Thus, it would take another doubling of world oil prices to make syncrude competitive with imported oil.

The second major point of concern is that a burgeoning synfuels industry will consume a major portion of U.S. capital goods and materials production, leading to runaway inflation and leaving little industrial capacity for the production of anything else. The Office of Technology Assessment study of oil shale technologies calculated that to produce 1 million bbl/d of syncrude would require one-third of the construction and engineering design services and up to 30 percent of new industrial equipment produced in 1978.

A market analysis prepared by Frost & Sullivan, Inc. projected that the plant and equipment expenditures needed to meet national synfuels targets will amount to $250 billion over the next 20 years. The immense bill of materials includes: engineered chemical process equipment and machinery, process piping, valves and fittings, and instruments and controls.

A Staggering Price Tag

The most staggering projection to date has come from the Exxon Corporation, a major investor in oil shale development. In a presentation before the Business Roundtable after the passage of the synfuels bill last



The San Francisco Zephyr, courtesy of Amtrak

Under the euphemism of phasing out "sunset" industries, the administration's reindustrialization policy would cut the heart out of U.S. industry.

summer, Exxon chairman Clifton Garvin told the gathered leaders of the nation's largest industrial corporations that the United States must gear up to produce 15 million bbl/d of synthetic oil and gas over the next 30 years. Exxon's projection for the total cost of such an effort is $800 billion in current dollars, $500 billion for the synfuel projects alone and the rest for capital formation to underpin them. Inflation could push these figures into the trillions of dollars.

These figures appear all the more steep when seen against the background of the nation's huge capital goods deficit and simultaneous plans to boost defense spending in real, inflation-adjusted terms each year. Any development of a synthetic fuels industry will take place at the expense of other industrial sectors.

Finally, the prospect of major synfuel development has raised the specter of intense competition between energy projects and water supplies in the Western states, where the bulk of the nation's untapped coal and oil shale resources lie.

A major study published this year by the National Resources Council of the National Academy of Sciences, *Energy in Transition 1985-2020,* concluded that water "is potentially a limiting factor in any plan to produce and use coal on a large scale. . . . Plans to triple or quadruple coal production and use during the transitional period of the next 20 years must include precise projections of how water requirements will be met. . . .

"Potentially most troublesome will be providing water needed in using coal (primarily to produce electricity and synthetic fuels), rather than in mining it. To service a 35- to 45-quad increment will be difficult, even with optimal planning at both regional and local levels."

Agricultural Impact

Public officials in the Western states are expressing even greater concern over the impact of the proposed synthetic fuels industry on their states' livestock industries and agriculture. In

Continued on page 78

Reindustrialization: The High-Technology Path

Genuine reindustrialization—in contrast to the Carter program and the "quick fix" military buildup and austerity varieties offered by the Reagan and Anderson camps—must emphasize long-term scientific and technological development and high-technology capital formation. As discussed in *Fusion*'s special report on reindustrialization in Oct. 1980, it is critical to focus on those areas of the economy that can effect the maximum growth in the rate of growth of the economy's "free energy."

The cornerstone of genuine reindustrialization today is the development of fusion energy, the energy source that is superior from the standpoint of energy flux density and hence efficiency, as well as price and availability. A 20-year commitment to the development of commercial fusion power will require a massive national effort to educate (and reeducate) and upgrade the labor power of the entire U.S. population and to gear up the nation's industrial infrastructure, based on the full development and utilization of nuclear fission technologies and advanced methods of coal production.

To achieve the high global economic growth rates requisite for fusion power development, the nation will need the full spectrum of advanced fission technologies—including advanced breeder reactors, high-temperature reactors and their chemical applications, as well as more conventional coal-fired power plants and coal-based magnetohydrodynamics (MHD), the technology that converts a plasma directly to electricity at up to double the conversion efficiency of conventional coal-fired plants.

(The Carter synthetic fuels program, by contrast, will lower energy production efficiencies by a third to a half and will minimally double the price of delivered electricity.)

The development of commercial fusion power will in turn revolutionize industrial production techniques—permitting the direct fusion torch processing of low-grade ores, for example—producing unprecedented leaps in productivity.

Synthetic Fuels

Within this perspective of a 20-year national commitment to the development of fusion energy it is possible to approach the question of synthetic fuels development from an economical standpoint.

There is no contesting that hydrogen and hydrides are the fuels of the future that will supersede conventional fossil fuels. There is an unlimited supply of hydrogen in ordinary seawater and there are no polluting waste products from its use as a fuel. The development of commercial fusion will permit the production of hydrogen from water at a cost at least competitive with today's petroleum prices.

Lawrence Livermore National Laboratory in California and Brookhaven National Laboratory in New York already have two potential designs under study for coupling the heat produced in a fusion reactor to thermochemical hydrogen production cycles and high-temperature electrolysis. The extremely high temperatures produced in a fusion reaction can raise the efficiency and lower the cost of splitting water to liberate hydrogen for use as a fuel.

While fusion is still under development, advanced forms of nuclear fission technology, such as the high-temperature gas-cooled reactor (HTGR), can be coupled to hydrogen production cycles. The high-temperature process heat produced in an HTGR can be applied to a variety of feedstocks to produce hydrogen and hydrogen-combination fuels—another cost-effective method of producing synthetic fuels.

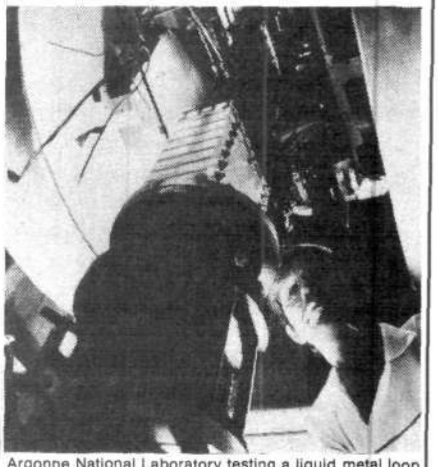
As an intermediate step to a hydrogen fuel-based economy, and where political conditions dictate this course, it is possible to produce coal synthetics with advanced, nuclear-based technologies. Both the Soviet Union and West Germany have developed processes to gasify and liquefy their large coal resources using nuclear power.

Basic Industry

The Carter administration is proposing to do something extraordinary: reindustrialize the country while shutting down U.S. basic industry. In actuality, basic industries like steel and machine tools must be modernized and expanded to underpin the development of advanced energy production and industrial technologies.

Take the bill of material requirements for the nuclear energy industry as an example. Meeting U.S. and world nuclear energy requirements over the next two decades will require an unprecedented expansion of U.S. steel capacity: each conventional nuclear power plant requires about 30,000 tons of carbon steel. The electrical power needs for rebuilding and gearing up the U.S. economy will require 1,000 gigawatts of nuclear capacity on line by the year 2000. And if the United States decides to participate in the effort to industrialize the developing sector, its contribution will involve in the range of 1,500 reactor exports over the next 20 years.

Added up, nuclear energy-related steel requirements alone will necessitate doubling U.S. basic steelmaking capacity (now around 150 million tons) and adding about 25 million tons of capacity for producing the alloy steels used in nuclear reactor cores.



Argonne National Laboratory testing a liquid metal loop
Advanced technologies like MHD ensure economic growth.

The American steel industry's only hope for gearing up to meet these requirements is to "leapfrog" current steelmaking techniques and concentrate on developing nuclear-based steel technologies. In one application of nuclear energy to steelmaking under development in Japan and West Germany, the high temperatures produced in an HTGR are used for the direct reduction of iron ore—bypassing the coal combustion stage and enormously boosting steelmaking productivity.

The paradigm for the proper relationship between "sunrise" and "sunset" industries is the nuplexes that the United States must help to establish in the Third World. Nuplexes are large industrial-agricultural complexes powered by one or more nuclear plants, which were on the drawing boards for a number of developing countries over a decade ago.

The nuplex principle involves locating a full range of new and old industries—steelmaking, fertilizer production, electronics, etc.—around a central nuclear energy source to make the most efficient use of all of the energy and waste products generated. Nuplexes, moreover, can be designed in such a way that more advanced industrial modules can replace outmoded ones as the country's economy and labor force advances; today's primitive mineral refining factory, for example, could give way to tomorrow's fusion-based ore processing plant.

A modern railroad system, a fully computerized trucking network for shorter hauls, inland waterway systems, and expanded port facilities are crucial for export-oriented reindustrialization.

The most serious bottleneck in the U.S. transportation system is the archaic rail system, which is about to be made more inefficient by railroad deregulation. The two principal avenues for upgrading the U.S. rail system are computerization and electrification. The widespread introduction of computerization will enable the railroads to keep track of the location of each car and locomotive, identify potential bottlenecks, and generally increase the smooth utilization of existing rail stock.

Electrification is even rarer than computerization in the rail system. Only 1 percent of the American rail system is electrified, compared to 25 to 50 percent in various European countries. Despite the initial cost of electrification, the energy-saving factor is 3 to 1 compared to locomotives run on diesel fuel. In addition, electric locomotives have much greater horsepower capabilities.

In the area of passenger travel, the technology of the not-too-distant future is magnetically levitated trains, bypassing the need for liquid fuels entirely. The use of electromagnetic fields to levitate and propel passenger trains has been under consideration for over a decade here and in other countries. The Japanese currently have a 310 miles per hour, 10-ton test model under development, which is powered by the repulsive levitation provided by high-field superconducting magnets. Maglev technology permits efficient, high-speed travel, eliminating the traction and frictional heating in conventional high-speed rail systems. Once commercialized, this technology will result in tremendous savings in time and eventually money for passengers.

—*Lydia Schulman*

The Synfuel Alternatives

Inefficient And Costly

There are two main avenues of synthetic fuel development being considered for meeting the 500,000 barrel-per-day (bbl/d) goal established by the Energy Security Act of 1980: deriving oil from shale and liquid or gaseous fuels from coal. In both cases, the processes are extremely inefficient and costly.

Oil Shale

There has been considerable interest in extracting oil from oil shale since the 1973 Mideast war, because the United States has vast deposits of shale rock. The Office of Technology Assessment of Congress recently estimated that about 400 billion barrels of oil could be ultimately recovered from the enormous shale deposits in the 17,000 square mile area at the intersection of Colorado, Utah, and Wyoming. (As a point of comparison, the United States currently consumes somewhat more than 6 billion barrels of oil per year.)

All the oil shale processes under development involve getting a solid hydrocarbon called kerogen out of hard shale rock by grinding and heating. When heated to a temperature of about 900 degrees Fahrenheit in a retort or heating vessel, the rock yields combustible gases, crude shale oil, sodium minerals, and a residue of spent shale.

One 50,000 bbl/d oil shale facility would have to mine, move, crush, and heat more than 24 million tons of rock per year.

One of the main environmental objections raised against oil shale development is the surface damage resulting from such a massive undertaking. In the true *in situ* (TIS) method, in which the shale is fractured explosively and then retorted underground, surface disturbance and waste disposal problems are minimized. However, this process is at a very primitive stage of development.

The processes further along the line are modified *in situ* (MIS), in which a portion of the deposit is fractured and retorted underground and the rest is mined, and above-ground retorts, in which the shale is mined in huge open-pit mines and heated in retorting vessels on the surface.

The resulting product is known as crude shale oil, which can be burned as a boiler fuel or converted into a synthetic crude oil—syncrude—by the addition of hydrogen, and brought up to the quality of crude petroleum. Syncrude, in turn, can be either burned as a boiler fuel or refined into petrochemical products, especially the heavier distillates such as diesel and jet fuel.

Any assessment of whether oil shale is economical must take into account the cost of retorting the shale and then hydrogenating it once it is cool; the cost of removing the toxic spent shale; the cost of constructing the vast production facilities; the large water requirements; and the resulting air pollution.

From this standpoint, a shale oil industry has not been economical in the United States since 1859, when the infant industry that was extracting shale oil from lean Eastern shale deposits gave way to the discovery of crude petroleum in Pennsylvania.

Coal Synthetics

Coal gasification technology has been in existence since the Nazi war economy, cut off from oil, developed the Lurgi gasifier process in 1936. It is worth pointing out that the Nazis never intended to run an economy on synthetic fuels; they simply needed an assured supply of fuel to get them to the point of taking oil from Romania and the Soviet Baku oil fields.

In more recent history, coal-rich South Africa, under conditions of increasing political isolation, developed a domestic coal gasification capability through the government-backed South African Coal, Oil and Gas Corp. (SASOL)—using the same Lurgi process developed in Nazi Germany.

In the normal gasification process, small chunks of coal are fed into the top of a pressure vessel where the coal is gasified with oxygen and steam, yielding carbon monoxide, hydrogen, and some methane, the main constituent of natural gas. The mixture is further processed to yield a medium BTU methane gas of 350 to 500 BTUs per cubic foot, compared with the 1,000 BTUs per cubic foot of natural gas.

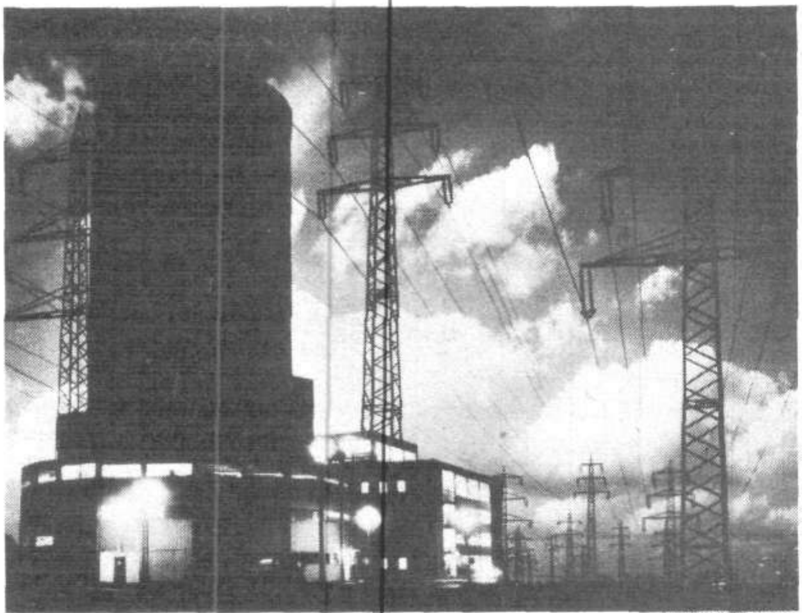
The other branch of development for coal synthetics is coal liquefaction. The best known method is a process developed in the 1920s in Germany by the chemists Fischer and Tropsch. This process, which is still used in South African coal liquefaction, is a two-step method of turning coal first into a gas and then a liquid. Operating under relatively low pressure and temperature, this process loses significant amounts of energy at each step of the conversion process.

Liquefied coal is regarded as a substitute for natural gas in the production of methanol, which is used in plastics, glue, and synthetic fibers.

Any decision to commit billions of dollars of capital resources to the development of these hydrocarbon-based synfuels must be weighed against the superiority of hydrogen as a substitute for conventional fossil fuels—produced through thermally efficient, cost-effective nuclear technologies, and evidence from a variety of respected sources, including the U.S. Geologic Survey, that the United States has only begun to tap its reserves of conventional oil and natural gas.

—*William Engdahl*

'Electricity alone cannot solve the future energy problem since it cannot be stored in large quantities economically. Hence, we must use nuclear energy to produce storable forms of energy.'



IN-Bild/WP Krupp

West Germany is planning on the most advanced nuclear technologies. Here a pebble-bed high-temperature gas-cooled reactor at Jülich, West Germany. The reactor owes its name to 100,000 graphite pebbles, each of which contains 1 gram of uranium and 5 grams of thorium and is surrounded by a gas-tight layer of graphite. Helium flows upward through the pebbles, conducting the heat that is generated inside the pebbles by nuclear fission. The helium then is heated in heat exchangers producing steam of 500 degrees Celsius to power the turbines of the generators.

European Perspectives on Nuclear Power

An Interview with Rudolf Schulten

The Role of Advanced Nuclear Technologies

Fusion *interviewed two European experts to see what role they thought nuclear energy should play in fulfilling overall energy needs. Hans Bandmann of the Fusion Energy Forum in the Federal Republic of Germany (West Germany) interviewed Dr. Rudolf Schulten, head of the Institut für Reaktorentwicklung in Jülich.*

Schulten, a worldwide authority on the high-temperature gas-cooled reactor (HTGR), developed the "pebble-bed" HTGR reactor. In addition to research on HTGRs, his work at Jülich includes industrial applications of the HTGR from coal gasification to chemical processing.

Question: For a long time you have been warning against the limitation of nuclear energy to electricity production alone. In what ways can nuclear technology help to solve the current substitution problem, and what measures must be undertaken in this direction?

Until now nuclear technology has been pursued too much from the standpoint of producing electricity. But electricity alone cannot solve the future energy problem since it cannot be stored in large quantities economically. Hence, we must use nuclear energy to produce storable forms of energy.

In the BRD [Federal Republic of Germany] the conversion of coal into gas and fuel using nuclear energy, particularly the HTGR, is possible. The procedures for this are known well enough that the appropriate materials for a commercial process can be developed. The ideal solution would be to convert nuclear heat into hydrogen [a portable liquid fuel]. Here, though, an economical and technologically feasible method has not yet been developed—fundamental research should be substantially increased.

Question: The problem of rising oil prices presents itself in a more drastic

form for the developing countries than for the industrialized nations. What significance can nuclear technology have for the industrialization of the Third World?**

For the developing countries nuclear technology has tremendous significance. After electricity production, a sensible area in which nuclear energy should be employed is to build up the chemical industry, which now uses oil as the main heat source. For this application we shall have at our disposal in the near future reactors that are suitable—smaller and simpler.

Question: The emphasis on nonproliferation has made the export of nuclear technology more difficult. The international conference (INFCE) convened to clarify this question has unequivocally rejected the Carter administration's thinking and has spoken out in favor of reprocessing nuclear fuel. What is the position of the high-temperature reactor with regard to nonproliferation?

In view of the fuel-supply situation in the next 30 years, the use of low-enrichment uranium will gain wide acceptance, since the least difficulties are associated with this technology (as long as one refrains from reprocessing). I am of the opinion that reprocessing can be postponed to the first decade of the next century without too great an economic penalty. The value of spent fuel, as far as the plutonium content is concerned, will surely grow with the wider extension of nuclear technology, so that this fuel will be at the disposal of different countries as an energy reserve.

Question: It is said that the U.S. extension of nuclear technology will be blocked for years as a result of the incident at Three Mile Island. Do you

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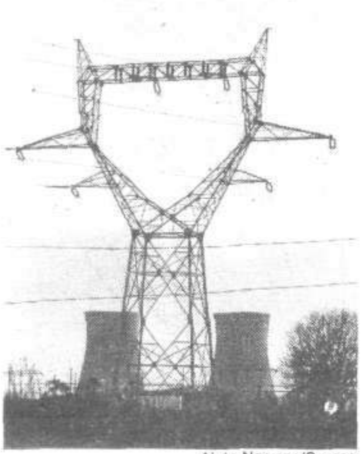
'Nuclear energy is the only energy available in significant quantities within a relatively short timeframe and at a reasonable cost. We therefore decided to accelerate the rate of development of our nuclear program.'



Alain Nogues/Sygma

By 1990, about 70 percent of France's electricity will be supplied by nuclear power. Here power cables carrying nuclear-generated electricity in Dampierre-en-Burly.

An Interview with Yves Coupin

Nuclear Energy 'Fundamental'

Fusion's Paris correspondent Sophie Tanapura interviewed Yves Coupin, director of gas, electricity, and coal at the French Industry Ministry. Coupin also thought that nuclear energy will play a key role in solving the energy problem.

* * *

Question: What is the general thrust of French energy policy?

France's energy dependence is very great, since we import around 75 percent of our energy supply. Oil, which is mainly imported, is the main element, fulfilling 56 percent of our energy needs.

Our fundamental objective is to reduce our dependence on oil. To do this, we must maximize energy savings, which is the first axis around which our energy policy is organized. We are trying to reduce the rate of growth of energy consumption without reducing the growth of economic activity.

The second axis of our policy is to develop substitute energies to oil, particularly those sources that would lessen our dependence on imports. Nuclear energy is the fundamental element, because it is the only energy available in significant quantities within a relatively short timeframe and at a reasonable cost. It is the least expensive method for producing electricity. We therefore decided in 1974 to accelerate the rate of development of our nuclear program and bring about 5,000 MW (megawatts) on line each year.

As for the level of production of electricity from nuclear energy, there are presently about 8,000 MW installed and 31 reactors under construction, representing a total of more than 30,000 MW. The reactors started in 1974 will be coming on line beginning this year at an accelerated rate, the equivalent of one reactor every two months.

This will lead to a strong increase of nuclear electricity. By 1990 we will be producing a little less than 350 TW-hr (trillion watt-hours) of nuclear electricity, about 70 percent of our production. Nuclear will represent in total about 30 percent of all our energy needs by 1990.

The last axis of our policy is, obviously, to reduce the vulnerability of our oil supplies through the development of cooperation with the producing nations, and with research on our national territory. We hope to obtain a more balanced supply by 1990 by bringing oil down to 30 percent of our energy needs. Nuclear,

think that the safety advantages of the HTGR could influence this situation?

With the proper construction and application of HTGRs, complete stability vis-à-vis accidents is achieved. I can imagine that these interesting properties of HTGRs would be attractive to the United States.

***Question:* There is a joint research agreement in the area of high-temperature reactors between West Germany and the United States and Bonn is very much interested in expanding it. How do you view the future development of this cooperation?**

It is noticeable that interest in the application of high-temperature reactors for nuclear process heat is now increasing in America. I believe that this interest will become stronger as Americans realize that Japan is also striving for similar development.

Question: The current presidential race in the United States is forcing a rethinking of U.S. energy policies. What are the most crucial points that a new administration should address?

I must, of course, answer this question with a possible bias as a development engineer who has spent many years working on high-temperature reactors. But it is my conviction that in light of the energy problem, the development of high-temperature reactors is an urgent task for the United States, although this system becomes practical only in the long run, as an extensive substitution of nuclear energy for oil. The HTGR functions satisfactorily with the thorium cycle, and with this technology, as with the fast breeder, uranium can be conserved for a very long period of time. I believe that the development of the thorium cycle for an implementation target date of 20 years is a vital goal.

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coal, and gas will each supply 30 percent, each being developed as much as resources permit. The final 10 percent will be the share taken by renewable energy sources: hydroelectricity, which will continue to play a certain role, solar, and geothermal.

Question: What is the future of the fast breeder?

The fast breeder is very important. It became clear very early on that it was necessary to use technologies that would take full advantage of the total energy potential of uranium, that is, by using the fast breeder. This awareness occurred not only in France, but also in the United States where the first production of nuclear electricity was done on the basis of a fast breeder.

At present, we are demonstrating the industrial feasibility of the breeder on a commercial scale: the Super-Phenix being built at Creys-Malville in cooperation with Italy and West Germany. It should be on line toward the end of 1983.

Question: How is the French nuclear program integrated into industrial development in France?

The advantage of nuclear energy is that it has a very strong national value, as well as being the kind of high-technology that has a pulling effect on the entire industrial world. It is what we call a "technological locomotive" toward industry in general. In order to carry out our nuclear program, we put together a competitive industry on the international level, both in terms of the fuel cycle as well as the reactors. This industry pulls the rest of industry along with it, spreading progress throughout the industrial world. This is a major advantage, along with the direct employment generated by the nuclear industry, since it now employs 150,000 people.

Question: Will France export these high technologies to the Third World?

France is particularly interested in cooperation with the Third World. Having this technology ourselves, we can help these countries achieve a higher technological level. Nuclear is an important technology in this context, one that can contribute to resolving the world energy problem. The energy problem is not specifically French, and anything that helps to loosen up the energy constraint on a world level is favorable for the world balance. At the same time, however, France is committed to exporting these technologies only when there are serious international guarantees of nonproliferation.

Question: Will the new "caramel" process contribute to limiting proliferation?

We must develop the least proliferating technologies. This is the positive aspect of the fight against proliferation. We think that too many prohibitions could actually go against nonproliferation.

Caramel essentially concerns the research reactors. It is a technology that achieves the same performance as highly enriched uranium at 93 percent, but uses only 10 percent enriched fuel.

We can therefore export research reactors while keeping within the nonproliferation guarantees. It is certainly preferable to export uranium, which is only mildly enriched. France has also developed other nonproliferating technologies, for example, a chemical enrichment process that does not allow the higher levels of enrichment necessary for nuclear weapons.

Question: Does the environmentalist movement represent an obstacle to the implementation of the nuclear program in France?

It should be realized that the French population, from what we can tell, is very conscious of the energy situation. As different polls show, the French population understands that it is necessary to confront the situation with all possible tools, including nuclear power. This is why the program is implemented under good circumstances, with the necessary effort to inform the public. The population must have the answers to legitimate questions it might have on nuclear energy. *In fact, there are now 20 sites where nuclear plants are either in operation or under construction.*

We could not have arrived at this result without the French population's support of the need for nuclear energy.

National Fusion Labs: A Firsthand Report

Carlos de Hoyos

Charles B. Stevens (above), our fusion technology editor, recently visited three of the national laboratories involved in fusion research. Here is his report.

* * *

The national laboratories involved in fusion research represent the scientific and technological future of America as well as the hope for realizing that future. The machines of tomorrow are commonplace at these "factories" of the future. Although I had known this from my extensive contact with the scientists working at these labs and my review of thousands of scientific papers and technical reports over the years, my recent personal tour of three of these laboratories—Los Alamos Scientific National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratory—gave me a much more exciting and meaningful insight into the actual status and dynamics of the national laboratories' major fusion projects.

I was deeply impressed by the range and depth of the work and by the personal commitment of the scientists and technicians involved in this tremendous effort to master fusion energy for the benefit of all mankind. A number of television documentaries are in preparation to help educate the American population about the national fusion effort, and I hope that they will convey some of the excitement of this important work.

Lawrence Livermore

Lawrence Livermore National Laboratory (LLNL) in Livermore, California is one of the two nuclear weapons' labs that are also major centers for energy research and development of science and technology in general (Los Alamos being the other). The two independent fusion programs conducted at LLNL are the magnetic mirror, which is the backup to the tokamak project in magnetic-confinement fusion research, and the laser program in inertial-confinement fusion, which is the most advanced in the world with the most powerful lasers yet constructed.

The Tandem Mirror

The LLNL Magnetic Fusion Program is now completing an extremely successful series of experiments with their tandem mirror experiment (TMX). These experiments have demonstrated the scientific principles of the tandem-mirror approach to fusion, which was designed to transform the magnetic mirror system into a viable, high-energy-gain reactor configuration.

The TMX consists of two mirror cells acting in "tandem" to end-plug a long, cylindrical magnetic bottle confining the fusion plasma. TMX will soon be rebuilt to test new concepts for further enhancing confinement in the tandem mirror configuration.

Some of these concepts are based on the work of Joffe, the Soviet scientist who recently showed that tandem mirror confinement of a plasma could be greatly improved and stabilized by forcing the plasma ions to "slosh" back and forth between the end-plug mirrors. LLNL will test this idea, using a new configuration of neutral beam heaters and adding further mirror magnetic fields to the cells.

Mirror Fusion Test Facility

Although the TMX is large compared to the usual tokamak experiment, the mirror fusion test facility (MFTF) at Lawrence Livermore is of awe-inspiring dimensions. Only one mirror cell is presently being fabricated for this next step in the mirror effort, but LLNL recently decided to go directly to a double-mirror tandem configuration, the MFTF-B, which will be completed by 1984.

MFTF-B will be almost exactly the same size as an economical commercial reactor—the center cell would have to be lengthened slightly—and will demonstrate that the tandem concept is capable of producing net fusion energy. Simultaneously, it will test many of the technologies needed for working reactors: superconducting magnets, automatic control and computer switching systems, and vacuum and refrigeration technologies.

For example, the MFTF-B will be controlled not by the usual array of knobs, switches, and buttons for output and input but by touch-sensitive images of buttons displayed on color monitor screens. In the Man-Machine Interface project being supervised by Glen Speckert of LLNL, the operator need display only a portion of the total controls at once, with other arrays accessible on the screen as desired or when the computer determines that important decisions must be made.

The MFTF-B is being built on an industrial scale because LLNL wishes to begin addressing the key questions involved in reactor viability to speed the overall advance to a commercial fusion reactor. This mammoth complex experiment is being constructed to attain 80 percent availability; that is, only 20 percent of their two-shift day will be lost in unscheduled shutdowns for maintenance and repair. Although such a goal might seem too ambitious for an experiment exploring the frontiers of science, it will give us valuable knowledge for realizing economic fusion reactors at a later stage.

Shiva

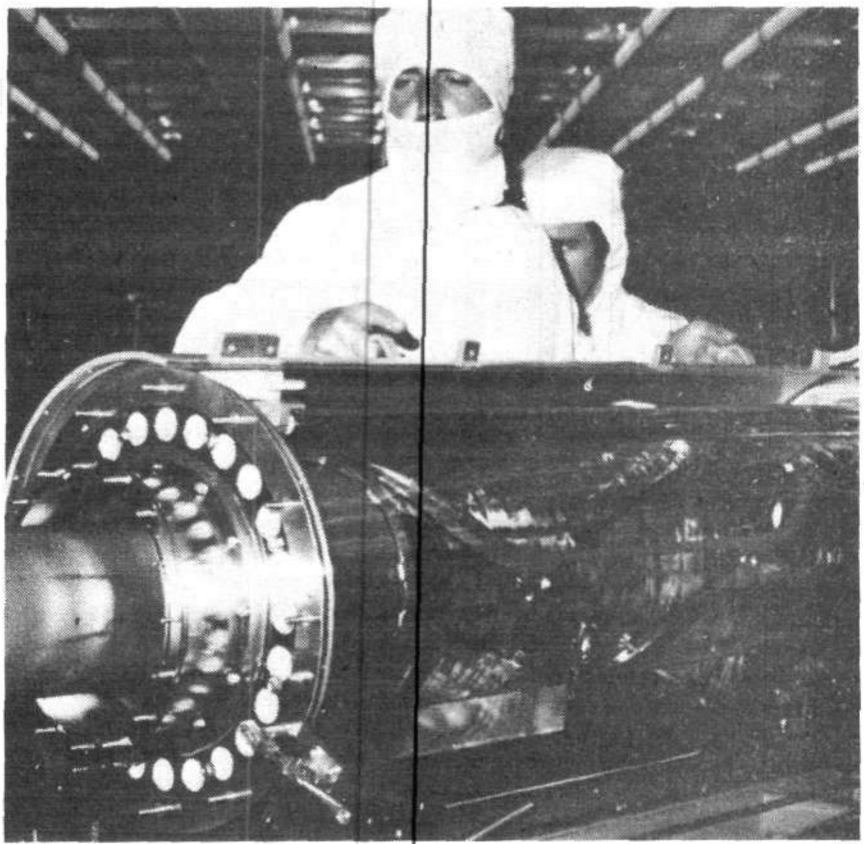
Although MFTF is immediately impressive by reason of its huge scale and combination of advanced technologies, the Livermore Shiva facility is more subtle in its impact. I entered a normal-looking five-story building about the size of a football field. But as I proceeded to the inner recesses of the building housing the Shiva laser, I seemed to be entering a great submarine or spaceship, unlike any other construction.

To enter the Shiva laser bay and target chamber, I had to don a safety helmet, goggles, and rubber boots. Through glass windows I could see the nearby assembly rooms where the optics and laser amplifiers are prepared for placement in Shiva. Men and women in white coats and masks were working in these "clean" rooms, which are kept cleaner than the surgical facilities of hospitals to avoid any contamination of the Shiva optical system.

The Shiva laser bay room is kept just as clean. In this room, 50 yards long and several stories high, stands a large, stainless-steel frame structure where the optics and amplifiers are placed.

The entire assembly must be maintained within less than a millionth-inch alignment, despite the thousands of components and long distances over which the components are linked. This is accomplished by careful construction and self-correcting alignment systems, including internal radar beams that carry out periodic checks of precision.

Although these alignment systems were designed only to correct slight perturbations caused by such factors as thermal gradients, stress, and creep fatigue, in reality they have proved to be quite rugged.



LLL

Clean-room technicians at Lawrence Livermore assemble a 20-cm-aperture disk amplifier on an assembly fixture for Shiva.

For example, a technician just happened to be carrying out a manual alignment check of one of Shiva's 20 laser beams when a recent earthquake hit near Livermore. As he was looking down the long chain of glass amplifiers that make up a Shiva beam, he noticed that the micron-scale crosshairs of his telescope were precisely on the mark. Then the earthquake hit, which one would expect to completely knock the optics out of alignment. But to his amazement, he watched as the alignment, thrown helter skelter by the quake, automatically restored itself to the perfect setting he had witnessed before the quake!

In a certain sense, Shiva is a scientific spaceship that takes fusion scientists on a journey to the stars, for Shiva's tremendously powerful beams recreate the extreme densities and temperatures of matter that had existed previously only in the cores of giant stars. Shiva recently attained one of its major program objectives in approaching and exceeding laser-driven implosions of matter to 100 times normal density, providing a window on matter in extreme conditions.

Shiva is also leading the research into laser fusion, which will be further advanced with the construction of the larger Nova laser system at LLNL.

Next month I'll continue my tour report on Los Alamos Scientific Laboratory and Sandia National Laboratory.

—*Charles B. Stevens*

Inertial Confinement Fusion Using Magnetized Targets

Dr. Friedwardt Winterberg

A new approach to achieving high-gain inertial confinement fusion combining magnetized targets with "staging" has been proposed by Dr. Friedwardt Winterberg of the Desert Research Institute in Nevada. A magnetized target consists of a magnetically confined fusion plasma, which is then imploded by the beams or projectiles of the inertial-confinement system.

Although it has been fully appreciated for some time now that magnetized plasmas could be ideal as targets, it was thought that they would be capable only of a low energy gain. That is, the yield of fusion energy generated would not exceed the energy needed for ignition by much more than a factor of 10 to 20.

A magnetic target was used by Sandia Laboratory in 1977 to achieve the first U.S. electron-beam-induced fusion, although on a microscopic scale, and D. Tidman and S. Goldstein more recently suggested that a magnetized target should be combined with impact inertial confinement (*J. Applied Physics,* March 1980). But the Winterberg approach would overcome the low-yield obstacles by combining the magnetized plasma target, a conventional target, and a careful staging of events to minimize the power density needed to ignite the fusion reaction and increase the final yield.

The chief advantage of using magnetized plasmas as the target for inertial confinement implosions is that fusion can be ignited and a significant portion of the fuel reacted with a relatively low-power driver. In a magnetized target, ignition of fusion takes place in a relatively low-density magnetically confined region, which min-

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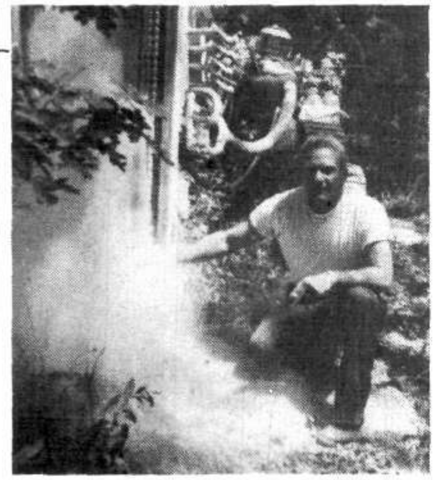
'Save America' Group Hits USDA Wilderness Lockup



Challenging the wilderness lockup: Jack Brettler of the Save America Club, shown here testing uranium milling equipment.

A legal challenge with national implications is underway in North Carolina to Secretary of Agriculture Robert Bergland's controversial "RARE II," an administrative program that is blocking the development of some of the most mineral-rich lands in the country.

RARE II is the second phase of the Roadless Area Review and Evaluation program launched by Bergland in the early months of the Carter administration. Under RARE II, Bergland has recommended that Congress study some 62 million acres nationally for proposed wilderness designation, which would prohibit any leasing or development of these lands.

As in the case of the 104 million acres in Alaska that were locked up during congressional review, these lands contain vast deposits of valuable minerals such as oil, gas, and uranium.

Wilderness Concept Challenged

Plaintiffs in a legal case contesting Bergland's lockup of the Pisgah National Forest area in North Carolina—including the Southern Appalachian Multiple Use Council and the North Carolina Wildlife Federation—point out that in addition to locking up resources, the wilderness designation is actually detrimental to the wildlife and ecology of an area. Multiple use of wilderness areas including regulated hunting is required for necessary herd control and enhancement of the ecology.

The Pisgah National Forest area is part of the Blue Ridge Overthrust Belt, a geological formation stretching along the eastern Appalachians from West Virginia down to Georgia and Alabama. Geologists believe that the formation contains vast, untapped resources of oil, gas, uranium, and other minerals.

Eastern uranium ore is thought to contain five times the density of uranium as the more-explored sandstones in the West. A number of uranium mining companies, including Urangesellschaft of West Germany and French American Metals Corp., have given up trying to fight the endless challenges from environmentalist groups like the Sierra Club and RARE II, and have pulled out of the area.

The Legal Challenge

However, a group led by Jack Brettler, a geologist and president of the Carolina Uranium Co. of Franklin, N.C., is now directly challenging the RARE II process initiated by Secretary Bergland. Two years ago, Brettler and a number of others formed an organization called the Save America Club, bringing together individuals interested in mining, lumbering, farming, hunting, fishing, and developing tourism in their area, all of which is prohibited under RARE II.

The organization launched a legal suit challenging the administrative procedures through which the National Forestry Service, under Bergland's direction, has locked up the Carolina lands. The suit contends that in applying the Wilderness Act of 1964, Bergland has violated the Eastern Wilderness Act of 1975, which governs lands east of the 100th meridian—approximately the Mississippi River.

The Eastern Wilderness Act states that only Congress, not the secretary of agriculture, has the authority even to propose areas for wilderness designation.

Brettler pointed out in a recent interview with *Fusion* that even the 1964 act was not supposed to go into effect until 1984, and in the interim inventories were to be taken of potential wilderness areas and their mineral and other resources. "The government is proceeding as if the act were in full effect, and it is putting land into wilderness long before the year 1984," Brettler said.

Several staffers administering the RARE II program, such as Ruppert Cutler, head of the National Forestry Service, are clearly biased. Cutler was formerly a leading member of the Wilderness Society, funded by Ford Foundation and Atlantic Richfield foundations, which opposes multiple use of wilderness areas.

FEF Support

The Fusion Energy Foundation has recently conducted a study that supports the North Carolina uranium miners and minerals developers who are fighting the land lockup in their state. In an Aug. 4 letter to the national forests supervisor for North Carolina, Jon C. Gilbertson, director of nuclear engineering for the foundation, urged "that prospecting permits should be issued for the exploration of uranium on the national forest lands cited." After evaluating the government's own geological estimates of the area in the Pisgah National Forest known as the Grandfather Window, Gilbertson pointed out that the potential 47,000 tons of uranium in the region could fuel 10 to 15 nuclear power plants of a 1,000-megawatt size for their entire 30-year operating lifetime.

Gilbertson calculated that the area could yield nearly 500,000 barrels-of-oil equivalent per day for this 30-year period, or the entire national synthetic fuels goal for 1987. The development of these uranium resources alone, Gilbertson added, could yield between \$1.4 and \$2.8 billion in economic benefits for the region.

The FEF's recommendation has received prominent coverage in the Asheville, N.C. press and has drawn letters of appreciation from North Carolina Senator Jesse Helms and Governor James Hunt.

—*William Engdahl*

Maine Yankee Referendum Has Int'l Implications

"The Sept. 23 referendum to shut down Maine Yankee, Maine's one and only nuclear generating plant, is much more than a local or regional issue," Fusion Energy Foundation director of nuclear engineering Jon Gilbertson told a press conference in Portland, Maine, Sept. 11. Gilbertson said the real issue is global economic development and whether the United States is going to have the capability to export nuclear reactors to the developing sector.

This is the first state referendum called to close an operating nuclear facility, and even its presence on the ballot represents a dangerous precedent and possible infringement of constitutional law, Gilbertson said.

Gilbertson, who traveled to Maine to meet with supporters of the plant, reported that popular sentiment in the state was overwhelmingly against shutting down the Maine Yankee. "This plant has had the best operating record of any nuclear plant in the country since it opened eight years ago, and its continued operation is critical for Maine's economy," Gilbertson noted.

Maine Yankee currently supplies 26

An Interview with Fermi Lab's Dr. Leon Lederman

U.S. High-Energy Physics: Going Out of Business?

Before Congress recessed in late July, the House voted to appropriate \$263.4 million in the fiscal year 1981 budget for basic energy research. This is \$77.8 million short of that proposed in President Carter's January budget message and just 8 percent above the fiscal year 1980 budget—a significant cut after inflation. As Fusion *went to press, the Senate and the House-Senate Conference Committee still had to settle on their final numbers.*

What these cuts will mean to U.S. basic energy research was the topic of this interview by Fusion *editor Dr. John Schoonover with Dr. Leon Lederman, director of the Fermi National Accelerator Laboratory in Batavia, Illinois.*

Question: What is the situation for the funding of basic science research at this time?

The fiscal year 1981 bill is now in Congress. The House Appropriations Subcommittee on Water Resources and Energy approved a large cut in basic energy research. A large fraction of that cut has been restored, but we are still short a significant amount of money from the revised president's budget, which is itself a cut from the original budget. In my own field, high-energy and particle physics, we are missing about \$19 million, and there are proportionate cuts in the other basic research budgets.

Our problems are compounded by inflation and by the fact that there has been a long slide since about 1968 in the support of physics. This has resulted in a very large contraction in the number of operating accelerator centers from six or eight to three.

At this point there is very little flexibility left in the physics budget. About 70 percent of the budget goes for salaries, another 15 percent is for power. Any cut is very significant; it has enormous leverage.

Question: Do you think that the budget cuts may lead to layoffs?

The big problem is that the idea of maintaining even three laboratories is becoming questionable because of the competition from Europe. You can't ask a guy to spend three or four years of his creative life on a piece of research that is going to be done sooner and better in Europe. Therefore, we have to improve our facilities.

All three laboratories use innovation and so on to try to cut costs and make the laboratory more productive. This involves developing high-risk technology like superconducting magnets in the case of the Brookhaven and Fermi labs. These programs are also a burden on the whole budget, and yet if the budget is that tight there is a real risk that we can't carry out these programs and that we'll have to contract further. In that case there will certainly be a large loss of people.

Question: To what do you attribute the erosion in government support for basic research?

percent of the state's electric power and still sells more than 30 percent of its power to neighboring New Hampshire and Massachusetts. If the plant were shut down, its power would have to be replaced by more expensive energy, which utility company sources estimate would cost the Maine rate payers an additional $140 million a year.

Industry representatives from Maine's iron, wire, and lumber and paper industries told Gilbertson that the closing of the Maine Yankee would "push them over the line"—raise their costs and make them noncompetitive with industry in the "sunbelt."

The Committee to Save the Maine Yankee has spent $.5 million on a mail and TV ad campaign and is preparing a legal battle, should the referendum win, challenging the constitutionality of a public referendum to close down an operating, privately owned facility.

Environmentalist Showcase

The special referendum—which was deliberately worded so that a "yes" vote is a vote to shut down the plant—was put on the ballot by the Maine Nuclear Referendum Committee run by Ray Shadis, an artist and sculptor who moved to Maine from New Jersey in 1967. Shadis was a delegate for California Governor Jerry Brown at the state Democratic convention last summer and was active in getting an antinuclear plank into the state's Democratic platform. Shadis's group has had people in about 60 towns and cities running a door to door "get out the vote" operation in the hope that they can muster sufficient "yes" votes from the college towns and southern coastal area of the state to pass the referendum

Although the Shadis group claims to be home grown, the antinuclear effort in Maine has received support from such quarters as the internationally funded Friends of the Earth, the Sierra Club, the National Lawyers Guild, and the Natural Resources Defense Council. It is known to have received funding from at least one of those groups—the NRDC.

In its coverage of Gilbertson's press conference, the *Portland Press Herald,* ironically, called Gilbertson and his FEF colleagues the "outsiders."

Basic research is a rather easy target during times of fiscal crisis. Since the return on basic research is long term and there are very few voters in the field, it becomes a convenient target. There is a failure to perceive the long-range necessity of the subject.

I personally believe that all of the crises we have today are technology-based. They come from depletion of natural resources, pollution of the environment, and so forth. It is not at all clear that we know enough about nature to handle the crises of the next century without basic research.

The foolishness is compounded by the fact that, as history has shown, in the long run basic research more than pays for itself. In the short range it has technological spinoffs. If you add them up, they probably pay for the basic research on a continuous basis.

There are many examples, superconductivity being the most recent. The high-energy labs have transferred an enormous amount of technology to industry. . . . Someone calculated that the total cost of basic research from the time of Archimedes was only $25 billion.

Question: If things continue as they are now, don't you think basic U.S. science research and development will be in trouble?

I think you are right. And I suspect that all the other disciplines in basic research are having the same trouble that we are having. You have to be careful, because when you attack the officials, they'll point to the fact that support of mathematics has been constant, but a lot of that is related to computers; it's applied research. And you've got to really focus on the basic research. I suspect that all basic research fields are feeling the pinch, and that we are in bad shape, really bad shape.

'Somebody is going to get us out of the energy crisis, and it's going to be somebody who's a kid in high school now. If he's lost because of discouragement or because of lack of opportunities in basic research, we may have to wait another 20 or 30 or 50 years to develop that mind.'

Fermi Lab director Leon Lederman

Fermilab Photograph

We are losing people, and they are precious, and you can't reverse that. Somebody is going to get us out of the energy crisis, and it's going to be somebody who's a kid in high school now. If he's lost because of discouragement or because of lack of opportunities in basic research, we may have to wait another 20 or 30 or 50 years to develop that mind.

The failure of American technology

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Lederman

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in the last few years is generally perceived. We can't keep helicopters in the air. We tried to make small cars, and we didn't make them well.

Even in the area where we are still very strong, in the computer business, there's a softening and very, very impressive competition from overseas. I'll bet you anything that a large component of that has to do with this neglect of basic research. It sets a standard; people call it the cutting edge. Once you diminish that, you start to get weak in all the other aspects.

Look at our steel industry: it's archaic compared to some of the modern stuff they have in Japan. On a per capita basis, they are investing enormously more of their GNP in basic research. Europe is a factor of 2 over us, at least in high-energy physics. The thing that worries me is that they have something like 2,000 PhDs practicing high-energy physics, and we are at a very static 1,100 in the United States. I'm worried about those 900 people we lost. That's the real catastrophe.

Question: There has been a lot of discussion about the relative weakness of our ability to produce trained scientific and technical workers compared to the Soviet Union.

That's true. The universities have also suffered from this. Because the research money, or at least a significant fraction of it, does go directly into the universities. That allows the universities to expand. There has been a contracting university position in basic research as the research budget has been contracted.

Everything is regenerative. When we were doing well, as we did from the end of World War II up to the end of the 1960s, everybody who had scientific competence could get his research supported and we flowered, both in the universities and in the research results. I think we have been largely coasting on these results for a long period.

Science and Law

'If Congress does not possess the power to encourage domestic manufactures by the regulation of commerce, the power is annihilated for the whole nation. . . . Why, then, should the power be surrendered and annihilated? . . . A foreign nation might, as a conqueror, impose on us this restraint as a badge of dependence and a sacrifice of sovereignty, to subserve its own interests; but that we should impose it upon ourselves is inconceivable. The achievement of our independence was almost worthless, if such a system were to be pursued.'

—Justice Joseph Story

The Real Constitutional Issue In the 'Right to Patent Life'

One of the most important of recent legal decisions that bear directly on the future course of science and technology in the United States is the U.S. Supreme Court's "Right to Patent Life" decision last June in the case of *Diamond v Chakrabarty.*

The specific issue in dispute was whether the successful generation of a single *pseudomonas* bacteria capable of digesting all of the components of crude oil could be patented by biologist Chakrabarty, an employee of General Electric. The court ruled in Chakrabarty's favor. However, the deeper issue involved—obscured by the images of Frankenstein monsters called up by the opponents of Chakrabarty's patent—was a central point in the U.S. Constitution.

The Constitution empowers the Congress to "Promote the Progress of Science and the Useful Arts by securing for limited times to authors and inventors the exclusive right to their respective writing and discoveries."

To that end, the United States passed its first Patent Act in 1793, and that act has continued essentially unchanged on the books to this day. In relevant part it reads:

"Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent thereof."

Antiscience Arguments

In *Diamond v Chakrabarty,* Diamond, U.S. Commissioner of Patents, had sought to deny a patent to Chakrabarty for his biological discovery. The government argued its case by adopting the antiscience arguments put forward in the *amicus* brief submitted by Jeremy Rifkin, one of the leaders of the Jacobin "People's Bicentennial Celebration" in 1976 and author of the antigrowth, antiscience book *Entropy.*

The court noted that the briefs submitted by the government and friends of the court "present a gruesome list of horribles. Scientists, among them Nobel Laureates, are quoted suggesting that genetic research may pose a serious threat to the human race, or at the very least, that the dangers are far too substantial to permit such research to proceed apace at this time."

Although the government tried to focus the case on the issue of the patenting of life, the arguments it drew on are essentially the same ones that have been thrown against nuclear energy development and all frontier areas of scientific inquiry. If the Su-

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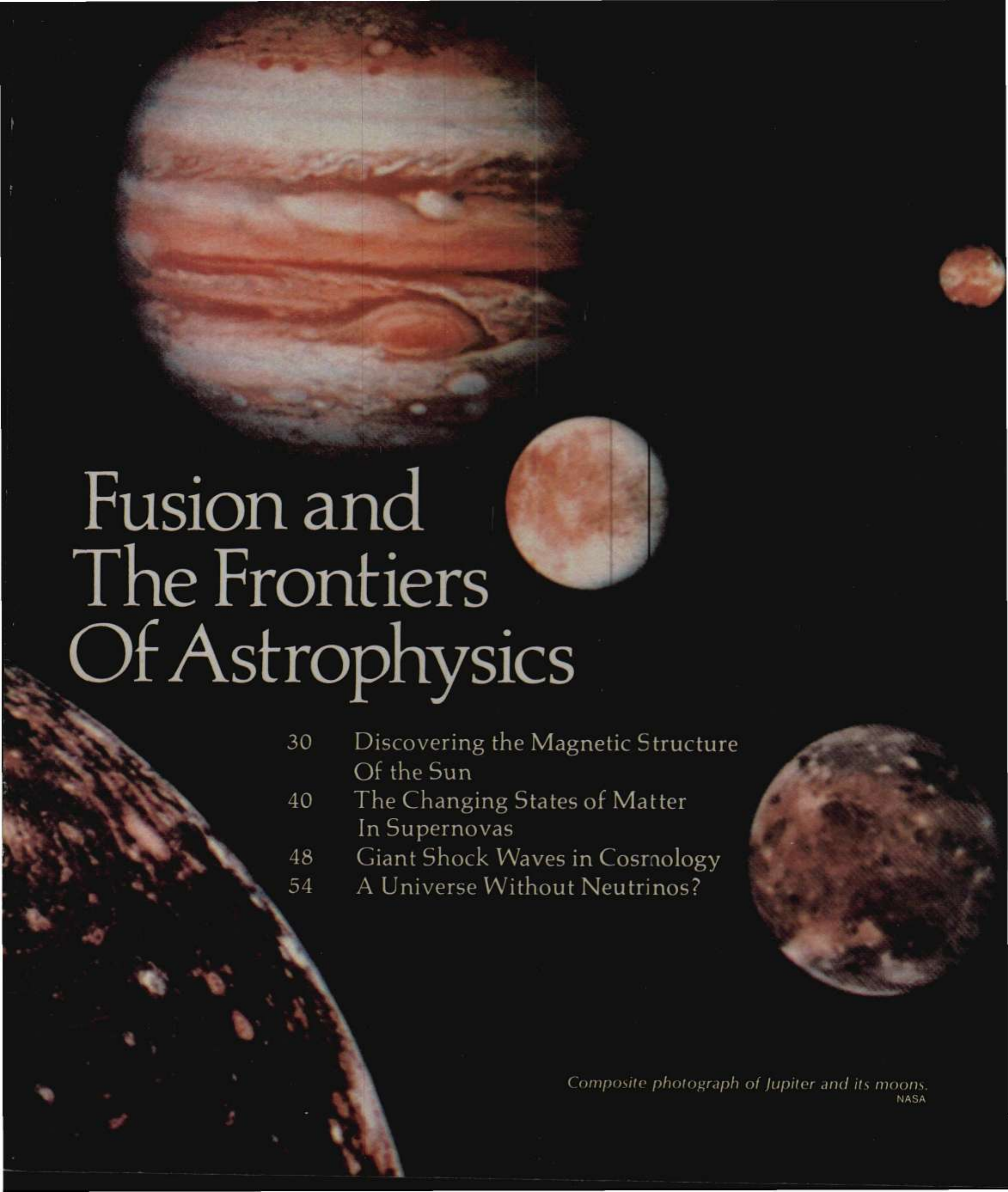


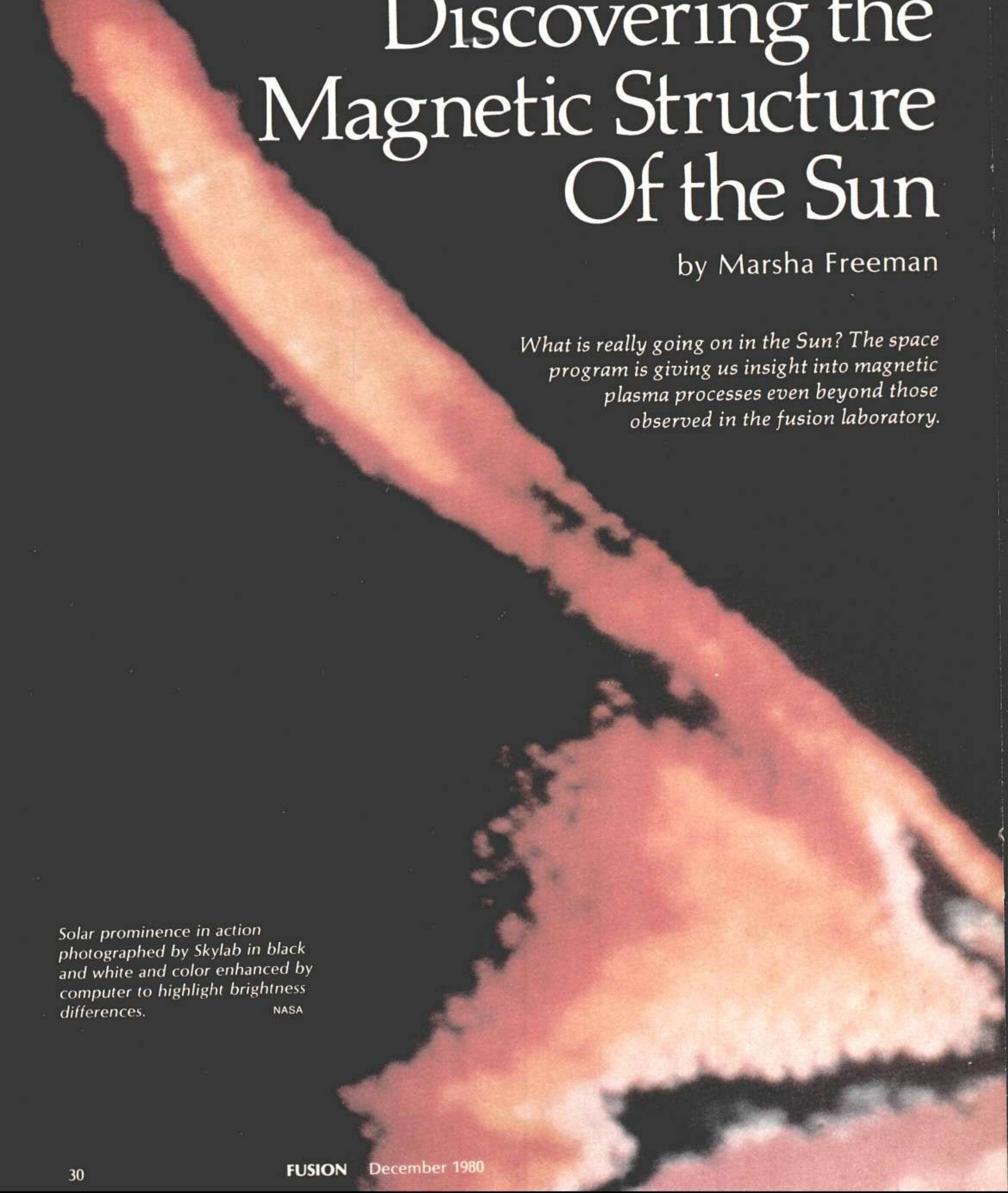
Fusion and The Frontiers Of Astrophysics

Composite photograph of Jupiter and its moons.
NASA

Discovering the Magnetic Structure Of the Sun

by Marsha Freeman

What is really going on in the Sun? The space program is giving us insight into magnetic plasma processes even beyond those observed in the fusion laboratory.



Solar prominence in action photographed by Skylab in black and white and color enhanced by computer to highlight brightness differences. NASA

The Sun is both the celestial laboratory from which we *will learn about the billions of other stars in the* universe and the *in situ* experiment from which we will learn about plasma processes in terrestrial fusion laboratories. Discovering the dynamic development of the Earth's nearest star will broaden the knowledge of the astrophysicist *in understanding the evolution of the other* energy-giving bodies in space and help to answer the how, why, and when about the existence of the cosmic system.

Probing the questions of how fusion-produced energy is organized and transported throughout the Sun and through interplanetary space from the Sun will also help to answer questions in plasma regimes that cannot be duplicated in the current fusion laboratory experiment. The interaction of the solar wind with the magnetic atmosphere of the Earth poses questions that must be answered in both magnetic and inertial fusion plasma physics in the laboratory to bring the energy of the stars to Earth.

Although its importance has not been generally recognized, NASA has provided invaluable data in furthering our understanding of the magnetic structure of the Sun. The continued exploration in space from NASA vehicles like Skylab is essential to reveal some of the most important mysteries of the Sun and its relationship to the interplanetary space-plasma medium, to the Earth, and to other planets. If these magnificent observations and measurements are studied with the collaboration of plasma physicists in fusion theory who are trying to answer the same questions in laboratory plasma systems, we will close in on an understanding of this fourth state of matter that makes up 99 percent of the universe *and that will provide* life-giving energy for all mankind.

Unanswered Questions

From 1610, when Galileo began solar observations with *the first telescopes*, the Sun has been the major object of investigation for all scientific space exploration. However, not until the last 20 years have many of the Sun's basic phenomena been closely observed as modern telescopes were able to stretch above the distorting and masking effects of the atmosphere.

We now have an impressive picture of the most striking features and dynamics of solar phenomena, but in most cases we still cannot fully answer the questions: Why does the solar wind propagate thousands of miles through space instead of becoming disorganized and dissipated long before reaching the Earth and even farther planets?

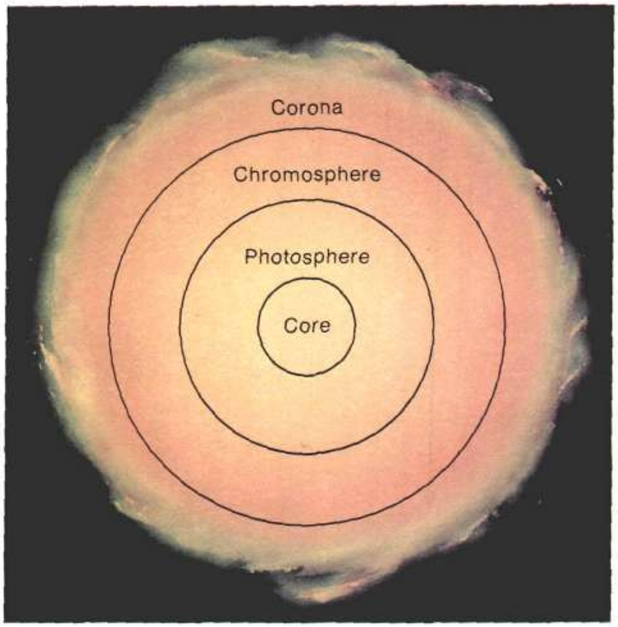
Why does the Sun's plasma heat up in layers farther away from the fusion-energy-producing core, rather than cool off the farther away it gets?

How is the energy stored in successive layers of the Sun and of geospace and why is it released in concentrated bursts at specific times?

The behavior of the Sun affects the Earth in terms of weather and climate and in familiar radio transmission disturbances and auroras. These effects may be considerable, and a real understanding of this process has to take into account the interaction of the life system on Earth with the Sun. There have been attempts to correlate changes in the observable Sun's activity with changes in the Earth's climate. For example, a period of solar quiescence from 1645 to 1715, researched by the French astronomer Maunder and referred to as the Maunder minimum, resulted in an overall *decrease in the solar constant* (the total average energy delivered from the Sun to the Earth). Recently, John Eddy of the University of Colorado has postulated that this perhaps 1 percent decrease in energy led to the recorded cool period then known as the "little *ice age," which coincided with a period of bad crops* and famine. Shorter-term changes in weather patterns on Earth will most likely be found to be related to changes in solar activity as well, but further research is needed to understand how this works.

The real challenge to plasma physics in fusion and solar physics alike, however, is the integration of observed solar phenomena with theoretical study of plasma behavior in the laboratory. A recent evaluation of space plasma physics by the nation's leading scientists on the Space Science Board of the National Academy of Sciences encouraged exactly this type of collaboration: "Future research in space plasma physics should involve a much closer integration between theory and *observation . . . in order* to bring the research into closer contact with the mainstream of plasma physics research."

The advances in space plasma physics and laboratory theory were each given a boost during the Eisenhower era. The first discovery and observations of the Van Allen radiation belts of trapped solar-originated particles orbiting the earth were accomplished by the spacecraft Explorer I at almost the exact time research in controlled thermonuclear fusion was declassified and the understanding of the turbulent loss of trapped particles from fusion mirror devices was under investigation. The scattering of electromagnetic radiation from turbulent *laser fusion and from ionospheric* plasmas was pursued in parallel.



VITAL STATISTICS

Magnetic field strength by type of structure
Photosphere: sunspots 3,000 gauss
Polar field: coronal holes 1 gauss
Chromosphere: 25 gauss
Chromosphere: plages 200 gauss
Chromosphere: prominences 10 to 100 gauss

Temperature (in degrees Kelvin)
Core: 15 million° K
Photosphere: 6,000° K
Photosphere: sunspots 4,200 to 5,600° K
Chromosphere: 4,300 to 50,000° K
Corona: 800,000 to 3,000,000° K

Distance (in kilometers)
Diameter (core to chromosphere): 1.39×10^6 km
Photosphere: 500 km
Chromosphere: 2,000 km
Corona: larger than Sun's diameter

Figure 1
A MAP OF THE SUN

The Sun's layers above the fusion core were mapped for the first time in many wavelengths by the Skylab telescopes, including precise measurements of the temperature, thickness, and magnetic organization of solar layers and structures. The conclusion by space scientists studying the tens of thousands of pictures taken on the Skylab missions is that the magnetic organization of plasma particles on the Sun accounts for the sunspots, prominences, and other observable structures. The lack of magnetic field strength concentration at the poles, on the other hand, accounts for the coronal holes that allow the constant outflow of plasma that makes up the solar wind. The corona itself, photographed for the first time without the need of a lunar eclipse, extends ephemerally into interplanetary space.

Now what must be pursued in parallel is energetic beam propagation through a laboratory fusion plasma, in the ionosphere and in the Sun's layers or through interplanetary space. Magnetic field line reconnection, shock wave formation, and particle acceleration in tokamaks, on the Sun's surface, and in the geospace also need to be integrated. The spontaneous formation of magnetic fields from fluid turbulence in fusion devices and the large-scale force-free structures produced by the Sun that organize and concentrate energy may be the key to celestial and terrestrial plasma systems.

The challenge to all plasma physics—particularly in the next two decades when the need to develop and commercialize an unlimited energy source like fusion makes it imperative that we understand the science of fusion energy—is to tackle the "why's" in plasma and begin to bring under man's control the Sun's extraordinary processes, as yet unexplained.

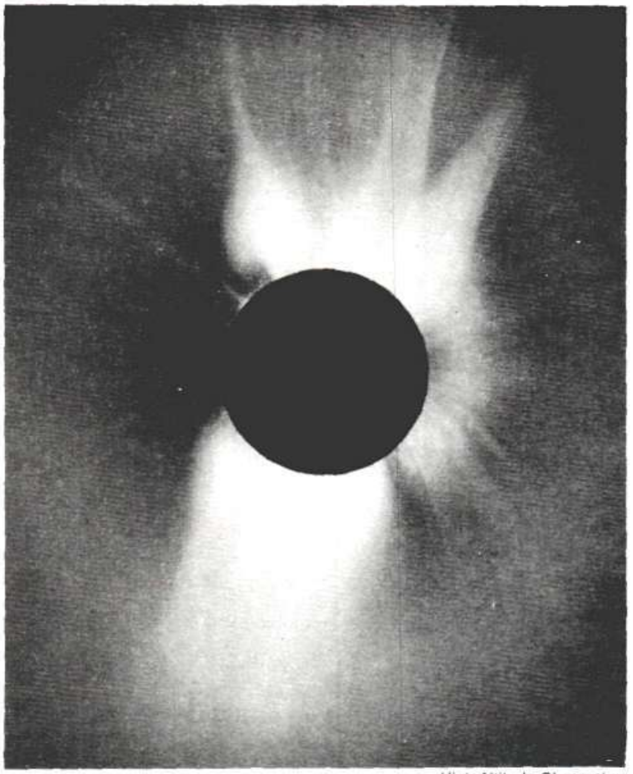
The Phenomenology of the Sun

The Sun is a white-dwarf star (a star of small radius and high density), estimated to be about 4.5 billion years old. At a distance of more than 100 million kilometers (km) from Earth, the Sun has a differential rotation rate that varies from 26.8 days at the equator to 31.8 days near the poles (as seen from Earth).

The Sun's diameter is 1.36 million km, or 109 times the diameter of the Earth, and its mass is 333,000 times that of the Earth. The chemical composition of the visible photosphere region of the Sun is estimated to be about 73 percent hydrogen and 24 percent helium with traces of other elements. The fusion process at the core of the Sun is constantly converting hydrogen to helium at a temperature of about 15 million degrees Kelvin.

The hot gases undergoing fusion at the Sun's center are contained by the huge gravitational force produced by the highly compressed matter, estimated to be 250 billion times the gravitational force of the Earth. The energy transformation process as the fusion energy makes its way from the inner core to the outer layers of the Sun is minimally understood and cannot be studied by direct measurement through probes of the Sun's inner layers. It is estimated that inner core energy can take 50 million years to reach the Sun's surface.

The Photosphere. The first layer of the Sun accessible by direct measurement is the photosphere, which produces the visible white light astronomers have been studying for millennia. It is about 6,000 degrees Kelvin in



High Altitude Observatory

The Sun's corona photographed from the ground June 30, 1973 during a total eclipse. The black disk is the Moon, which covers the Sun's chromosphere and photosphere, revealing the corona. Rays of light emanating from the sides resemble the patterns of iron filings sprinkled over the poles of a bar magnet.

temperature and extends for a distance of about 500 km, a thin layer less than 0.1 percent of the solar radius.

Although the visible photosphere appears unchanging to the naked eye, beneath it is a turbulent plasma fluid flow. The photosphere is organized throughout into a constantly changing pattern of small circulation cells, which last only a few minutes. Caused by the turbulent plasma flow beneath the photosphere, these granulation cells break up and re-form continuously, regardless of other solar activity.

The Chromosphere. The layer above the white light is the chromosphere, which has an increased temperature range between 4,300 and 50,000 degrees Kelvin. Because of their higher temperatures and lower densities, neither the chromosphere nor the Sun's crown, the corona, could be seriously studied until NASA's Skylab carried ultraviolet and X-ray telescopes outside the Earth's filtering atmosphere.

The chromosphere is organized into a network of giant circulation cells that reflect the activity of the photospheric granulation cells beneath the chromosphere. Several times thicker than the photosphere, the chromosphere ends in a ragged boundary that contains spicules, or spiked extensions of chromospheric material up to heights of 5,000 to 15,000 km into the Sun's corona. These spicules rise and fall like choppy waves in a stormy sea every 5 to 10 minutes, producing constantly changing motion at the top of the chromosphere (see photograph, page 36).

The Corona. The crown of the Sun, the corona, is the hottest region outside the core, and has been "seen" only with the X-ray technology made available by Skylab's two X-ray telescopes. Before the NASA era, astronomers had to travel thousands of miles to catch the Sun in full eclipse, when the Moon blocks out the visible solar disk and a glimpse of the corona is possible. Even then what the astronomers could see was only the corona's white light; this light is not radiated from the corona but is a reflection of photospheric light from the corona's circulating electrons (see photograph at left).

Under X-ray examination scientists learned that the corona of the Sun is made up of radiating rays of particles and streamers that stretch millions of kilometers into interplanetary space, constantly releasing coronal material. Although the solar wind was discovered in 1960 on an early satellite mission, coronal holes from which the Sun continuously propels solar material were not well mapped before Skylab's mission in 1973-1974.

Coronal Holes. Coronal holes at the poles of the Sun are regions of greatly reduced magnetic field strength that are relatively stable. Unlike other more ephemeral solar phenomena, they seem to rotate as if they are attached to a solid Sun. In contrast, the structures of the photosphere and chromosphere rotate differentially at different latitudes of the solar sphere. Also of interest, solar plumes have been observed emanating from bright spots in the "dark" (in terms of X-rays) coronal holes, as if they are following along radial, open magnetic field lines.

The Active Sun

The most interesting solar phenomena, however, are not the constantly changing structures of the surface layers, nor the near-constant stream of solar wind particles; they are the temporary bursts of solar activity that for 2000 years have been associated with sunspots.

Sunspots. Sunspots, which appear as darker regions on the Sun's surface because of their cooler temperatures, occur generally in 11-year cycles, coinciding with a reversal in the Sun's magnetic field. The relationship between the reversal of the Sun's magnetic field and the sunspot cycles is largely unknown. Scientists know from observation since Galileo's time that the 11-year cycle is not ironclad, but they do not know why.

Although it is uncertain whether sunspots themselves are the real barometer of solar activity, they have certainly been the longest-observed periodic behavior of the Sun. The darkened center of the spot, or the *umbra*, is a region about 30 percent cooler than the surrounding photosphere where intense magnetic field configurations prevent the escape of light.

The magnetic fields in sunspots, first measured by astronomer George Hale in 1908, are 3,000 gauss compared to the Sun's polar fields of about 1 gauss. (By comparison, the Earth's magnetic field at the equator is about 0.7 gauss in strength.) The lighter penumbra of a sunspot can be observed to be made up of filaments of concentrated solar matter organized along intense magnetic field lines.

There is approximately a 1,500-degree increase in temperature from the umbra to the penumbra. It was only when simultaneous "pictures" of the chromosphere and corona could be taken measuring X-ray, ultraviolet, and magnetic energies, however, that scientists began to have some idea of the dynamics of the sunspots themselves, and their effect on the upper solar layers.

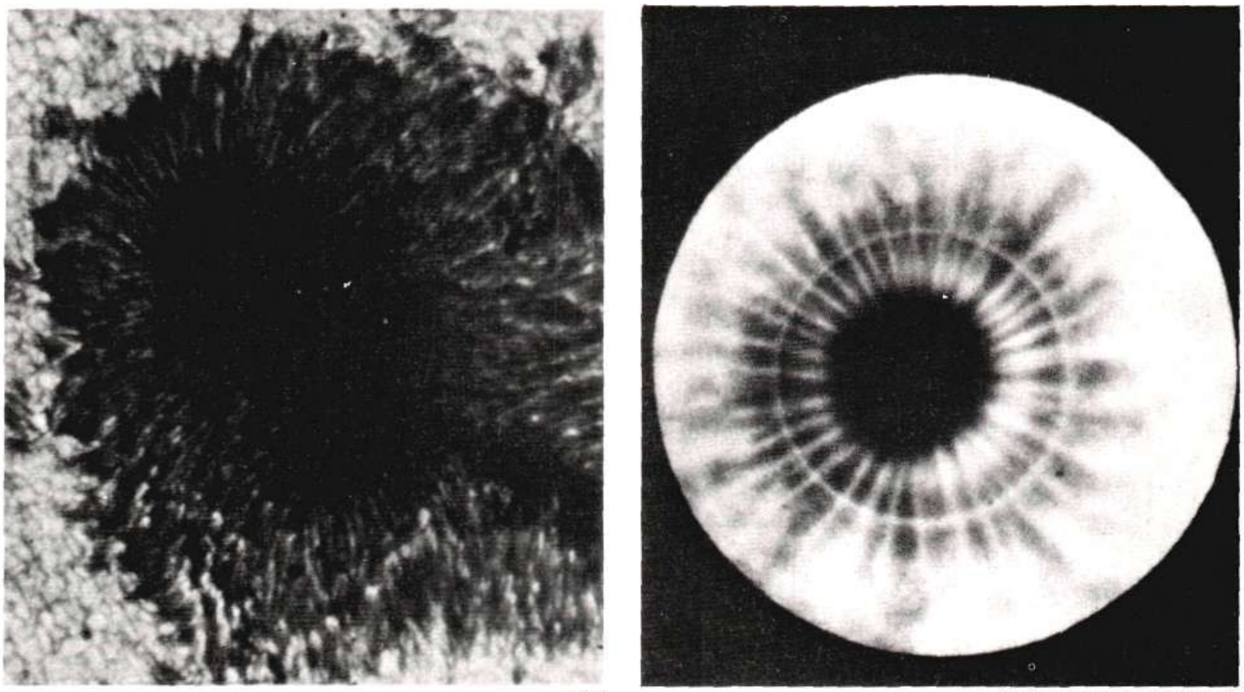
Perhaps the most important general discovery from the hundreds of thousands of pictures brought back from Skylab's missions between 1973 and 1974—virtually in all electromagnetic wavelengths simultaneously—is that the major organizing phenomenon of the Sun is its complex of magnetic fields.

Magnetic mapping of sunspot areas of solar activity revealed that all solar activity in every area is organized into regions of concentrated magnetic fields that are connected to other regions of *opposite polarity*. At the beginning of the 11-year sunspot cycle, two bands of concentrated magnetic fields form at about a 45-degree latitude on the Sun. At the solar maximum these bands have drawn closer together to the Sun's equator and to each other. It appears that sunspot groups are made up of magnetic loops of opposite polarity that reverse as the Sun's overall magnetic field reverses every 11 years.

Solar Flares. In the chromosphere above the photospheric region of sunspots, Skylab identified the formation of plages (it rhymes with mirages) or localized regions of bright emission out of which are produced solar flares. These solar flares, spewing out bursts of charged particles and radiant energy, most directly produce the geomagnetic activities that affect the Earth.

The localized temperature in flares can reach 20 million degrees, as hot as the interior of the Sun. Initially, flares are confined to small, intense magnetic concentrations that burst forth at currently unpredictable points in their development.

What causes the solar flares? Considering the magnetic field intensity, temperature, and velocity of particles released from flares, it is possible that they are the result of the magnetic fields associated with the sunspots, in groups of opposite polarity, which undergo collapse and reconnection producing shock waves, particle acceleration, and dramatic temperature increases. These shock fronts then may be energetically coupled to the next layer chromosphere in such a way as to produce solar flares.



NASA

Courtesy of Dr. Winston Bostick

Figure 2
PLASMA FILAMENTS IN SUNSPOTS AND THE LABORATORY

There is an uncanny resemblance between the filamentary structure of the penumbra of sunspots (left) and structures generated from plasma theta pinch experiments in the laboratory. The plasma organization in both is characterized by concentrations of magnetic energy and it appears to organize itself spontaneously under certain plasma conditions. Also visible in the sunspot picture are the granulation cells in the photosphere, out of which the sunspots are formed.

Solar Prominences. The phenomena of magnetic field reconnection can be dramatically seen in another solar activity observed in the connecting region of the photosphere and chromosphere—solar prominences. Sometimes extending 240,000 km above the Sun's surface, solar prominences are bursts of material organized in loops along magnetic field lines.

Close examination has revealed that these closed loops along arched magnetic field lines have their "footpoints" rooted in regions of opposite magnetic polarity, extending down into the photosphere (and perhaps farther). Full-spectrum mapping of prominences has revealed that they contain cooler material trapped in the center of the arched field lines, similar to the protons and electrons in the Van Allen radiation belts that are trapped by the Earth's magnetic field. The cooler core appears to be surrounded by a large shell of hotter coronal material.

Solar prominences can persist for hours, rotating along with the Sun; they can also be slowly changing magnetic structures on the surface, extend as ribbons, and then persist or erupt. Active prominences, which are associated with increased solar activity in general, can suddenly erupt, rising through the corona. These eruptive prominences appear as twisted filaments of plasma along magnetic field lines, propelled from the Sun, much like the filamentary structures found in laboratory plasmas.

Coronal Transients. Expulsions from such erupting prominences and from solar flares cause transients in the Sun's corona. Coronal transients can explode into an area of space that is larger than the diameter of the Sun, most likely as a result of the decreased density and gravitational force of the Sun. Like the solar wind expelled from coronal holes, coronal transients expel particles at a speed of about 100 km per second, and these are accelerated to more than 1,200 km per second as they propagate.

Key questions in the propagation of the coronal solar wind and the coronal transients produced by flares and prominences are why these beams of particles do not dissipate as they interact with the interplanetary background plasma and why they increase in velocity. One theory suggests that Langmuir waves (the simplest electrostatic waves in a plasma) are created as the beam of energy is absorbed by the background plasma. In laboratory plasmas, these Langmuir waves have been demonstrated to form solitons (spatially concentrated wave energy) that concentrate the energy in a coherent structure and actually "push" forward the propagating beam.

An understanding of this propagation phenomenon in

Skylab: A New Look at the Sun

Skylab, the Earth's first orbiting laboratory, was conceived in 1960 when the National Academy of Science's Space Science Board, headed by Dr. Lloyd Berkner, recommended the "installation in space of a very large orbiting solar laboratory, weighing several thousand megagrams and comparing favorably with ground-based observations in terms of light-gathering power and angular and spectroscopic resolutions."

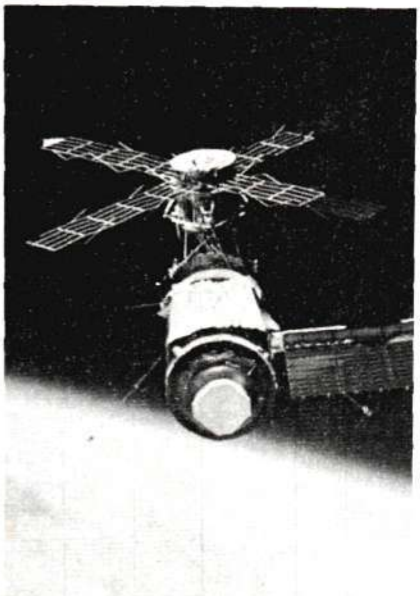
The Apollo telescope mount system that flew on Skylab was begun in 1965 as the final step in fulfilling that 1960 strategy for solar astrophysics.

Skylab was launched May 14, 1973. It operated for 171 days manned by astronauts and space scientists and for 251 days in all, manned and unmanned. Because Skylab completed its Earth orbit every 93 minutes, it could take pictures of the Sun without long interruptions.

The Apollo telescope mounts included eight telescopes, as large as those on Earth used at the nation's finest observatories. The power came from an independent solar photovoltaic array, separate from that of the rest of the laboratory. Two of the telescopes measured X-ray emissions, one measured extreme ultraviolet emissions, and two other UV telescopes measured visible light and hydrogen alpha emissions for target identification and reference.

Simultaneous observations of the Sun were made in nearly every part of the electromagnetic spectrum, providing a two-dimensional view of the Sun for the first time. The planned Solar Polar Mission, using two spacecraft making simultaneous observations at different points outside the plane of the ecliptic, would give scientists the first three-dimensional view of the Sun.

Skylab discovered entirely new solar phenomena—like bright points—and gave us the first hint at what may be the organizing principle for much of the Sun's activity—its highly organized magnetic field system. Although the Skylab mission raised more questions than it appears to have answered, it has defined the new questions that future missions will strive to answer.



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Skylab as it looked to the three astronauts as they approached it Nov. 16, 1973 to begin their 84 days in space.

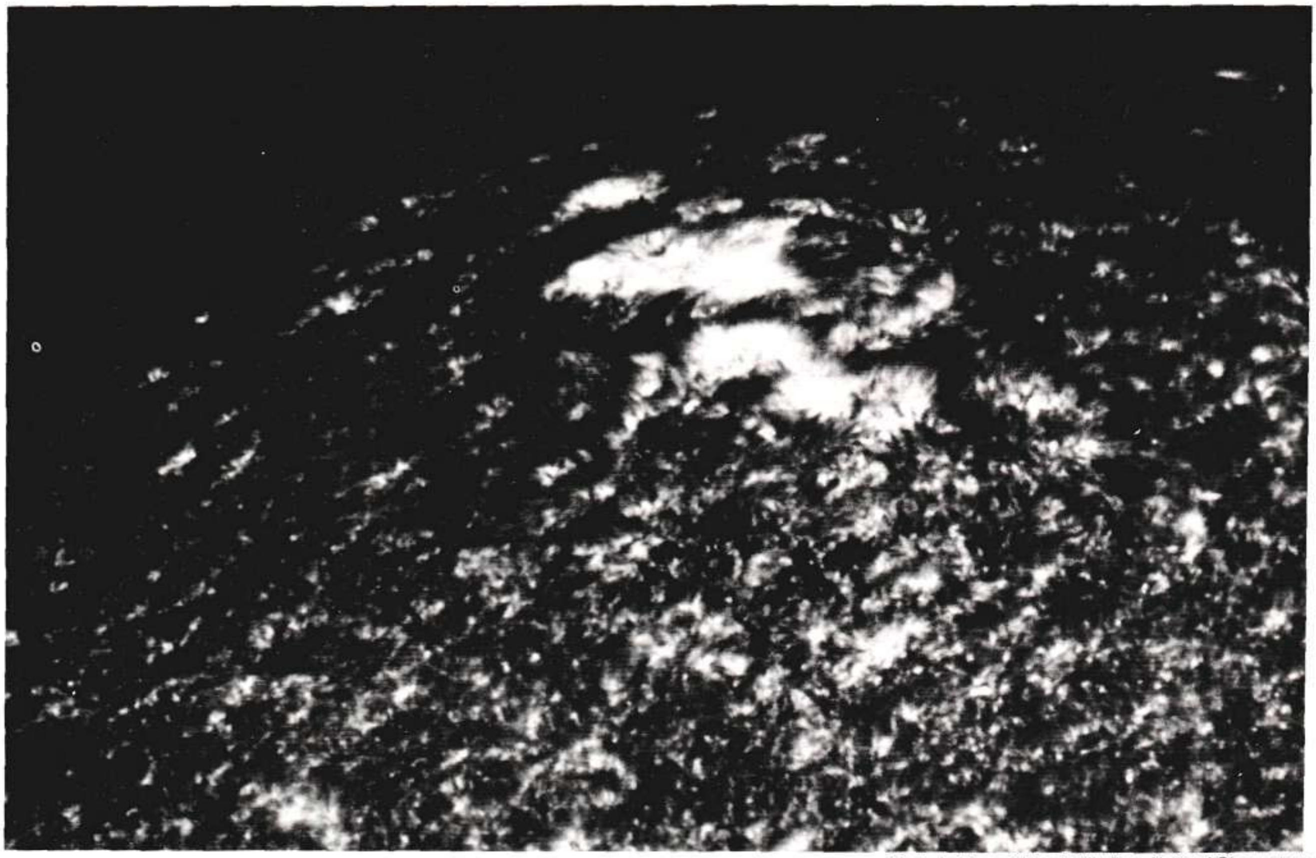


Photo by Bruce Gillespie/Kitt Peak National Observatory

The mottled surface of the upper chromosphere, as seen in a high resolution spectroheliogram. Near the top is an active region or plage. Gigantic circulation cells, about 30,000 km in diameter, form a network pattern that covers the entire Sun. The cells are bounded at their edges by a fence of dark spicules.

the energy released by the Sun could have important consequences for beam propagation questions in inertial fusion systems. For instance, if soliton formation could be controlled, it could potentially help in the efficient propagation of fusion driver systems. In weapons development, where coherent beam propagation through the Earth's plasma atmosphere (both the ionosphere and magnetosphere) must be efficient and maintain coherence, solar propagation phenomena are of similar importance.

A key question in magnetic fusion development has been the problem of electron transport in tokamaks—the preferential transfer of energy from hotter to cooler electrons or the actual escape of the hotter electrons across magnetic field lines, thereby cooling the fusion plasma. Although this worrisome electron transport observed in tokamaks apparently will dissipate at higher plasma temperatures, understanding the "why" of the more general question of the distribution of particle energy in all plasma systems is important (Figures 2 and 3).

Again, the answer may lie in the structures created by the magnetic turbulence in plasmas that result from magnetic field reconnection and shock wave phenomena. For example, accelerated deuterons (nuclei of deuterium atoms) in fusion theta pinch and reversed pinch experiments have produced coherent and structurally organized particle beams resembling those of the Sun.

Bright Points. Another intriguing observation made from Skylab's array of eight telescopes was the discovery of bright points on the solar surface. Interestingly, these points *increase* in number and magnetic field flux as sunspot and general active solar regions *wane*. They have been identified as small sources of X-ray and ultraviolet emission associated with intense, localized magnetic fields of opposite polarity. Bright points appear all over the solar surface, including in coronal holes at the poles, and they seem to be of short duration.

There are usually about 100 bright points observable on the Sun's visible hemisphere and they seem to account for much of the Sun's magnetic energy during times of solar quiescence. This raises a question of whether there is an overall "magnetic balance" or magnetic budget for the Sun that is maintained by different mechanisms. The same question, of course, might apply to laboratory plasma physics.

Skylab gave astronomers, solar physicists, and the scientific community in general a "look" at the Sun that had never been possible before. The international Solar Polar Mission, in which U.S. participation is uncertain because of budget considerations, would extend Skylab's "pictures" by providing the first three-dimensional observations of the Sun outside the plane of the ecliptic, focusing on the more quiet solar poles.

As this review of the Sun's phenomenology indicates, Skylab's fall a year ago was unfortunate not because of the danger that it might have hit a populated area, but because its demise brought an end to the critical data obtained over the year of its mission.

The Earth-Sun Relationship

The behavior of charged particle interactions as organized by intense magnetic fields into coherent and lasting structure can be studied closer to home, as well as near the Sun. Geospace, that region of interaction between the Earth's magnetic field and the oncoming solar wind, is a near-Earth laboratory with plasma/magnetic field interactions similar to those on the Sun.

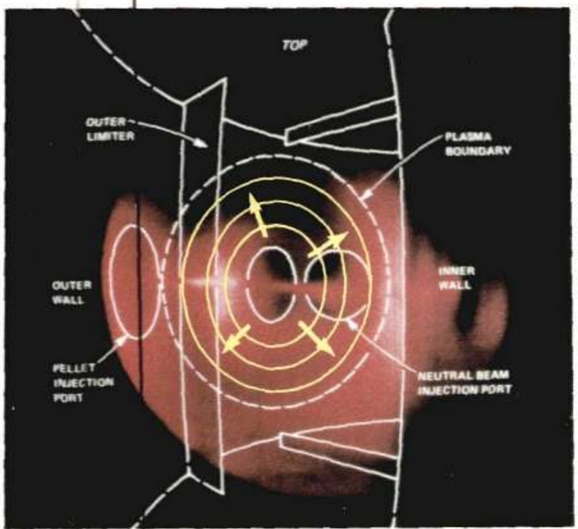
Until the discovery of the solar wind and Van Allen radiation belts, it was assumed that the Earth was traveling more or less in a vacuum around the Sun. In reality, the Earth is "plowing through" magnetic fields, charged particles, and radiation that covers the entire electromagnetic spectrum.

Earth's geospace extends for millions of kilometers asymetrically around the Earth and contains the atmosphere, ionosphere, magnetosphere, and near-Earth interplanetary medium. It is an integrated, interacting system throughout which energy is continuously being generated, stored, transformed, and released.

From Skylab and concomitant satellite missions scientists have at least a preliminary mapping of geospace and it appears that each region is populated by distinctly different plasma regimes. The most important and intriguing question, which future missions will have to answer, is how the energy generated by interaction with the solar wind and in the Earth's ionosphere is captured, stored, transformed, and transported.

The impact of the solar wind as it nears the Earth results in a compression shock wave along the edges of the impact region facing the Sun, pulling the magnetic field of the Earth into a teardrop shape on the downstream side. The magnetopause is the boundary area that separates the solar wind from the magnetosphere and plays an important role in reorganizing the behavior of the oncoming solar particles, plasma waves, and electric currents. The magnetopause traps particles that feed the Earth's radiation belts and confines low-energy plasma to keep it from escaping into space (see Figure 4).

The magnetosphere narrows to form a tail on the downstream side of the Earth along the center of which appears to be a neutral sheet of plasma. Most of the energy deposited from the solar wind appears to be stored in the magnetotail to be released in bursts of accelerated charged particles. These releases cause substorms, similar to the particle release of the Sun through the solar wind itself, which cause electromagnetic disturbances in the Earth's ionosphere and atmosphere and in electrical transmission lines.



ORNL

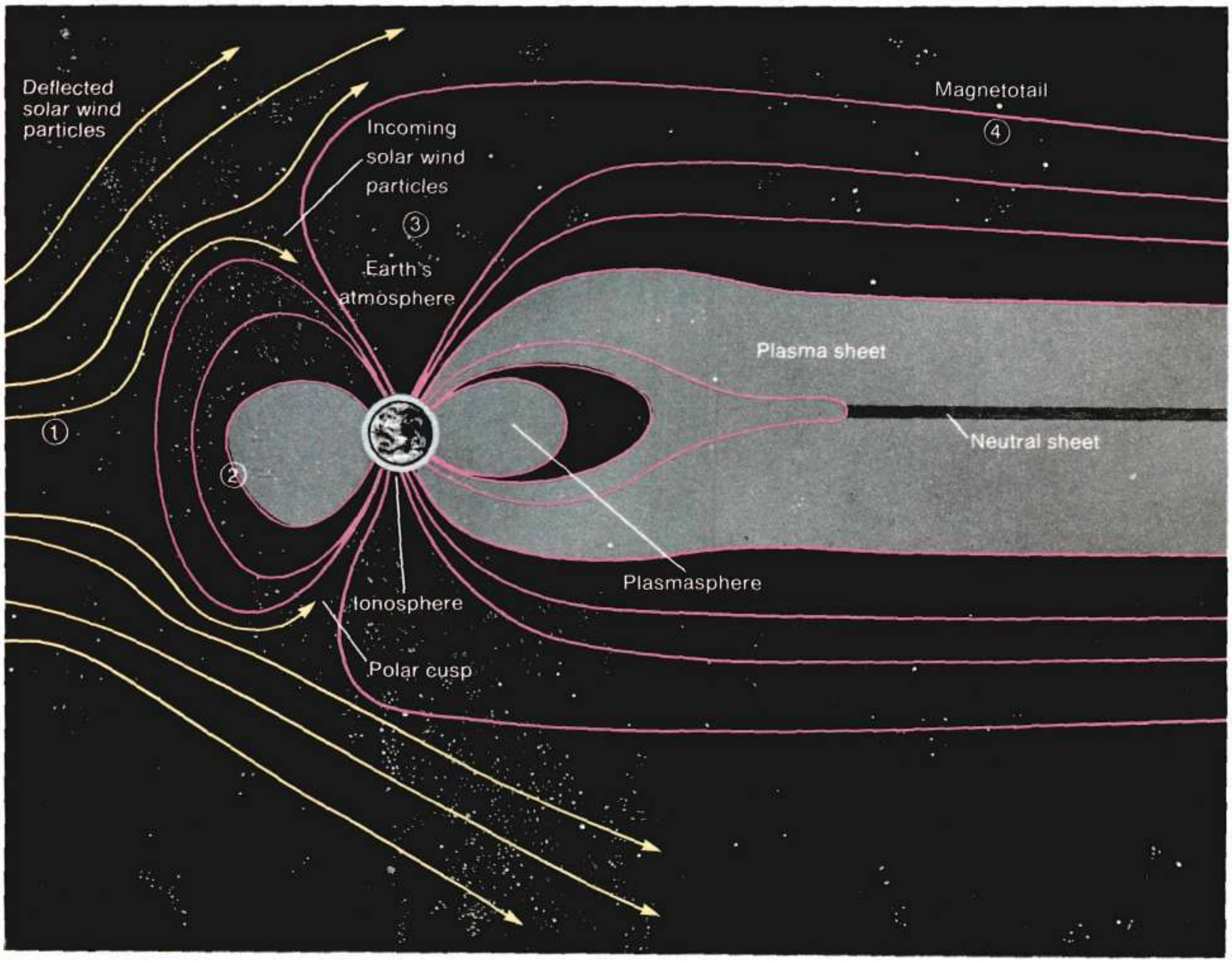
Figure 3
PLASMA FUEL INSIDE A TOKAMAK
This extraordinary photograph shows the plasma fuel inside the ISX tokamak at the Oak Ridge National Laboratory as viewed from one of the ports in the tokamak machine. The yellow lines superimposed on the photograph represent the bubbly magnetic field surfaces that allow for the electron transport from the hot core of the plasma to the cooler outer parts. The arrows show the direction of this energy transfer.

These sudden energy releases may be the result of magnetic field reconnections taking place along the neutral plasma sheet at the center of the magnetotail, but this explanation is still speculative. It is likely that overall a process of reconnection and shock wave generation accounts for energy release from the magnetosphere to the ionosphere, as in the Sun where such a process among various surface layers may produce flares and prominences.

The magentospheric tail extends about 1,000 Earth radii downstream and has not been empirically measured. But not all the solar wind energy is captured by the tail and overall magnetosphere. The Earth's magnetic field appears to thin at the poles, forming polar cusps where solar wind plasma flows down magnetic field lines in the dayside ionosphere.

These streams of electrons to the atmosphere seem to be accelerated by magnetic-field-aligned currents and parallel electrical fields that accelerate solar electrons downward at the same time that positive ions are pushed upward. The solar wind is not the only energy source in geospace. Positive ions of hydrogen and helium escape from the ionosphere to the magnetosphere (a cooler to hotter flow) at supersonic speeds.

Although little understood, it seems possible that this



Plasma source regions: Solar wind, Ionosphere
Transport regions: Boundary layer, Plasma mantle, Dayside cusp, Auroral field lines, Tail plasma sheet
Storage regions: Geomagnetic tail, Ring current and near-Earth plasma sheet

Figure 4
THE ORGANIZATION OF GEOSPACE

One of the most important areas of study in solar plasma physics is the interaction of the Sun's input of energy with the magnetic and plasma atmosphere of the Earth—geospace. This preliminary mapping of the organization of geospace was compiled from many measurements from dozens of experiments aboard satellite missions in the past two decades.

NASA has proposed to study in more detail how the Sun's energy and the energy contributed by the Earth's own ionosphere is stored, transformed, and transported into the Earth system (its atmosphere and biosphere) and interacts with these systems in the Origin of Plasma in the Earth's Neighborhood mission, known as OPEN.

The OPEN mission, planned for the mid-1980s, would set four spacecraft aloft (see numbers in figure) to measure energy dynamics in the two plasma source regions and in two of the storage regions in the geospace. Energy input from the Sun could be measured from point of entry near the magnetopause and traced all the way through changes in the Earth's magnetosphere, magnetotail, ionosphere, and atmosphere. The central dynamics of energy transformation and transport through this plasma atmosphere would shed light on similar processes in the Sun itself.

phenomenon is similar to the increasingly organized cooler-to-hotter energy flow on the Sun. The question of magnetic, electrical, and structural coupling between the Earth's active plasma regions, including the atmosphere, and how such behavior is reorganized by various transformations is one of the major areas for further study.

It has also been posited that activity on Earth may affect geospace activity, particularly the Van Allen radiation belts. It appears that belt particles are affected by very low frequency transmissions on Earth and by harmonics generated from the European and U.S. power grids. Electrification of an increasing area of the Earth may increase that effect. One suggestion is that terrestrial power systems may instigate a "leak" of energy into the magnetosphere causing a cascading precipitation back through the ionosphere, but the dynamic is largely unknown.

In order to study the complex questions of solar-Earth interaction and the energy dynamics in the near-Earth system that will undoubtedly open new horizons in understanding phenomenologically similar systems on the Sun, NASA has proposed a mission for the mid-1980s called OPEN—the Origin of Plasmas in the Earth's Neighborhood.

OPEN would send aloft four spacecraft; two would be positioned in the solar wind and ionospheric energy-source regions of geospace, while the other two would orbit in the energy storage and transformation regions of the geomagnetic tail and in the near-Earth plasma sheet. The purpose of the mission is to take simultaneous measurements allowing scientists to measure and map the flow of energy throughout the Earth's geospace.

Through fusion, the Sun produces the life-giving energy for the Earth. Whatever life may exist in other parts of the universe will be found in systems connected to other stars. The Sun's energy is transmitted, reorganized, and amplified by Earth plasma systems to make the Sun's energy usable.

It would seem unnatural if the development and evolution of life systems on Earth did not mirror an underlying process of development and organization in the Sun. The Sun's energy is not a disorganized, dissipating blob of particles and radiation, wasting away with no responsibilities, and neither is life on Earth.

Marsha Freeman is director of industrial research for the Fusion Energy Foundation.

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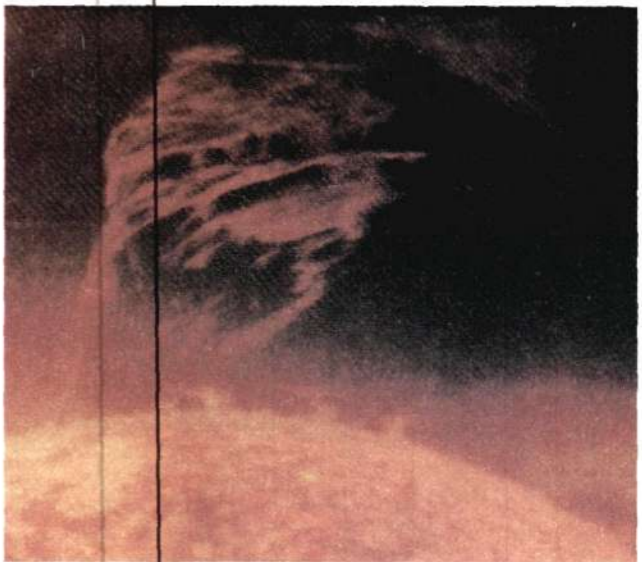
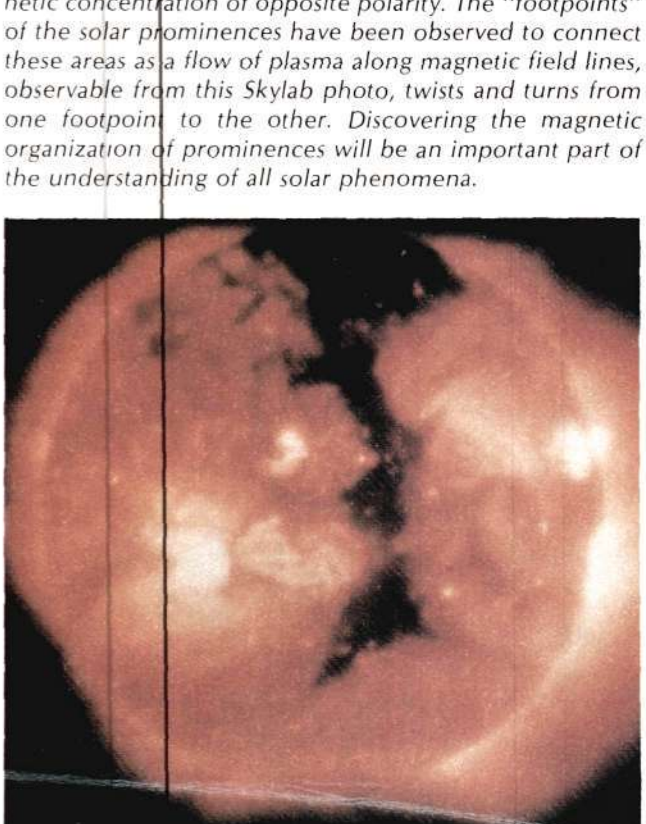


NASA

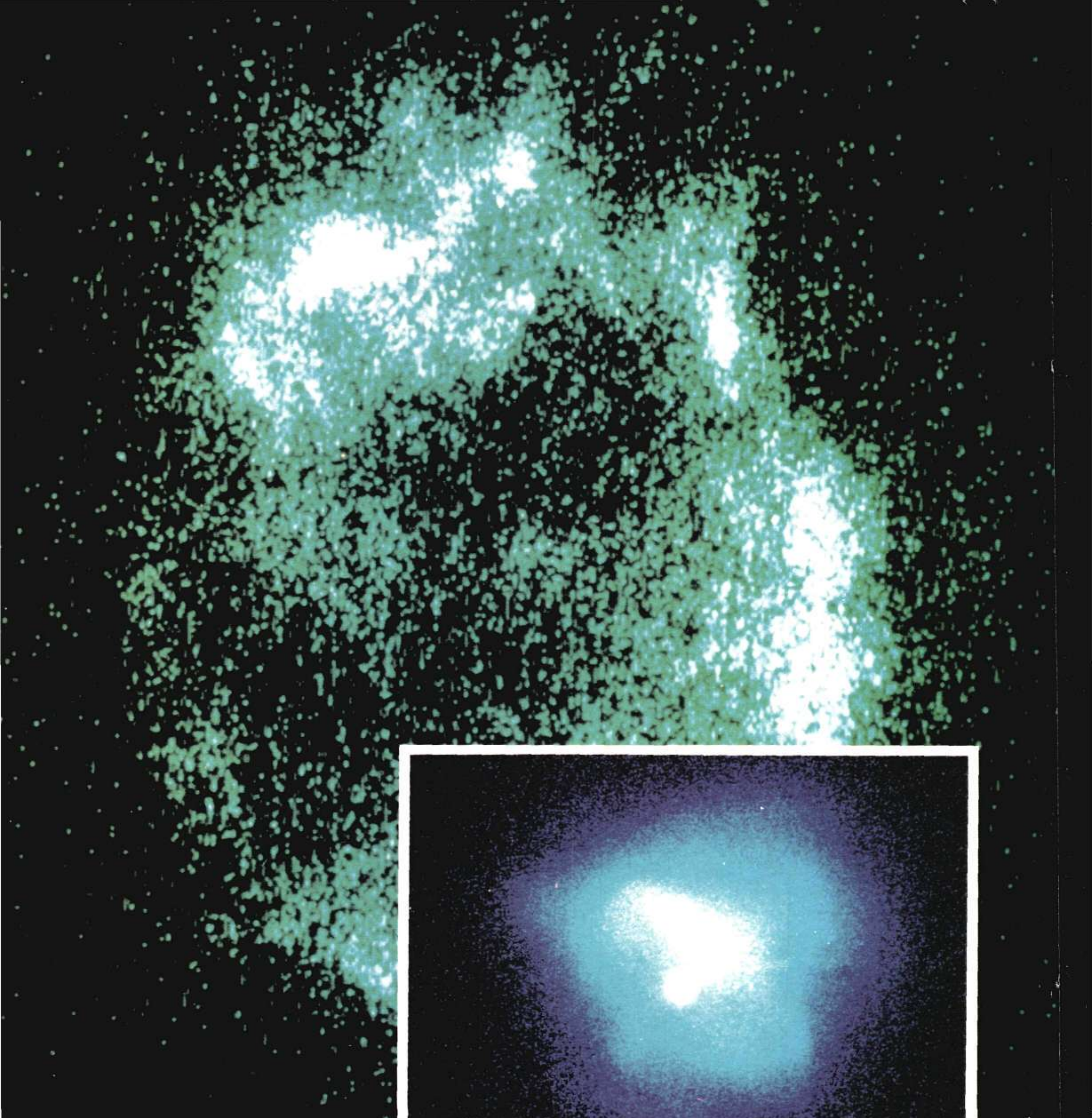
Solar prominences, like sunspots and bright points, are characterized by the connection of areas of intense magnetic concentration of opposite polarity. The "footpoints" of the solar prominences have been observed to connect these areas as a flow of plasma along magnetic field lines, observable from this Skylab photo, twists and turns from one footpoint to the other. Discovering the magnetic organization of prominences will be an important part of the understanding of all solar phenomena.



NASA

Small, concentrated regions of magnetic field strength that cover nearly the entire Sun and are most observable in periods of solar quiescence were not discovered until Skylab. It is thought that these bright points may maintain an overall magnetic energy balance on the Sun by appearing when sunspots and other magnetic activity on the Sun are decreased.

The spectacular final collapse of stars can be better understood with new theoretical developments that describe the relationships among basic thermodynamic variables—the equation of state.



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X-ray photograph of a remnant of an exploding supernova in the constellation Cassiopeia, which is estimated to have occurred in 1657. The bright spots correspond to regions of intense X-ray emission from very hot gas. Inset: X-ray photograph of the Crab nebula remnant of a supernova that exploded in 1054. The bright object in the center is a pulsating star known as a pulsar.

The Changing States Of Matter in Supernovas

by Dr. John Schoonover

Recent research into the nature of supernovas by Nobel laureate Hans Bethe and his coworkers has again demonstrated the fertility of 19th-century German mathematician-physicist Bernhard Riemann's epistemological method. Riemann's scientific work is grounded in his understanding of physical processes as self-organizing phenomena that give rise to new orderings of material relationships, where the evolution from one state of apparently fixed laws to a superseding state is primary relative to the particular state before or after the transition.

In investigating supernova explosions, Bethe and his colleagues applied Riemann's discovery that the invariance of certain physical quantities—in this case, the constant entropy of the system—serves as the bridge between two qualitatively different systems of physical law. In supernova explosions, the maintenance of constant entropy during the stellar compression phase leading up to the explosion allows the formation of a shock wave, which then propagates through the outer regions of the star, creating the heavy elements necessary for life and broadcasting them over wide reaches of space. In fact, ejection of supernova material into space is the major source of all heavy elements found throughout the universe.

Furthermore, the explosion itself can create condensations of matter in gas clouds, which will themselves become the next generation of stars. This second generation of stars can use the heavy elements to form planets and to provide the conditions for life to evolve. The maintenance of constant entropy during the supernova phase of stellar evolution is thus a mechanism through which matter can reach a new, more *negentropic* stage in its evolution, characterized by greater differentiation and greater ability to form complex structures.

States of Matter

As we scan the visible universe, we see matter in tremendously varying stages of concentration, spanning many orders of magnitude in density—from the most tenuous interstellar gases to the tremendous densities found in white dwarf and neutron stars. In these varied states, matter probes the manifold ways in which it can transform itself: the ways in which it can create energy from itself and the ways in which it can combine to create entities of varying complexity and varying rates of evolution.

Similarly, the temperatures we can measure throughout the universe vary tremendously, from the near-zero frigidness of empty space to the hundreds of millions and even billions of degrees found in stellar interiors at different stages in their evolution.

By far, most of the matter we see is in the form of plasma, a state of matter distinguished from the gaseous state by the characteristic that atoms appear as ions, with electrons drifting freely among them. However, if sufficient pressure is applied to a plasma and if the temperature is not too high, the plasma can pass through several phase changes; as it yields to the pressure, thus becoming denser, it can become in turn a gas, a liquid, and ultimately a solid.

The conditions necessary for these latter states of matter to exist are relatively rare, occurring only on planets. But although rare, these are the conditions in which the self-evolving tendencies of matter take on their most striking form. These are, of course, the conditions under which life and ultimately human self-consciousness can emerge. The cross-fertilization of evolutionary possibilities generated by matter in its solid, liquid, and gaseous phases is energized initially by matter in the plasma (stellar) phase. With the advances of industrial society, mankind is fast approaching the time when the stellar fusion processes that have created the conditions for man's existence will come under conscious and constructive control.

To produce the planets and the panoply of elements that participate in the complex geophysical and chemical processes leading to life, it is necessary that at least a second generation of stars be formed from the remnants of earlier stars. In these early stars, the primordial hydrogen, the simplest atomic form, is converted by fusion processes into heavier elements up to iron. But even higher temperatures are required for heavy elements above iron, and such temperatures occur only in supernovas.

Toward the end of its life, a star of a certain mass (several times that of the Sun), whose fuel, atomic nuclei, has been used up so that radiant pressure is no longer sufficient to support the outer stellar layers, will become a supernova. That is, it will implode to become a neutron star, releasing tremendous amounts of radiation and matter at extreme velocities, creating a celestial display as bright as an entire galaxy of billions of stars.

It is during these tremendous supernova explosions that some of the most extreme states of matter accessible to present study occur. These states of self-transforming matter are so removed from normal states of burning stars that the time scales during which significant changes occur decrease from millions or billions of years down to thousandths of a second. In the process, the supernovas both create and disperse the heavy elements that are necessary for life and, by creating condensations of matter in gas clouds, they are the catalyst for the formation of a next generation of stars, which will energize future material evolution.

The Equation of State

In order to follow the evolution of the stars, both prior to and during supernova explosions, one of the most important descriptive techniques available is the specification of the star's equation of state. The modern form of this concept, which is used for describing stellar material, derives from 19th-century thermodynamic usage. The equation of state is a relationship among the pressure, density, temperature, and composition of the matter in the star. Once the equation of state of a system comprised of bulk matter is known, various other characteristics of the matter can be derived from it, including its specific heat, entropy relations, speed of sound, and the way in which shock waves will propagate in it.

The equation of state for normal gases reflects the fact that there is a relatively large amount of space between individual atoms. Since this is the case, the gas becomes denser with relative ease as pressure is applied to it. Similarly, if the temperature of the gas is raised, while keeping it at a constant density, then the pressure must rise. The simplest case is the behavior of the so-called ideal gas, a gas that does not actually exist in nature. The ideal-gas concept treats molecules in the gas as if they were noninteracting balls that simply collide with each other. The relations in such a gas among the pressure, temperature, and density are particularly simple:

$$P = \rho RT,$$

where P is the pressure, ρ is the density, T is the temperature, and R is a constant of proportionality called the Rydberg constant. For an ideal gas, it can be shown using elementary thermodynamic arguments that during adiabatic compression (changes in volume during which energy is neither allowed to enter nor leave the gas) the

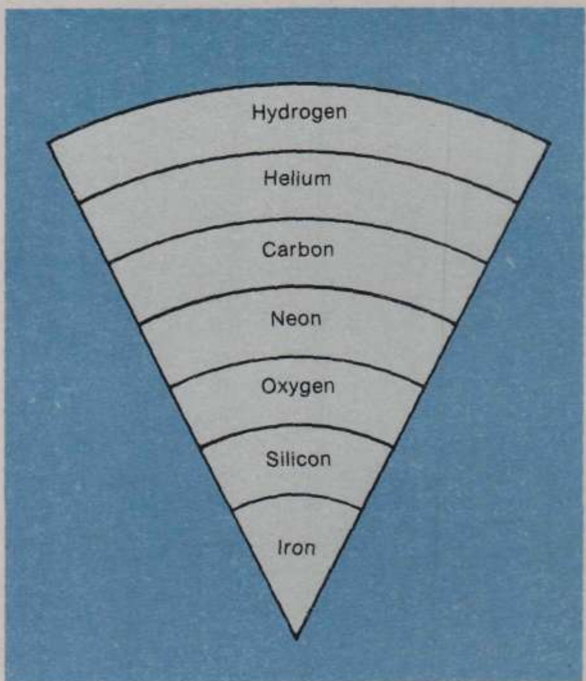


Figure 1
BURNING LAYERS IN A STAR PRIOR TO COLLAPSE
The iron core is composed of ash produced by the fusion of lighter elements in the combustion shells surrounding it. Each shell is labeled with the name of the element that serves as fuel in that shell. After hydrogen, the fuels are the fusion products from combustion in shells farther out in the star.

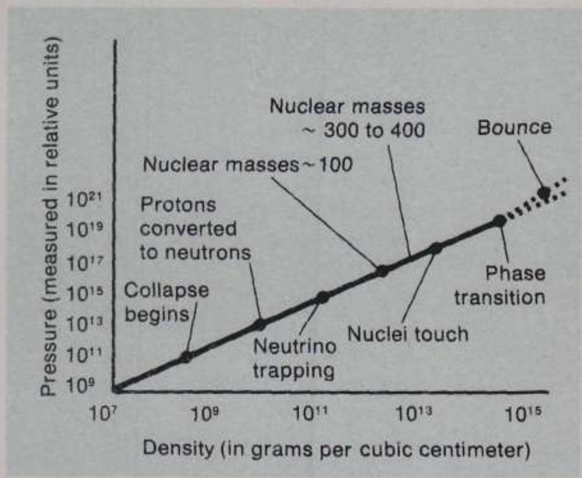


Figure 2
EQUATION OF STATE OF A SUPERNOVA
The simple equation of state that describes the relationship of pressure to density in a supernova stays the same until the point where the matter reaches nuclear density. At that point, there is a phase change and pressure rises more rapidly than density. At this point, the adiabatic index, γ, goes from approximately 4/3 to approximately 5/2 in the equation of state $P = k\rho^{\gamma}$. The horizontal axis measures density, ρ, in grams per cubic centimeter and the vertical axis measures pressure, P, in relative units; k is a constant. The figure shows the equation of state from the beginning of stellar collapse to the bounce.

pressure and density of the gas are related to each other by the expression

$$P = k\rho^{\gamma}.$$

The quantity in the exponent γ is the ratio of the specific heats; for an ideal gas this ratio is 5/3. The expression k is simply a constant to be determined experimentally.

These simple formulas are insufficient for explaining the behavior of real gases, however. If real gases are cooled sufficiently or compressed sufficiently, they will become liquids and solids. These phase transitions cannot be accounted for in the simple expressions above, since they do not take into account the real interactions of the molecules in real gases. Where sufficiently high temperatures exist, gases become plasmas, again undergoing phase transitions that are not accounted for in the simple formulas.

Despite its limitations, the ideal gas formula does provide an approximate description for the bulk behavior of gases and plasmas in regimes where they are not undergoing phase transitions. By supplementing the treatment of a plasma as an ideal gas to take into account the actual transformations of state that occur during stellar evolution, the useful simplicity of the ideal gas formula can be retained, while the actual state of affairs in the star is more accurately portrayed.

How a Star Becomes a Supernova

During the early and longest period in the life of a normal star, the star generates energy by burning hydrogen. In this process, which occurs at temperatures in the range of 10 to 30 million degrees Kelvin in the stellar core, hydrogen nuclei are fused together to produce the next heavier element, helium. The energy released in this process is sufficient to halt the gravitational collapse of the gas cloud that has formed into the young star. However, as the hydrogen fuel in the core is exhausted, the pressure decreases and the star begins to compress further.

As a result of this compression, the core temperature and pressure rise from values characteristic of the interior of the sun to levels at which the accumulated helium can burn to form carbon and oxygen. The temperature in this regime is about 200 million degrees Kelvin. Outside the core, the temperature and pressure have risen sufficiently for hydrogen burning to begin in that region, providing fuel for an expanding core that is now burning helium.

As the core becomes denser and hotter, carbon burning will begin at around 800 million degrees Kelvin, forming oxygen, neon, sodium, and magnesium. Then at about 1.5 billion degrees Kelvin, neon will begin to burn, leaving oxygen and magnesium as ashes. As new burning cycles begin in the center of the star, the previous burning cycle migrates outward, forming a shell above the core, just as the hydrogen did vis-à-vis helium.

At any time in the later stages of evolution, there will be a number of these shells feeding fuel to each other as ashes from their burning. All the time the core temperature and pressure are rising to higher and higher values, demanding higher-intensity energy production to stabilize the star from further collapse.

The next-to-last burning stage before the fuel in the core exhausts itself involves oxygen, which produces the elements from magnesium to sulfur at a reaction temperature of around 2 million degrees Kelvin. In the last stage, silicon (one of the elements produced in the oxygen phase) burns, producing the elements near iron at a reaction temperature of around 3 billion degrees Kelvin.

Once iron has been formed, the energy-producing powers of fusion reactions are exhausted, and any further production of heavier elements involves the absorption of energy. The silicon-burning region begins to migrate outward from the center of the star as more iron ash is produced.

At this time, the energy-producing powers of the star are nearly exhausted, and it will soon begin to collapse, ultimately exploding in one of the most extravagant displays to be seen in the universe. From this point to the explosion, the equation of state goes through a rapid succession of changes, which must be accurately known in order to understand the supernova.

Final Stellar Collapse

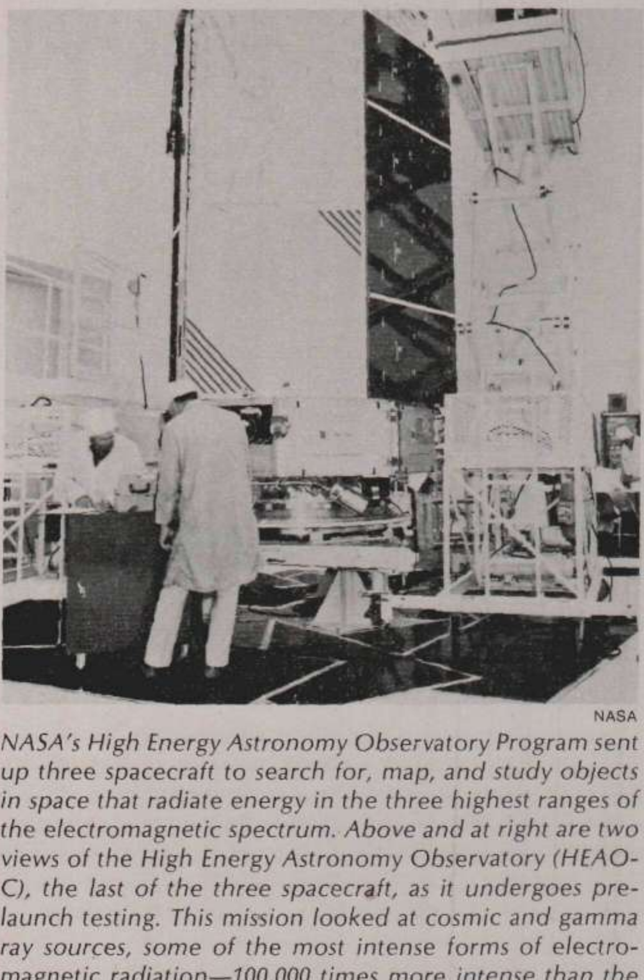
Dr. James Lattimer of the State University of New York at Stony Brook, an expert in determining the equation of state of supernovas, points out that at the beginning of the final stellar collapse the iron core of the star has a density of 100 million to 1 billion grams per cubic centimeter (see table of comparative densities). All the electrons are stripped from the iron nuclei and are floating around between the nuclei, carrying most of the thermal energy in the core. Even at this extremely high density, the nuclei are separated from each other by distances comparable to hundreds of times their diameters. Nevertheless, this is a very close packing compared to the distances between nuclei in terrestrial solids, which are on the order of millions of times their diameters.

Most of the pressure in the core is contributed by the electrons, which can be treated nearly as if they were the ideal gas of the formula discussed above. However, there are some modifications that must be made in order to arrive at a more accurate assessment of the bulk conditions in the core. First, the pressure expression must be adjusted to account for the fact that the electrons have sufficient energy to act relativistically; that is, their speeds are comparable to the speed of light, contributing to an increase in their apparent mass.

Also significant at this stage of compression is the fact that the electrons are governed by quantum mechanical laws—in particular, Wolfgang Pauli's discovery from the early days of the quantum theory that no two electrons can occupy the same state. If they are of the same energy, their magnetic moments must be oriented differently. However, since there are only two possible orientations for the magnetic moments, the electrons are forced to occupy higher and higher energy states as they are compressed into denser and denser spatial configurations. In this way the Pauli exclusion principle—an as yet unexplained quantum law—gives rise to the formation of what is called a degenerate Fermi gas of electrons in the stellar core.

Following the ideal gas treatment of the equation of state, the index γ for the adiabatic compression is 4/3 for this case unlike the simple ideal gas for which $\gamma = 5/3$. In the process of absorbing a large fraction of the total energy in the core to reach the high-energy states they must achieve, the electrons leave the iron nuclei in a relatively low energy state; that is to say, the nuclei are relatively cool. Consequently, the nuclei form into a lattice almost as if they were forming a terrestrial solid. This long-distance lattice correlation among the nuclei provides a slight decrease in the overall pressure in the star, countervailing some of the pressure caused by the degenerate Fermi gas of electrons. The result is expressed by a slight decrease in the adiabatic index γ below 4/3, and the stellar collapse proceeds to higher densities. The simple equation of state holds for the entire collapse of the star, right up to the point where densities approach those of nuclear matter.

While silicon burning continues in the shell around the core, more iron accretes to the point where the strength



NASA

NASA's High Energy Astronomy Observatory Program sent up three spacecraft to search for, map, and study objects in space that radiate energy in the three highest ranges of the electromagnetic spectrum. Above and at right are two views of the High Energy Astronomy Observatory (HEAO-C), the last of the three spacecraft, as it undergoes prelaunch testing. This mission looked at cosmic and gamma ray sources, some of the most intense forms of electromagnetic radiation—100,000 times more intense than the photons that comprise visible light.

of the gravitational pressure on the core is more than the pressure provided by the electron gas can withstand. Until this time, there have been approximately equal numbers of neutrons and protons in the core. But as the pressure continues to rise, electrons are forced to combine with protons to form neutrons, a process known as electron capture.

Current Theory

According to current theory, when the electrons are captured, neutrinos are formed as a by-product of neutron production. (There is some dissent on this matter—see accompanying article on neutrinos.) The star becomes increasingly neutron rich as some of the core energy is carried away by the escaping neutrinos. The neutrinos do not continue to escape as the collapse proceeds, however. Once the matter density reaches about 100 billion grams per cubic centimeter, the neutrinos are sufficiently slowed down by collisions in the core that they are effectively trapped for the rest of the collapse. At this point, the neutrinos themselves form a degenerate Fermi gas, just as the electrons did at a lower pressure.

The pressure from this second gas is not as effective at slowing the stellar collapse as the gas from the electrons had been; some of the neutrinos escaped before this state was reached, leaving fewer neutrinos in the core than electrons that were lost by capture. Also, since many of the neutrinos remain in the core, the electron-capture process reaches an equilibrium similar to a chemical equilibrium, in which as many electrons are being captured to form neutrons as there are neutrons decaying back to protons and electrons. This stage occurs when about 65 percent of the core is composed of neutrons. Prior to the work of Hans Bethe and his colleagues, it was thought that the core would be about 96 percent neutrons at this stage of stellar collapse.

The work of Bethe's group, which includes James Lattimer, G.E. Brown, and J. Applegate,[1] has been based on applying some of the newer ideas developed in recent work on nuclear structure to the area of astrophysical calculations. The group thinks that it has thereby improved understanding of the extreme conditions matter is subjected to in the period leading up to supernova explosions.

At the pressure of about 100 billion grams per cubic centimeter, some of the neutrons begin to leak out of the nuclei, changing the shape of the nuclear surface. This effect can be imagined if we think of the situation before the neutrons leak out as one in which as far as the nuclei are concerned, they are in a vacuum. This is essentially the case since the electrons do not interact very strongly with the nuclei, whereas the neutrons do, distorting their shapes in ways that can be estimated by treating them as if they were liquid drops.

As the collapse continues, the nuclei become larger as they are crushed closer and closer together. At 1 trillion grams per cubic centimeter, the nuclear masses are about 100 units, up from about 55 units when iron dominated. As the size of the nuclear mass increases, the fusion reactions become endoergic; the nuclei absorb some of

TYPICAL MATTER DENSITIES (in grams per cubic centimeter)	
Prestellar gas cloud	10^{-10} to 10^{-7}
Earth's atmosphere (sea level)	6×10^{-4}
Jupiter	1.2
Earth	5.5
Sun	25
Solar core	75
Inertial fusion	10 to 100
Iron core of presupernova star	10^7 to 10^9
Neutron star	10^{14}

These are typical densities for matter under different conditions found throughout the universe.

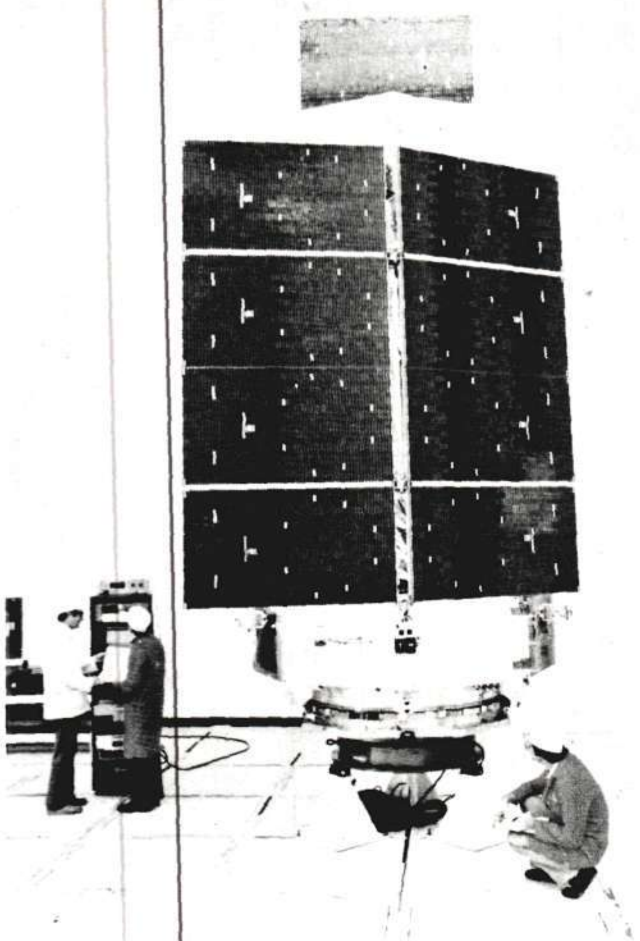
the available energy in the core, reducing the ability of the core to withstand the inexorable increases in pressure. By the time the pressure is up to about 10 trillion grams per cubic centimeter, the nuclear masses are in the 300 to 400 unit range—well above the masses that can be observed in terrestrial laboratories.

Since some of the energy is absorbed in forming heavy nuclei, the temperature in the star remains relatively low, compared with estimates by previous investigators. These investigators thought that the collapse would stop at about this pressure with the disintegration of the nuclei, rather than continuing to increase in size. There are still some neutrons outside the nuclei at this point, contributing to the pressure as the electrons and neutrinos do, although they are not yet in the degenerate Fermi gas stage.

Finally the nuclei themselves touch at a density that is about half that of nuclear matter itself, around 100 trillion grams per cubic centimeter. If we imagine the nuclei as spheres packed tightly together, there is some space between them in which neutrons are trapped, forming a gas. As the collapse continues, these spaces become spherical bubbles in a medium composed of nuclear matter, and the total energy in the core decreases still further. These bubbles disappear with the absorption of the neutrons into the uniform nuclear matter.

At this point the core of the star is a uniform sea of nuclear matter. The internal pressure caused by the nucleons is now zero, as the star continues to seek its lowest energy state. The equation of state is now dominated by the pressures provided by the degenerate electron and neutrino gases. The adiabatic index γ remains slightly less than 4/3.

As the nuclear matter is rapidly compressed beyond 100 trillion grams per cubic centimeter to several times that value, a rapid phase transition sets in. With this phase transition, the adiabatic index γ rapidly rises to approximately 2.5. The same kind of Fermi degeneracy that has characterized the electron and neutrino pressures now affects the nuclear-matter pressure. The total pressure inside the core zooms to tremendous values, and in-falling matter hits a brick wall, as the density reaches about three times nuclear-matter density.



NASA

The core bounces at this point, plowing back through the falling matter and creating a tremendous shock wave. The core gives up its kinetic energy in this way, staying behind as a hot, hydrostatic, proton-rich neutron star. The current, as yet unsolved problem is to chart the course of this shock wave as it passes through the various zones of stellar matter described by varying composition, temperature, and density of matter.

Such a problem can be solved only by high-speed computer simulations of the shock propagation. The numerical methods, which call for fine increments in the calculation as the shock progresses, are currently plagued with distortions that do not allow an accurate picture to be created. One of the questions to be resolved is whether or not the shock wave is damped by energy loss from the escape of neutrinos produced during the nuclear reactions ignited as the shock passes through different zones. If there is damping, can the neutrinos account for the explosion?

Constant Entropy

Hans Bethe supplied the key idea that has made the supernova collapse scenario possible in the form just described. He noticed that as nuclei more massive than iron are formed during the collapse, they can extract sufficient thermal energy from their environment to keep the core temperature relatively low. Otherwise, as the thermal energy in the core is compressed into smaller and smaller volumes, the temperature should rise dramatically, leading to the disintegration of large nuclei into lighter ones such as alpha particles.

This latter effect could be described in thermodynamic terms as an increase in the entropy of the system. Bethe's observation was that during the collapse—right up to the bounce—the total entropy in the core remains nearly constant.

Bernhard Riemann introduced the idea that entropy might be an invariant in the motion of certain significant physical systems in his epoch-making paper "On the Propagation of Plane Air Waves of Finite Amplitude" in 1859.[2] The context for introducing the concept of isentropic compression in this paper was Riemann's observation that the differential equation describing the normal propagation of sound waves in a compressible medium such as air generates singular solutions for wave propagation over finite periods of time.

Riemann insisted that this behavior of the equation of motion represented a change in the lawful relations governing the propagation of energy in the sound waves and that it would be necessary to investigate the new type of motion that arises from the singular behavior. In order to arrive at the new manifold of lawful relations across the singularity, there must be a superseding invariance that is maintained despite the change. Technically, Riemann introduced certain invariants that allowed him to integrate the equation of motion. The physical phenomenon that corresponds to the Riemann invariants is the isentropic character of the process.

As Uwe Parpart points out, the invariance of entropy across the singularity is precisely the kind of concept necessary to provide a coherent connection between the normal propagation of sound waves, and the propagation of shock waves lawfully evolved from them.[3] Lord Rayleigh's subsequent criticism that Riemann's invariant conditions give rise to a failure of the energy conservation law when the medium is treated like an ideal gas simply emphasizes the necessity to investigate equations of state more realistic than that for an ideal gas.

Riemann's approach demands answers to the question: are there states of matter in which isentropic compression can occur without violating energy conservation? Bethe's analysis of the conditions in stellar collapse elucidates this question to a certain degree. Although the stellar material acts very much like an ideal gas during compression—that is, its pressure can be simply related to its density via a power law governed by the ratio of specific heats—the internal differentiation of this matter occurs continuously during the collapse. From the lighter nuclei, larger, more complex ones are being formed, converting the thermal energy of the bulk matter into binding energy of the nuclei.

The most accessible laboratory for observing the kinds of self-organizing phenomena associated with shock-wave propagation is in the realm of hydrodynamics and aerodynamics. Here, the creation of singular structures such as vortices and solitons is a graphic case of the reordering of energy from apparently random thermal forms into organized entities. In this process, the medium, gas or liquid, and the organized entity are one and inseparable; it is not necessary to reduce the soliton or vortex to elementary units from which it is constructed.

The analogy with nuclear matter is more than superficial. Most treatments of nuclear structure treat the nucleus as if it were composed of a number of elementary particles, protons and neutrons, interacting with each other via many one-to-one interactions. In this fashion, the theories attempt to mimic the observed nuclear properties with greater or less success. But there is no unified treatment of this type that is either particularly accurate or that can span the range of known isotopes.

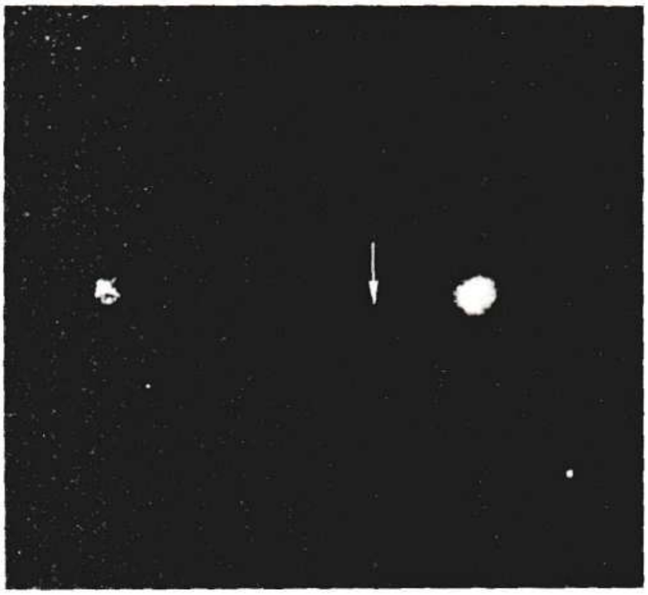
In some of these models, various simple, fluidlike properties are attributed to the nucleus, but a full hydrodynamic treatment has not yet emerged. It is insufficient simply to note that the excess energy in the stellar core is absorbed as binding energy in the growing nuclei and point to theoretical considerations based on Newtonian particle interactions that partially describe this situation. The existence of complex hydrodynamic mechanisms that accomplish similar effects in continuous media must be taken as a signpost along the path to better understanding nuclear matter.

Experimental Evidence

To test theoretical models of the supernova collapse and explosion is not an easy thing to do. Quite clearly, they cannot be produced at will but must be found somewhere in the heavens. Fortunately, supernovas are sufficiently dramatic in their effects that they can be detected in galaxies other than our own.

There are a number of different kinds of evidence that can be used to confirm whether a given model accurately reflects reality. The easiest approach is to find the remnants of a supernova and to look for the neutron star that was left behind. If a shock wave has blown the matter away from such a star, the star should have a mass in the range of 1.4 times the mass of the Sun. However, since the different supernova models predict only slightly different values, this is not a particularly sensitive test.

Since supernovas are responsible for the dispersal of the heavy elements throughout the galaxy, it should be possible to determine the correctness of a model based on the comparison between the relative abundances of the elements it predicts and those actually observed. To carry out this investigation, the theoretical calculation must be completed for the propagation of a shock wave of a given energy through all the burning shells in the star up to the surface. From this calculation, the amounts of different elements produced can be estimated. Finally, all the contributions to this process from different kinds of stars over the life of the galaxy up to the present must be added together and the result compared to actual measurements. This procedure seems to give approximately



Lick Observatory

It is hypothesized that pulsars are neutron stars remaining from the implosion of supernovas. Neutron stars are so small and dense that they could rotate 30 times per second without breaking up, with a magnetic field 10^{13} times that of the Earth. Shown are two phases of the Crab nebula pulsar (NP 0532): left, during a pulse and right, between pulses. In the X-ray photograph of the Crab nebula on page 40, the pulsar is the bright object in the center.

the right values for shock energies in the range of current estimates.

An ideal experiment to test supernova models would involve the use of a sensitive neutrino detector to determine the actual evolution of the neutrino flux during collapse and explosion stages. Before the collapse, there should be a very low neutrino flux, but as it starts, there should be a sudden increase followed by a sudden drop off as neutrino trapping begins. When the shock wave forms and reaches the "neutrino photosphere," where neutrinos can easily leave the star again, there will be a sudden burst of neutrinos from the shock-generated nuclear reactions.

Such an experiment would be very difficult to carry out, however. There is a detector now under discussion for use in observing solar neutrinos, which could be used for this type of experiment, and it might be able to detect supernovas from other galaxies in the Virgo cluster. With some nearby galaxies to observe, the detector might be able to discriminate as many as one or two supernovas per year. The realization of this experiment seems to be some 10 to 20 years down the road still.

One further type of experiment that would yield some information about the supernova process would be the examination of the distribution of light, both its intensity at different frequencies and the evolution in time of its intensity. This experiment would not afford as good a probe of the supernova as the study of neutrinos; light interacts so readily with matter that by the time it leaves the surface of the star, it has lost most of the information it carried about the occurrences unfolding deeper inside the star. However, such an experiment should make it possible to determine the total energy released in the explosion. In addition, it should be possible to determine whether all the light left the star with the shock wave or whether the new neutron star continues to emit light for an appreciable time after the explosion.

The entire collapse of the supernova from beginning to the bounce takes a total time of about one-tenth of a second, a virtually instantaneous process, compared with billions of years during which the star evolved through the various stages of fuel burning to achieve the iron core.

At the present time, mankind is on the threshold of mastering the hydrogen-burning phase of stellar combustion, with mastery of some of the later, light-element burning stages just beyond the realm of technical feasibility. At some time in the future, man will control these processes and also eventually the tremendous energy release in the supernova. The increasing richness and diversity of the processes that occur as matter is subjected to more and more extreme conditions, from transformations of the outer surfaces of the atom by chemical reaction to the ultrahigh supernova compressions probing deep into the nucleus, indicate the infinite potential for new energy sources that matter provides.

Dr. John Schoonover is director of nuclear physics for the Fusion Energy Foundation and managing editor of the International Journal of Fusion Energy.

Notes

1. H.A. Bethe, G.E. Brown, J. Applegate, and J.M. Lattimer, *Nuclear Physics*, A324: 487 (1979).
2. Bernhard Riemann, *International Journal of Fusion Energy* (Translated from German by U. Parpart and S. Bardwell), Vol. 2, No. 3, p. 1 (1980).
3. Uwe Parpart, "Riemann Declassified," *Fusion*, March-April 1979, p. 24.

The ubiquitous shock wave plays a determining role in fusion processes from the subnuclear to the supergalactic level.

Giant Shock Waves In Cosmology

by Charles B. Stevens

Shock waves, first investigated by Bernhard Riemann in the 19th century,[1] now appear to be important in understanding all physical processes. At almost every stage of the evolution of the cosmos, ranging from the diffuse interstellar gas clouds in which stars are born to the dense cauldrons known as supernovas in which the heavy elements necessary for life are forged,[2] shock waves play a key role. Shock waves are also the cornerstone of the man-made starlike conditions produced in inertial confinement fusion and in some magnetic confinement fusion configurations.

In fact, these solitary waves seem to emerge on every frontier of physical science and in dimensions ranging from thousandths of a centimeter up to thousands of light years! They have become the determining elements of the most advanced technologies known to man—the H-bomb, supersonic aircraft, and rocket-propelled spaceships. And recently, the 120-year-old Riemannian concept of shock waves became the basis for the most advanced and successful computer model of human economic activities.[3] Most important, they seem to provide a link between gross hydrodynamic processes and the microscopic processes that must be understood for fusion power.

In this report I shall review some of the most important recent theoretical and observational advances in understanding the crucial role of shock-wave structures in astrophysics and fusion research.

The Livermore Supernova Simulation

The same corps of scientists, laboratories, and computers that made possible the latest developments in thermonuclear weaponry—the neutron bomb and the more recent reduced residual radiation (RRR) bomb, a clean hydrogen bomb—are also engaged in developing controlled thermonuclear fusion and exploring the frontiers of the cosmos.

Representative of the scientific work of the national weapons laboratories is the work of the Lawrence Livermore National Laboratory (LLNL) on supernovas, including advanced research into equations of state (the relationships between pressure, density, and internal energy) for superdense matter like that found in the center of stars. It is important to note the interconnection between the theoretical astrophysics investigations at Livermore and the more practical experimental work generally related to inertial confinement.

Livermore scientists are investigating the entire life cycle of massive stars. As the LLNL group describes its research:

> The birth, evolution, and explosive death of stars are the fundamental examples in nature of the controlled and explosive release of nuclear energy and the transmutation of the chemical elements. These stellar events are essential in shaping the universe and are the ultimate source of virtually all energy resources we now use. The physical processes involved are of interest to us at LLNL because they are central to many of our defense- and energy-related programs. Indeed, knowledge of such astrophysical phenomena has directly inspired and contributed to the successful effort to duplicate, here on earth, the process of thermonuclear fusion.
>
> Our present research is directed toward understanding stellar events by building comprehensive mathematical models that relate the fundamental microscopic laws of physics to available and potential astronomical observations. In a collaborative effort with the University of California at Santa Cruz, we have recently completed the first calculations that model entire life cycles of massive stars. These calculations show such stars to be prime candidates for the birthplace of most of the chemical elements now found in the universe.

Figure 1 depicts the equation-of-state relation between internal energy and density for dense matter based on experiments with laser-driven shock waves. As noted by the Livermore group, a "vast central portion of this plane cannot at present be mapped either by accurate theoretical calculation or by experiment." That is, there is a large region of high density and temperature of matter—a region of great interest for astrophysics—for which even the most general aspects of matter-energy relations are totally unknown.

In reality, this region is even larger than that implied by Figure 1, as pointed out by Parpart.[4] At extremely high densities and temperatures (the Thomas-Fermi model region of Figure 1), the actual equation of state of matter

"The birth, evolution, and explosive death of stars are the fundamental examples in nature of the controlled and explosive release of nuclear energy and the transmutation of the chemical elements." At right: a group of young stars in the Pleiades cluster.
NASA

may be quite complex. The Livermore work on modeling supernovas has begun to explore this possibility.

In particular, Livermore scientists are developing a new model for the equation of state of matter at superhigh densities—the density of nuclear matter at about 10^{14} grams per cubic centimeter. This new model will allow scientists to take into account possible phase changes resulting from the propagation of shock waves during the evolution of supernova implosions and explosions. What this crucial work is accomplishing is the development of the connection between the microscopic properties of matter-energy (the atomic, nuclear, and subnuclear aspects) and its macroscopic dynamics—its hydrodynamics. After a series of complex calculations, the Livermore team has modeled the abundances of the elements in the universe. Their preliminary results are compared with actual measurements in Figure 2.

This work has broader implications for nuclear physics in general. For example, the precipitation of atomic particles by nuclear shock waves has been observed in high-energy proton collisions.[5] This involves a "phase change" in the nuclear matter caused by the propagation of shock waves generated by the collision. The speed of sound dramatically increases in the region of the shock wave from the increased density of nuclear matter in that region. Clearly, something significant is occurring in this reaction.

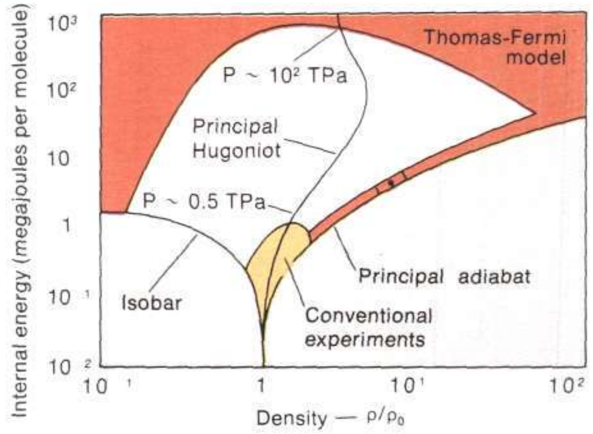


Figure 1
EQUATION OF STATE RELATION BETWEEN INTERNAL ENERGY VS. MATERIAL DENSITY PLANE FOR A TYPICAL MATERIAL

This schematic from Lawrence Livermore Laboratory shows where various theoretical models are valid (red region) and where conventional experiments can be successfully performed (orange region) in order to measure the equation of state of materials subjected to laser-generated shock waves. As the Lawrence Livermore group notes, "the vast central portion of this plane cannot at present be mapped either by accurate theoretical calculations or by experiment." Filling in this region, by learning how materials behave over a wide range of extremely high pressures, densities and temperatures, will be key to many problems in astrophysics, planetary physics, nuclear explosions, and inertial fusion.

The horizontal axis measures density and the vertical axis measures the internal energy in megajoules. Also shown are three important thermodynamic tracks: a low-pressure isobaric expansion path (isobar), a low-temperature adiabatic compression path (principal adiabat), and the principal Hugoniot, which represents the final states of the material after simple shock waves have passed through it. The pressure is designated in TPa, a trillion pascals.

The Cygnus Mystery

Shock waves in astrophysics have also been found to be interrelated with basic processes of cosmological evolution on a scale even larger than supernovas. The largest structure observed in our galaxy is a super shock wave, the Cygnus Superbubble. Satellite X-ray measurements have shown the Cygnus Superbubble to be a spherical shock wave more than 1,000 light years in diameter, equal to the thickness of the Milky Way Galaxy disk itself. (The Milky Way has 100 billion stars with a thickness of 1,000 light years and a diameter of about 80,000 light years.)

As Figure 3 shows, scientists observed a giant sphere (or bubble) of X-ray-emitting plasma. When it was understood that this sphere was a coherent structure, they concluded that it was generated by a shock wave. The passage of the shock wave through the insterstellar gas around Cygnus heats the material to the high temperatures at which X-rays are emitted. The Cygnus shock wave is hypothesized to have originated from a series of supernova explosions, though its actual cause is not really understood yet.

The shock wave that is observed from measurements of X-rays appears to lead to the generation of stars out of the dilute interstellar gas through which it propagates. That is, the shock wave causes a local increase in density of the interstellar gas through which it passes. This, in turn, leads to the formation of new stars.

After the observation and analysis of the Cygnus Superbubble, many scientists have hypothesized that the entire galaxy has been formed in this manner and have posited that other Superbubbles can therefore be identified from astrophysical measurements.[6]

Observation of radiation patterns also indicates that huge shells surround the envelopes of entire elliptical galaxies. These are hypothesized to be gigantic, powerful shock waves.

According to one report:

> Photographic plates taken with the UK Schmidt and Anglo-Australian telescopes reveal the existence of giant ellipsoidal shells within and around the envelopes of several normal elliptical galaxies. The dimensions of these features are vast. . . . We report here that these features probably consist of stars and are either the result of a burst of star formation initiated by a powerful shock wave in an intergalactic medium,

perhaps during the formation of the galaxies, or are old stars displaced from the nucleus by an explosive event.[7]

New Horizons

Recent new insights from inertial-confinement fusion experiments, satellite astrophysics observations, and theoretical analysis of these data are rapidly leading toward a new comprehension of processes on the cosmological scale. As an example, consider the possible relationship between separate proposals by J. Rand McNally on thermonuclear shock waves[8] and F. Winterberg on autocatalytic thermonuclear shock burn-wave processes.[9]

When nuclear fusion reactions are ignited in fuel that has been compressed in some manner to high densities, the high-energy fusion reaction products tend to escape rapidly from the burning region into the colder, outer layers of the compressed fuel. These reaction products, which generally are the new nuclei formed during the nuclear fusion reaction, rapidly heat the outer, cold layers of fuel to thermonuclear ignition temperatures as they escape from the ignited region. Considered in its entirety,

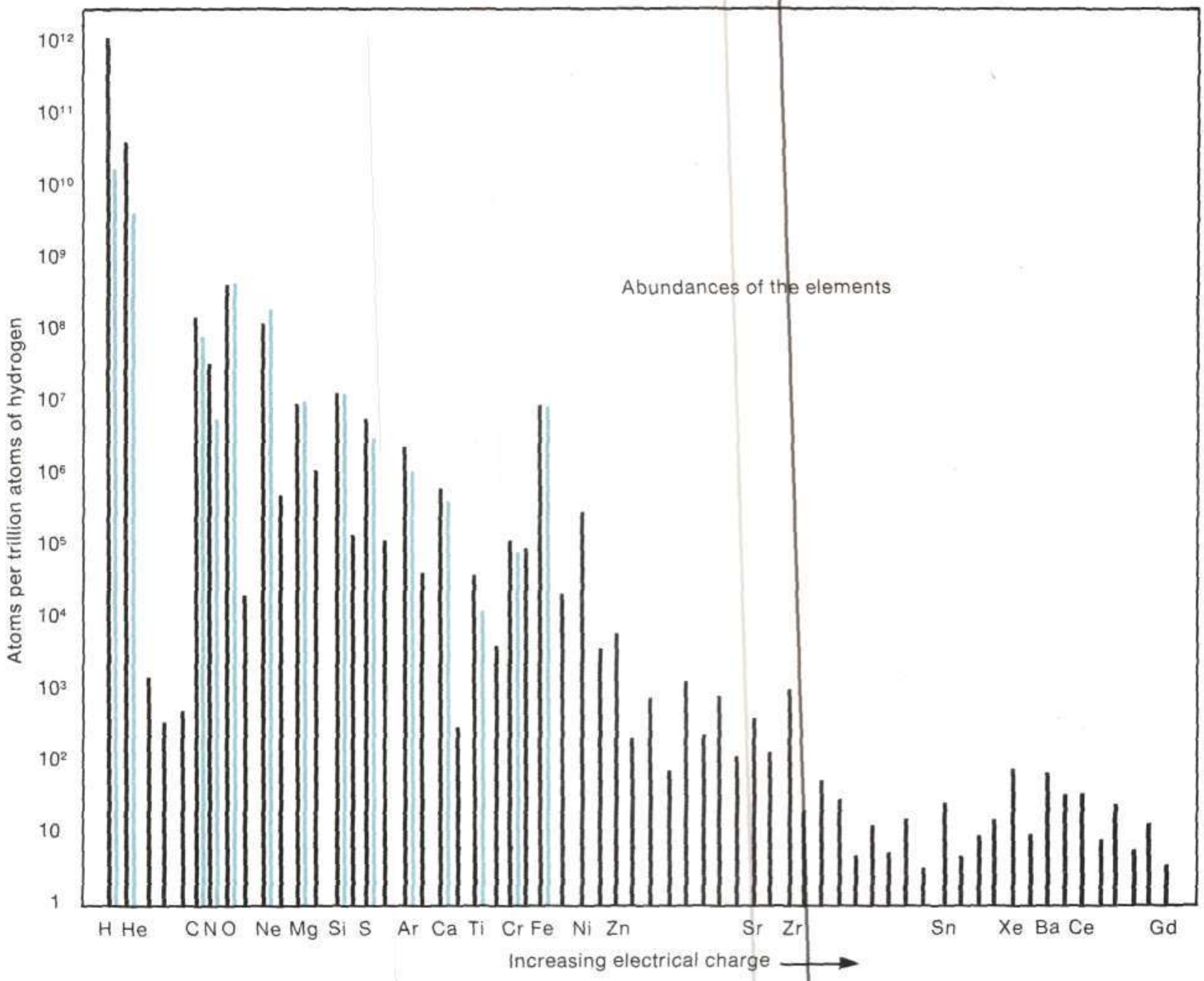


Figure 2
SUPERNOVA PRODUCTION OF THE ELEMENTS

Compared here are the abundances of elements in the solar system (black bars) with those produced and ejected by a Lawrence Livermore Laboratory mathematical model star (blue bars) that corresponds closely to a certain class of supernovas. The agreement is generally excellent, providing striking evidence that stars 10 to 100 times the mass of the Sun that eventually died in supernova explosions created many of the heavy elements now present in the solar system and the universe as a whole. The notable exceptions are hydrogen and helium, present in greater amounts than the Lawrence Livermore model star indicated.

The horizontal axis shows the elements in order of increasing nuclear charge. The vertical axis represents atoms per trillion atoms of hydrogen.

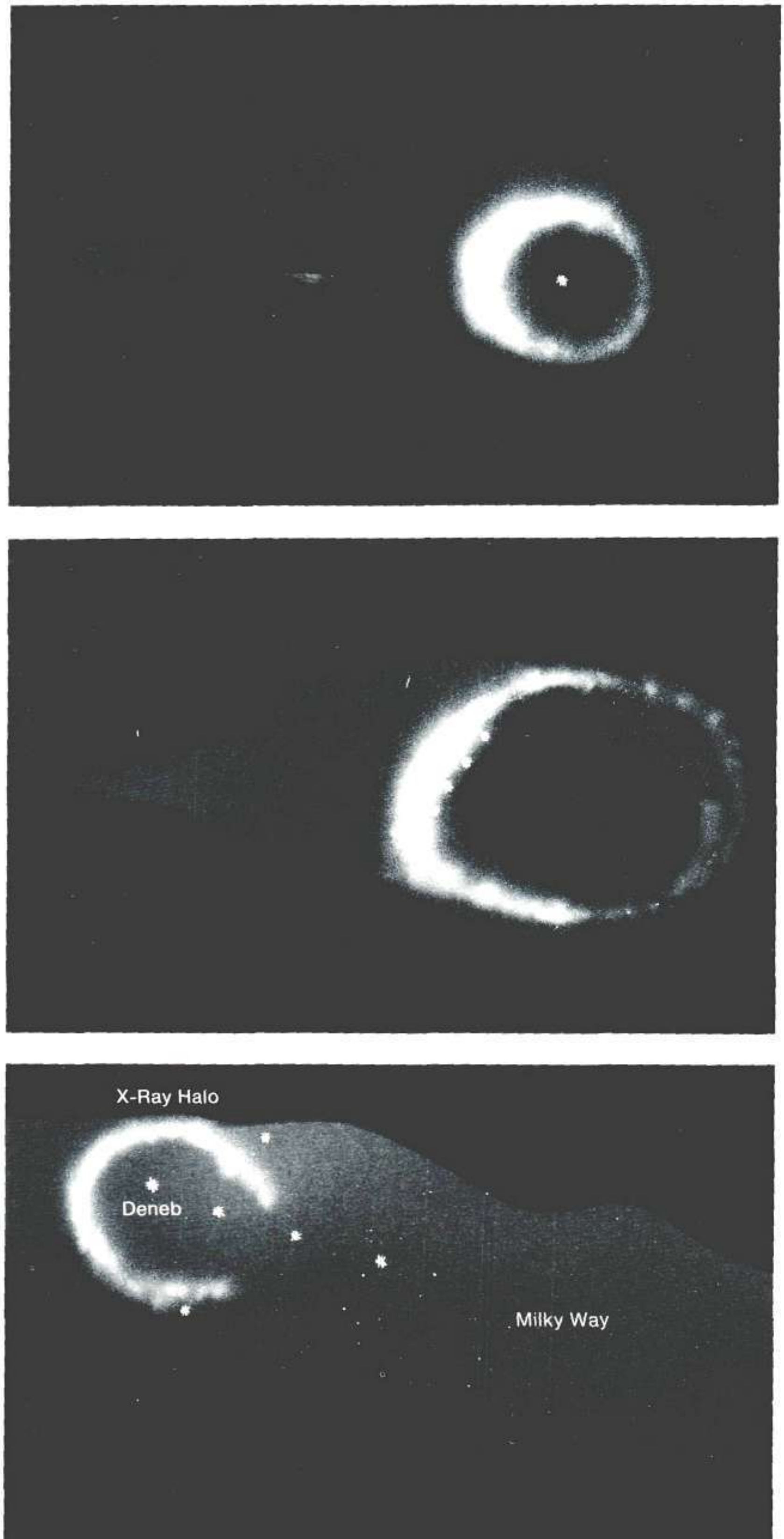


Figure 3
THE CYGNUS SUPERBUBBLE: A SHOCK WAVE CREATING STARS?

The stars in the Cygnus constellation shown here are only 1 million years old. But judging by its size and velocity of expansion, the superbubble (labeled in the figure X-Ray Halo) is at least 3 million years old and may have formed the current Cygnus star association. The superbubble itself may have resulted from the explosion of several preceding generations of 30 to 100 supernovas, steadily driving a shock wave into a nearby, massive interstellar dust cloud, precipitating the formation of stars. As shown in this artist's depiction, supernova explosions blow a bubble into empty space; in the direction away from the cloud; in the other direction the supernova wind will run into the dense dust cloud and coalesce new stars, whose supernova members end their brief, 1-million year lives in explosions, causing the bubble to gain in energy. Thus, new stars form constantly in the gas cloud, while outside the blast wave from the new stars blows the giant bubble bigger.

It is only through the X-ray observations in space made possible by NASA satellite observatories that astronomers have been able to measure such phenomena.

this process is a complex, thermonuclear-driven shock burn wave that could propagate *indefinitely* given the presence of unlimited quantities of compressed cold fuel.

McNally pointed out that at higher densities of the compressed fuel the rate at which nuclear fusion reactions proceed increases, while simultaneously the deposition of the energy from the reaction products into the cold fuel tends to go exclusively into the fuel ions and not the electrons; this enhanced ion-energy deposition also increases the rate at which nuclear fusion proceeds. At the temperatures and densities ordinarily found in stars, fusion reactions with heavy elements proceed quite slowly and no substantial amount of fusion with these heavier elements can be expected. But at superhigh densities, the reaction rate can be greatly increased to the point that thermonuclear shock burn waves could be generated to rapidly burn highly unreactive fuels. Entire chains of reactions with heavy elements could become possible.

For illustration, McNally took the case of the dense outer mantles of supernovas just prior to their detonation. A *local increase in density* is sufficient to start a thermonuclear shock burn wave, which once ignited proceeds to burn its way through the mantle. Because of the intensity of the process, reactions that do not even produce net energy can be supported in the reaction chain. This process could account for the presence in the universe of what appear to be anomalous amounts of some heavy elements.

If, then, we combine this work with the autocatalytic thermonuclear burn-wave configurations proposed by Winterberg, an interesting possibility results. In the Winterberg autocatalytic process (Figure 4) some of the fusion energy output from the ignited region in the form of soft X-rays proceeds to jump ahead of the thermonuclear burn wave. Before the thermonuclear burn wave arrives, these precursor X-rays, given the proper geometry, can compress the unburned thermonuclear fuel through ablative implosion like that seen in laser fusion. In this way, the high densities needed to burn heavy elements could be attained in ordinary stars.

One possible fruitful field for the application of these concepts would be in studying the famous AP stars, whose exteriors contain anomalous amounts of heavy elements and, simultaneously, small quantities of helium.

As man now explores the cosmos with direct observations from spacecraft, fusion scientists working in laboratories throughout the world are using these observations together with their own experiments on inertial-confinement fusion to better understand the physics associated with the densities and temperatures found in the core of stars. Throughout the domain of this scientific frontier, hydrodynamic processes highly relevant to the evolution of the cosmos are being found to be intimately related to microscopic fusion processes. The singularity that appears to identify such newly discovered coupled processes is the shock wave.

Charles B. Stevens is the fusion technology editor of Fusion *magazine.*

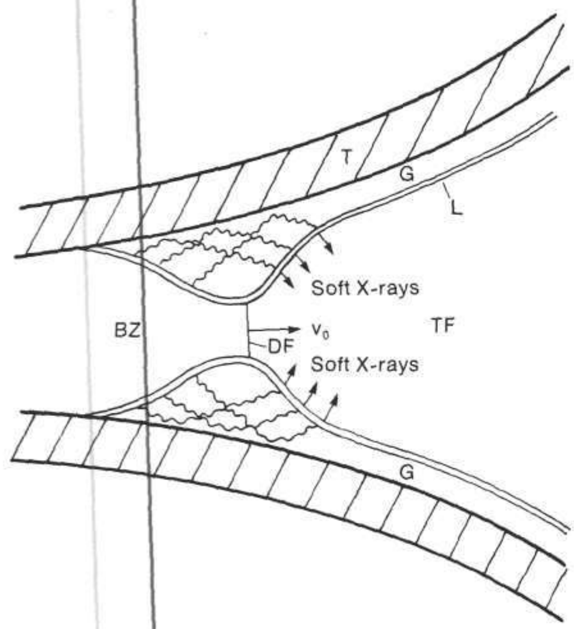


Figure 4
THE WINTERBERG AUTOCATALYTIC THERMONUCLEAR DETONATION SHOCK WAVE

In this cross-section of the Winterberg concept, fusion has been ignited in a burn zone (BZ). Part of the fusion energy output heats the dense metal liner L and causes the emission of soft X-rays from this material. These soft X-rays (shown by wavy arrows) propagate through the gap G, which lies between the liner L and the outer tamp T, ablatively compressing cold fusion fuel. A second part of the fusion energy output—the high-energy products of fusion reactions—escapes from the burn zone BZ to deposit its energy into the cold thermonuclear fuel TF. This causes a detonation front DF to form, which represents a shock-wave-like propagation of ignition of thermonuclear fuel.

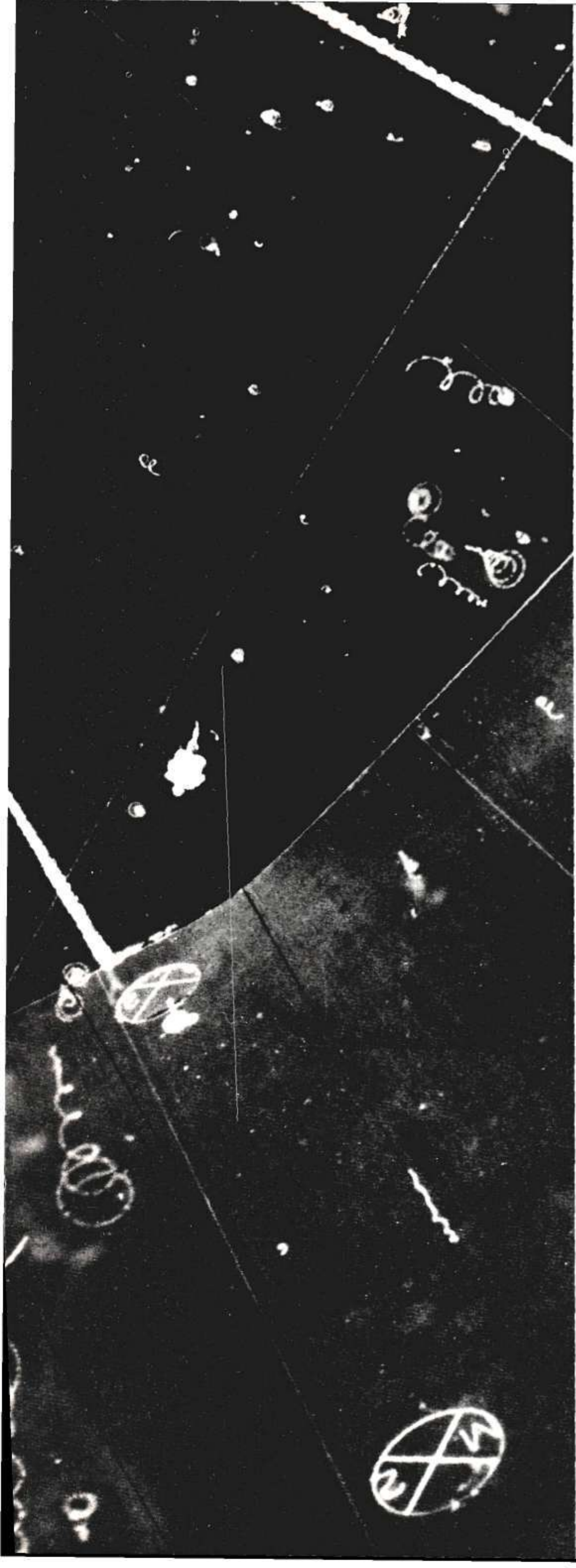
Notes

1. For a discussion of Riemann's work on shock waves, see "Riemann Declassified" by Uwe Parpart in *Fusion*, March-April 1979, p. 24. Also in the same issue see "The Secret of Laser Fusion," p. 38.
2. Supernovas are described in the preceding article by John Schoonover in this issue.
3. The LaRouche-Riemann economic model has been the subject of several articles in *Fusion*. See "Economics Becomes a Science" by Dr. Steven Bardwell and Uwe Parpart, July 1979, p. 32 and "The Riemann-LaRouche Model: Breakthrough in Thermodynamics" by Carol White, Aug. 1980, p. 57.
4. "The Theoretical Impasse in Inertial Confinement Fusion," *Fusion*, Nov. 1979, p. 30.
5. Erwin M. Friedlander and Richard M. Weiner, *Physical Review Letters*, July 2, 1979, p. 15.
6. Webster Cash and Philip Charles, "Stalking the Cygnus Superbubble," *Sky and Telescope*, June 1980, p. 455.
7. David F. Malin and David Carter, *Nature*, June 26, 1980, p. 643.
8. J. Rand McNally, Jr., "Nuclear Fusion Chain Reaction Applications in Physics and Astrophysics," IAEA-SM-170/49, p. 41.
9. F. Winterberg, "Rocket Propulsion by Nuclear Microexplosions and the Interstellar Paradox," *Journal of the British Interplanetary Society*, Vol. 32, 1979, p. 403.

A Universe Without Neutrinos?

Once the missing piece in the jigsaw puzzle, the neutrino is now raising more unanswered questions than ever.

Nuclear reactions are detected from the paths of ionization their products leave in bubble chambers. At right, the first photograph of particle interaction taken at the hydrogen bubble chamber at Argonne National Laboratory in November 1971.
Argonne National Laboratory



Modern cosmological theory rests heavily on the existence and properties of a subatomic particle so reluctant to interact with other matter that it is virtually invisible to the most advanced methods of detection. In fact, the neutrino is presumed to exist chiefly to "balance the books" of the universe. Yet a new theory by Erich Bagge of the University of Kiel in the Federal Republic of Germany performs the same function without calling for the existence of the questionable neutrino.

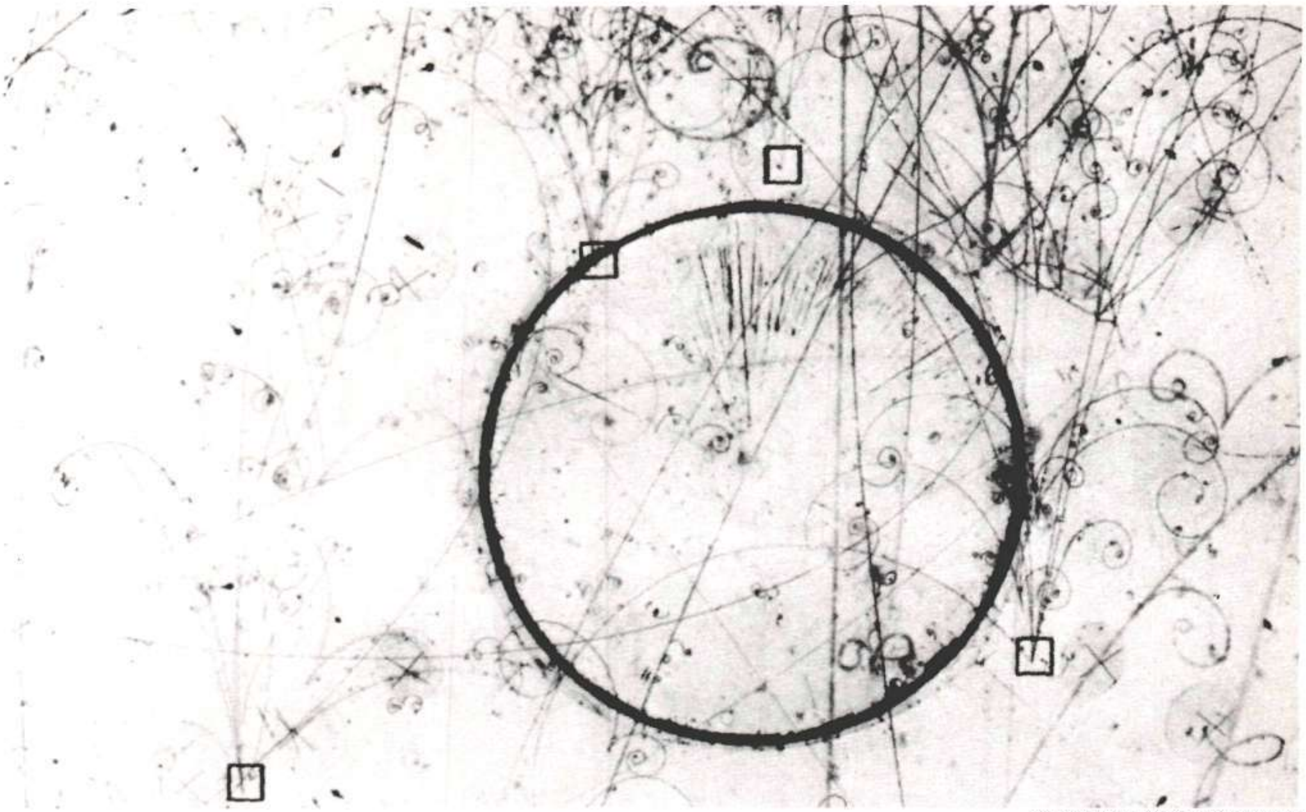
There has been much excitement about neutrinos recently because experimental evidence indicates that they have a mass not equal to zero, as had been previously thought. If this is true, the enormous number of neutrinos—hundreds per cubic centimeter of the universe—would account for the "missing mass" in the universe and provide sufficient gravitational attraction to eventually stop the expansion of the universe.

The neutrino was first postulated in 1932 by Wolfgang Pauli to solve the conservation problems encountered in the radioactive process called beta decay. From the early days of radioactivity research, scientists had noticed that radioactive atoms emit three distinct kinds of radiation. As the atoms decay, they give off alpha rays, later identified as the nuclei of helium atoms; gamma rays, high-energy electromagnetic radiation closely related to visible light; and beta rays, soon identified with the electron, which was discovered in 1897.

Of these three, beta radiation created a unique problem for scientists because it seemed to violate the laws of conservation of momentum and energy. As nuclear measurements became more sophisticated, some startling observations were made. A neutron could be observed to decay, emitting a proton and an electron (a "beta ray"). Elementary mechanical laws predicted that the two should leave the decay site moving in exactly opposite directions, to conserve momentum. Furthermore, each of the two decay products should carry away a precise amount of energy that could likewise be determined from the same mechanical laws.

The experiments, however, showed unequivocally that the proton and the electron produced from the decay of the neutron could leave moving in any relative directions, from parallel to opposite each other. In addition, they could carry away varying amounts of energy, but never quite enough to account for the total energy released in the decay. Apparently, the time-tested laws for conservation of energy and momentum were not valid for beta decay.

With the advent of quantum mechanics, a new measurable quantity, the spin, was discovered, which has its own conservation laws. The spin of an atom, nucleus, or elementary particle is related to the strength and orientation of its magnetic moment. In beta decay, both the proton and the electron produced from the neutron's decay carry one-half unit of spin, as does the neutron. According to theory, the spin, a vector quantity, should be conserved. But two particles each with spin one-half have a total spin of zero or one, depending on whether their spins are aligned parallel or antiparallel to each other, the only two



Fermi National Accelerator Laboratory

In this photograph from the hydrogen bubble chamber at the Fermi National Accelerator Laboratory, every line is the track of an electrically charged particle. Scientific researchers postulate that the sprays of curling tracks moving upward are where a neutrino has caused a nuclear transformation. The squares mark the presence of the four neutrinos; the circle is for reference only.

orientations allowed. In beta decay, then, the final electron-proton system apparently either gains or loses one-half unit of spin relative to the parent neutron.

To save the conservation laws for beta decay, and consequently the ability to make useful predictions in theoretical physics, Pauli postulated that a third entity must also be emitted in beta decay. Then the energy and momentum conservation laws could be dealt with easily, since there are an infinite number of different ways for sharing the momentum and energy among the particles of a three-body system. And if this third entity, the neutrino, carries one-half unit of spin, the spin conservation law would also be maintained.

The only problem with this third particle was that none could be observed emerging from the beta decay. But this was explained by the expected properties of the neutrino, which would be uncharged (electrically neutral). Since most detectors operate through sensitivity to charged particles, the neutral neutrino could pass through undetected.

As Pauli and other scientists developed the theory of beta decay, the idea soon emerged that a new force, the so-called weak nuclear force, was responsible for beta decay and a number of related phenomena. The neutrino was always posited to be present in these reactions, balancing the books for the conservation laws. It was not until 1953, however, that two American physicists, C.L. Cowan and F. Reines, observed nuclear transmutation of chlorine into argon that was presumed to be caused by neutrinos from the Savannah River reactor.

This test for the presence of neutrinos has become standard. Chlorine has an atomic number of 17; that is, it has 17 protons in its nucleus. It changes into argon, with an atomic number of 18, when one of the chlorine's neutrons decays, forming a proton and an electron. This decay is assumed to be caused by a neutrino hitting the nucleus, since chlorine is not normally a radioactive element.

Further experimental results now indicate the existence of two additional particles with properties similar to those of the electron, the muon and the tau particle. Since both these particles participate in the weak interaction, they each have a neutrino associated with them. Today, then, there appear to be three types of neutrinos: electron neutrinos, muon neutrinos, and tau neutrinos.

The Big Bang

According to current cosmological theories, the universe began with a tremendous explosion, the "big bang." Shortly after this primordial event, large numbers of nu-

Fermi National Accelerator Laboratory

A neutrino-electron scattering spectrometer at the Fermi National Accelerator Laboratory, an apparatus to detect the collision of neutrinos with electrons. The tubes are connected to scintillation plastic that gives off flashes of light when charged particles pass through it. The light flashes provide information about the nature of the particles going through. When combined with information from other detectors, the ensemble of evaluations is statistically analyzed to produce a representation of the high-energy physics involved.

clear reactions should have occurred, creating tremendous quantities of neutrinos. In fact, there should be about as many neutrinos as photons in the universe, according to this theory.

One way to test the validity of this big bang theory is to measure the residual effects from this large number of neutrinos. For example, according to current estimates by David N. Schramm and Gary Steigman,[1] the observable mass in the universe is inadequate to explain the existence of clusters of galaxies. That is, the gravitational force from the masses that are actually observed is too weak to account for the way that clusters of galaxies form and stay together (although this problem does not apply to smaller-scale objects such as single galaxies). Neutrinos could make up this difference if they have a small mass, say 10 eV compared to more than 500,000 electron volts for an electron. Then, since there are about 10^8 neutrinos for every heavy particle, their total mass would create a mass density throughout the universe that is many times what is observed directly.

As originally conceived, however, neutrinos should be massless, like photons. But recent experiments imply that neutrinos may actually have a small mass, perhaps as much as 0.005 percent of the electron's mass. A mass as small as 0.0006 percent of the electron's mass would be large enough to account for the "missing mass" in the universe. Additionally, the neutrino mass might suffice to eventually halt the expansion of the universe.

In the early 1970s, R. Davis and his coworkers[2] set out to test some of these theories by measuring the flux of neutrinos from the Sun. As the fusion reactions proceed, generating the Sun's energy, there should be a steady flow of neutrinos from several of the reactions. Davis's experiment focused on the neutrinos emitted from the decay of boron to beryllium, one of the products formed when helium burns in the Sun's core.

Davis built a detector consisting of a tank of cleaning fluid, which is rich in chlorine, deep underground. The rock and soil above the detector acted as a shield to prevent other cosmic radiation from reaching the chlorine in the tank. Only neutrinos would be nonreactive enough to reach the chlorine. As a neutrino passed through the cleaning fluid, there is an extremely small chance that it would transform a chlorine-17 atom into an argon-18 atom by causing a chlorine neutron to beta decay into a proton and an electron, thus increasing its atomic number. This experiment should, therefore, indicate the number of neutrinos produced by boron decay in the Sun's core.

The results from Davis's experiment have caused quite a stir, since Davis observed only about one-third as many neutrinos as the best estimates of the burning rates in the Sun indicate. There have been several different efforts to explain this anomaly.

First, it is recognized that the rate for the boron-decay process is not completely reliable since we do not have a very accurate model of the fusion process occurring in the solar interior. We do have a better understanding of the first step in the solar fusion cycle, the transformation of two protons into a deuterium nucleus, which also gives off neutrinos, but of too low an energy to be detected by the chlorine-argon transformation of Davis's experiment. A new experiment is therefore being designed to detect these neutrinos using gallium or indium.

Another possible explanation for Davis's results arises from recent measurements of the Sun's pulsation at a period of 160 minutes and a velocity of 33 cm/sec. This period is twice as long as predicted by standard models of the Sun, but could be explained if the central temperature is reduced by about 10 percent, which would also reduce the number of neutrinos being produced in the solar core.

Another approach to solving this problem is based on the hypothesis that neutrinos oscillate. That is, if electron neutrinos do have mass, they can transform themselves into muon or tau neutrinos so that any neutrino flux would become a mix of all three by the time it traveled from the Sun to the Earth. This possibility, which would require experimental evidence that they do have mass and that they do oscillate, could partially explain Davis's results because if some of the electron neutrinos had oscillated to become muon neutrinos during the journey from the sun they would not be detected in Davis's experiment. But the best current estimates are that this would account for a reduction of the flux by about only one-half, rather than the two-thirds reduction measured by Davis.

So far the experimental evidence to support this hypothesis is tentative. A recent experiment performed at the Institute for Theoretical and Experimental Physics in Moscow indicates that perhaps the neutrino does have a small amount of mass. And another experiment performed by Frederick Reines and his associates at the University of California in Irvine indicates that perhaps the neutrinos do oscillate. But a third experiment performed at the Institut Laue-Langevin in Grenoble, France indicates that the neutrinos do not oscillate. Obviously, much work needs to be done to support or disprove this theory.

But Do Neutrinos Exist?

The most novel and sweeping approach to the problem of explaining the Davis results has been put forward by Erich Bagge from the University of Kiel in West Germany.[3] Bagge's idea is to extend the conservation laws for energy and momentum to include the negative energy states proposed in the Dirac relativistic theory of the electron. Then there is an alternative mechanism to explain beta decay without using the neutrino hypothesis.

In this case the beta decay of the neutron, for example, is interpreted as an electron-positron pair production event, with the electron being emitted by the neutron and the positron being captured. (A positron is a positive electron.) Pair production is a well-known phenomenon that is readily described by the Dirac theory.

In this case, since there are three particles—the neutron, the electron, and the positron—with one-half unit of spin each, participating in the reaction, all the conservation laws are observed. Furthermore, there is no need to posit the neutrino or to invoke a weak nuclear force. In the elaboration of the theory, Bagge is able to reproduce the apparent strength of the weak interaction by purely electromagnetic considerations.

If Bagge turns out to be correct and neutrinos have no mass or don't exist, a large area of modern particle theory will have to be rethought. For example, just last year Steven Weinberg and Abdus Salam were awarded the Nobel Prize for their theoretical work unifying the electromagnetic and weak interactions in one formalism. But if the two forces were actually only one to begin with, both the premises and results of this theory will have to be reconsidered.

The reader may be thinking at this point that, if neutrinos have actually been observed, isn't it somewhat presumptuous to put forward a theory that claims they don't exist? But if we examine the experimental evidence for the neutrino's existence, we find ample room for questioning. Since the early experiments of Reines and Cowan in the 1950s, there have been a number of physicists—including the eminent Soviet theoretician Bruno Pontecorvo—who have disputed the validity of the experiments.

Detecting a neutrino is an extremely difficult task. The very few real events recorded by the detectors must be sorted out from the large background noise. This process is far from reliable, especially when two large numbers are subtracted from each other to result in a very small number for the neutrino. In short, the existence of the neutrino relies on statistical methods that are subject to criticism.

Thus, no conclusive evidence exists to prove that neutrinos have mass, that neutrinos oscillate among three types, or that neutrinos exist at all.

For example, after the Reines and Cowan observation of neutrinos was announced, a Soviet research team attempted to reproduce their experiment but received negative results for the existence of neutrinos. This work, however, was never published. Bagge is currently conducting experiments that he hopes will determine whether his theory or that of Pauli is correct. Depending on which of these turns out to be the case, it can either confirm or call into question our understanding of the structure of the universe and galactic formation, the cycle of fusion reactions in the stars, and the "weak force" quantum field theory.

—*Dr. John Schoonover*

Notes

1. David N. Schramm and Gary Steigman, "A Neutrino Dominated Universe," First Prize Essay, Gravity Research Foundation, 1980.
2. R. Davis and I.C. Evans, Proceedings of the Thirteenth International Cosmic Ray Conference, Denver, 1973, p. 2001.
3. Erich R. Bagge, "Pair-Production and the New Interpretation of the Conservation Laws of Physics." Institut für Reine und Angewandte Kernphysik der Christian Albrechts Universität, Kiel, IFKKI 78/2. April 1978.

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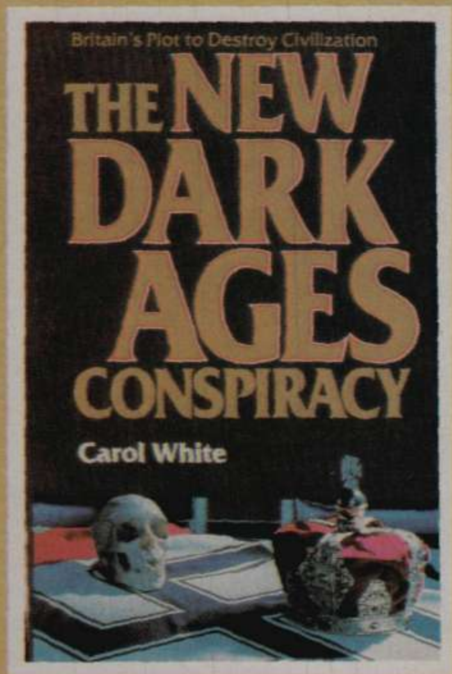

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Maligned for centuries as a "wild flight of fancy," Kepler's "Harmony of Spheres" doctrine remains a rigorous scientific challenge to modern astrophysics.

Kepler and the Harmony of the Spheres

by Robert Zubrin

RECENT THEORETICAL WORK has revealed a remarkable harmonic ordering in the dynamics of the solar system. Perhaps even more remarkable, these recent discoveries corroborate the point of view first developed in modern scientific form by Johannes Kepler in the early 17th century.

Kepler's life and work are often portrayed in the narrow terms of specific hypotheses; for example, he is revered for the discovery of the basic laws of planetary motion. What is essential about Kepler, however, is his impassioned commitment to the advance of science for the sake of furthering human progress and his conviction that the universe was a coherent unity—heaven and Earth—with causal processes that man through science would comprehend.

For these commitments, Kepler fought politically against the faction he characterized as the "Patrons of Ignorance." And for these commitments, today's Patrons of Ignorance have chosen to picture Kepler as a schizophrenic personality who mixed science with so-called mysticism. In this prevailing mischaracterization, it is acknowledged that Kepler revolutionized astronomy and laid the foundation for major advances in physics, but it is stressed that his exotic theological views produced such outlandish doctrines as the Harmony of the Spheres. The necessary relationship between Kepler's achievements and his theological doctrine is denied. (A case in point is Arthur Koestler's popular book *The Sleepwalkers*, which fraudulently asserts that Kepler is "clinically schizophrenic.")

Kepler's theology, in fact, represented a rigorous Neoplatonic epistemology in the apostolic Christian tradition associated with Proclus, Augustine, and Nicholas of Cusa, a tradition whose roots trace directly to Plato's Academy at Athens. His Neoplatonic outlook is identical in every essential respect with scientific principles, as his own writings show.

For Kepler, God was not mere ruler in the heavens, but immanent in a universe uniquely knowable as creative and self-ordered. "The world is the corporeal image of God. . . . The soul is the incorporeal image of God." Man's faculty of Reason or "soul," according to Kepler, is consubstantial with "corporeal" causal processes in the universe which are therefore subject to the soul's willful mastery. Nothing is unknowable to man, for what is incomprehensible to the soul is substantially nonexistent in God's universe.

In calling man to scientific discovery and "Dominion over Nature," Kepler wrote, God has endowed the soul with intrinsic guidance. For example: "Geometry is one and eternal, a reflection out of the mind of God. That mankind shares in it is one reason to call man an image of God." According to Kepler, the basic principles of geometry, perceived immanent in the development of the soul's reasoning powers, must invariably be proven by discovery to be also immanent in the causal ordering of the physical universe.

> It is no longer a surprise that man, the imitator of the Creator, should have finally discovered the art of singing polyphonically (*per concentum*) which was unknown to the ancients, namely in order that he might play the everlastingness of all created time in some part of an hour, by means of an artistic concord of many voices, and that he might to some extent taste the satisfaction of God the workman with His own works, in that very sweet sense of delight elicited from this music which imitates God. . . . The movements of the heavens are nothing but a certain everlasting polyphony (intelligible, not audible).

This is Kepler's Harmony of the Spheres, from which he derived his three celebrated laws of planetary motion.

Kepler's theology was necessarily ecumenical; the Neoplatonic faction with which he identified comprised both Protestants and Catholics who sought to use science to advance man's material and cultural position. The religious and political history of Kepler's times centered little, if at all, around the animosity between Catholic and Protestant factions per se. The actual struggle pitted a Neoplatonic elite in ecumenical accord across religious lines for a revival of Renaissance-period flourishing of art and science, against Aristotelian factions in both religious camps centered in the Counter-Reformation operations of the Jesuit order.

Kepler, Copernicus, and Aristotle

The scientific history of Kepler's period centered around the debate between the followers of the prevailing Ptolemaic model of heavenly bodies and those who espoused the innovation of Copernicus. The issue was only secondarily the position of the Earth or the Sun at the center of heavenly architecture; the primary issue was epistemological.

For example, Galileo first came to the attention of the Jesuit Inquisition when he created "shock waves" in the Ptolemaic camp by publishing a factual report on his telescope's disclosure of mountains on the Moon and the existence of four moons in orbit around Jupiter. At the time Kepler wrote in support that Galileo "should be armed against the sour-tempered critics of everything new, who consider unbelievable that which is unknown to them, and regard as terrible wickedness whatever lies beyond the customary bounds of Aristotelian philosophy."

What the Ptolemaics feared about Galileo's findings was that their model of the heavens rested squarely on the assertion that there was a qualitative distinction between heaven and Earth, astronomy and physics, theology and science. Aristotle's systematic approach to science denied causal hypotheses and substituted nominalist logical relations and nomenclature for causal relations in the universe. Over millennia, by reducing the contemporaneous achievements of science to purely formal interpretation (that is, "positivism"), Aristotelians from Ptolemy to Bertrand Russell have had the purpose of petrifying science.

Aristotle portrayed the heavens as a divine, unknowable realm of "crystal spheres" not susceptible to causal analysis because they did not exhibit the sort of phenomena that physics readily analyzes on Earth. Thus Ptolemy wrote:

> It is impermissible to consider our human conditions equal to those of the immortal gods and to treat sacred things from the standpoint of others which are entirely dissimilar to them. . . . Thus we must form our judgment of celestial events not on the basis of occurrences on Earth [physics], but rather on the basis of their own inner essence and the immutable course of all heavenly motions.

For Ptolemy and his followers, the motions of the planets, with Earth at the center, were subject to observational and mathematical description, but were in principle bereft of causal relations whose discovery could make astronomy a science. Descriptive power was believed to be astronomy's sole criterion, and the question of *causes* in planetary behavior, whose comprehension would both establish the principle of human mastery of the heavens and revolutionize man's knowledge and mastery of earthly processes, was banned from consideration.

In reply to this bifurcation of heaven and Earth, the great Neoplatonic Giordano Bruno stated succinctly, "We are in heaven."

Johannes Kepler (1571-1630) was born of middle-class Lutheran parents in the town of Weil der Stadt, then part of the Holy Roman Empire. He was educated in the Platonic tradition at the Augustinian monastery at Tubingen and there reportedly became acquainted with the Copernican astronomy through the mathematician and astronomer Michael Maestlin. Kepler's contacts ranged from Italy's Galileo to England's William Gilbert and Puritan leader Sir Henry Wotton. He and Galileo were reportedly affiliated with the Rome-based Lyncaem Academy—the "Lynx-eyed group" whose motto was "Fight Aristotelians to the end."

Nicholas Copernicus (1473-1540) was of this epistemological faction. He posited the Sun at the center of a system of planets in circular orbits. The principal consideration was not any demonstrated predictive power or descriptive advantage over the Ptolemaic Earth-centered model. At issue was the truth of an hypothesis from the standpoint of a *knowable causality* in the heavens. The system of planets cannot be ordered except as to reflect the Sun's role as *the source of the system's energy.*

Until Kepler's discoveries intervened, the Copernican model was besieged by Aristotelian challenges. The problems of correlating observational data with the assumed circular orbits of the planets compelled Copernicans to adjust by introducing the Platonic geometric tool of "epicycles." These epicycles explained the orbits of planets as a rotating small circle that traveled around the circumference of a larger circle (deferent) at whose center was the observer. The Aristotelians and Ptolemy took this method of analysis and reified it with the Earth at the center. They insisted that these circles were physically real and made of an ineffable stuff called "quintessence."

Kepler moved against this confusion by reintroducing the physical hypothesis: Something *powers* the motion of the heavenly bodies. "Let physicists show, if they can, that such a power be possessed by a point."

Against a "Copernican" colleague, Fabricus, whose astronomical theory preserved the Aristotelian bifurcation of heaven and Earth, Kepler wrote mercilessly:

> You say that a daughter has been born to you by geometry. I looked at her, she is lovely, but she will become a very bad wench who will carry off the many daughters which the mother physics has given me. Your theory will draw teachers and philosophers to it, it will offer loopholes to the enemies of celestial physics, to the patrons of ignorance, the master builders of solid orbits, the rough mechanics, loopholes by which they can escape the bands of physical proofs and reach freedom in order to manufacture their own Gods. Simple nature has guided me, free of all the attire of a hypothesis. In the place of this highly respectable girl, nature, your young whore with her wench's apparel and her conduct conducive to lust, not to virtue, is supposed to appear—that is the talk of Fabricus. One should listen to strict science and not to crazy philosophers.

Kepler advised the Copernicans that they did not require a more perfect epicycle to "save the appearances" of descriptive advantage, but required discovery of the physical cause. There is not only planetary motion, there is something that "dispenses" motion.

Kepler's fundamental proposal: As the source of energy impinging on the other bodies of the solar system, the Sun is assuredly the "center," but primarily, the origin of a *force field* causally governing the orbits of all planets.

> Let us then assume, as is very probable, that motion is dispensed by the Sun in the same manner as light. The proportion in which light emanating from the center is diminished is taught by optical writers; for there is the same quantity of light or of the solar rays in the small circles [orbits] as in the large; and therefore, as it is more condensed in the former, more attenuated in the latter, a measure of the attenuation may be derived from the proportion of the circles themselves, both in the case of light and of the moving virtue [force field]. Therefore, by how much the orbit of Venus is greater than that of Mercury, in the same proportion will the motion of the latter be stronger, or more hurried, or more swift. . . . The Sun's bodily virtue, sent forth in straight lines into the whole space of the world, serves instead of hands; and this virtue, being a corporeal species, turns with the body of the Sun like a very rapid vortex, and travels over the whole of that space which it fills as quickly as the Sun revolves in its very confined space around the center.

It is from this hypothesis, that a solar force field acts causally on the planets in a manner attenuating with distance, that Kepler's three laws follow: First, there is what is today called his "second" law, the Law of Equal Areas. In equal times, an orbiting planet will sweep out equal areas of "space" between it and the Sun. The emphasis on "area" reflects the notion of causal force "filling up" the space separating Sun from planet. While intuitively obvious from the standpoint of the force-field hypothesis, empirical verification of this first law required the use of mathematical devices akin to calculus.

Kepler applied this "second" law to formulate what is today called his first law: Planetary orbits are not circular, but elliptical with the Sun at one focus.

Since the Earth, like other planets, is subject to the Law of Equal Areas, Kepler "suspended judgment" on the shape of planetary orbits and established a fixed point in the orbit of Mars, interpreting data as if observations of the Earth's position were being taken from that point, "as from a watchtower." The *a priori* assumption of circular motion proved incorrect—the orbit of the Earth was in some manner "oval." In that knowledge, Kepler applied the Law of Equal Areas to data pertaining to the angular procession of the planet, mathematically determining the distances of the Earth from the Sun at a variety of points. The "oval" proved to be an ellipse, as Kepler wrote, "down to a nail." Correcting observational-data's interpretation based on the assumption of a circular Earth orbit, he established that the orbits of the other planets were also elliptical. Thus, Kepler's law: "Planets move in ellipses with the Sun at one focus."

The verification of Kepler's first two laws constituted a powerful demonstration of the reality of the solar force-field hypothesis. Kepler's third law, to him the most important for the future of science, suggested the existence of *lawful differentiation* within that force field, determining the relative positions of the planets as, not arbitrary, but necessary. Not only does each planet behave in lawfully determined fashion in relation to the Sun, but also, each planet has a well-defined mathematical relationship to every other. Kepler's third law:

$$t_1^2/t_2^2 = d_1^3/d_2^3$$

The squares of the planets' periods of revolution t vary directly with the cubes of their mean distances d from the Sun.

The Harmony of the Spheres

Does there then exist an underlying ordering principle—perhaps inherent in the vortical solar force field itself—that would efficiently reduce the three laws to one and comprehend the planetary system *as a single system?* Kepler's answer was yes!

From that point, he sought to locate this underlying ordering principle in the relationship between geometry and harmony, principles perceived efficient in the self-ordering activity of the reasoning "soul" itself.

Kepler's three laws were not self-evident in any empirical sense. There was nothing empirically obvious to support their formulation—although each was empirically verified in turn. In a fundamental sense, Kepler had proceeded at all times from his higher hypothesis, the much maligned Harmony of the Spheres; the three laws were purely its derivatives.

"My goal," he wrote, "is to show that the heavenly machine is not a kind of divine living being, but similar to a clockwork insofar as almost all the manifold motions are taken care of by one single absolutely simple magnetic bodily force. . . ." What is it in the nature of that force—Kepler followed Gilbert in the wrong supposition that it was magnetic—that defines the disposition of the planets as the necessary, only possible disposition? That necessity was operating, he left little doubt.

Geometrically, Kepler discovered that the mean distances of the known planets, treated as radii of concentric spheres, corresponded precisely to a certain ordering of the five Platonic (perfect regular) solids; namely, that ordering which allows them to be inscribed within each sphere while perfectly circumscribing the previous sphere (see figure). This remarkable fact he attributed to the primacy of the Platonic solids themselves in the geometric ordering of the universe ("Geometry is a reflection out of the mind of God. . . .") and in giving order to Euclidean geometry's "shapeless heap of propositons."

Kepler also made the discovery that the relative angular velocities of the planets were *harmonic*—closely corresponding to the mathematical ratios of different string lengths producing notes that harmonize. ("Give air to heaven, and truly there will be music.")

These geometric and harmonic correspondences can be no accident. Between this harmony of the spheres and the geometry of the spheres there must exist some "bridge," as signified in the relationship between the planets established in his third law. In truth, what has been maligned as Kepler's "wildest flight of fancy" (starting with the Aristotelians led by Isaac Newton) is a rigorous scientific hypothesis, sufficiently grounded in empirical truth that its significance can be known. For Kepler, the Harmony of the Spheres signified confirmation of the consubstantiality of the "soul" in the corporeal universe. In that, he proceeded from scientific impulse: When confronted with a mathematically well-defined relationship of both geometric and harmonic quality, the relative motion of the planets in a solar force field, he searched for *causal necessity* in that relationship.

Let us suppose, as Kepler's original hypothesis suggests to the fusion researcher, that the solar system originated as a vortical mass of plasma. In that case, singularities arising in that plasma *to form planets* will occur in specifically determined regions of plasma density and frequency. In the same way, a vibrating string yields nodal points at certain specific *and often harmonic* frequencies. Were the solar system to prove a product of processes akin to the self-ordering behavior of plasmas, then indeed, Kepler's Harmony of the Spheres will be taken out of the realm of mere correlation to be located as he proposed, in lawful necessity.

The point is negatively illustrated by the figure of Sir Isaac Newton, the avowed enemy of everything for which Kepler and the "continental science" stood. On the face of the matter, Newton contributed absolutely nothing to the understanding of planetary motion not already present in Kepler's laws. What Newton did do was to generalize Aristotelian astronomy into a form more appropriate to the description of Kepler's accomplishments without effecting the slightest improvement in Aristotelian method.

Newton's inverse square formulation of the "law of gravity," whose deduction from Kepler's laws is an elementary schoolboy exercise, represents a massive lowering of scientific outlook in relation to Kepler's *field-theoretic* conception of causality in the solar system. Resting on the fiction of "action at a distance," the Newtonian formulation reduces the solar system to so many separate "two-body problems" in which the real, causal problem has been abandoned.

Kepler, the scientist, bypassed the obvious inverse square formulation in his quest for knowable causality in the universe, while Newton, the practitioner of black magic, sought to eliminate the causal issue in a bowdlerized simplificaton of Kepler's actual achievements.

Perhaps the most eloquent statement of lawful necessity is that of Kepler after he worked out the third law:

> What I prophesied two and twenty years ago, as soon as I discovered the five solids among the heavenly orbits, what I firmly believed long before I had seen Ptolemy's Harmonics, what I had promised my friends in the title of this book, which I named before I was sure of my discovery, what sixteen years ago, I urged as a thing to be sought, that for which I joined Tycho Brahe, for which I settled in Prague, for which I have devoted the best part of my life to astronomical contemplations, at length I have brought to light, and have recognized its truth beyond my most sanguine expectations. Great as is the absolute nature of Harmonics with all its details, as set forth in my third book, it is all found among the celestial motions, not indeed in the manner which I imagined (that is not the least part of my delight) but in another very different, and yet most perfect and excellent. It is now eighteen months since I got the first glimpse of light, three months since the dawn, very few days since the unveiled Sun, most admirable to gaze on, burst out upon me. Nothing holds me; I will indulge in my sacred fury; I will triumph over mankind by the honest confession, that I have stolen the golden vases of the Egyptians to build up a tabernacle for my God far away from the confines of Egypt. If you forgive me, I rejoice; if you are angry, I can bear it: the die is cast, the book is written; to be read either now or by posterity, I care not which; it may well wait a century for a reader, as God has waited six thousand years for an observer.

Robert Zubrin is on the fundraising staff of the Fusion Energy Foundation.

New Delhi Report

India Accelerates Nuclear Program

The director of nuclear engineering and heavy water projects for the Indian Atomic Energy Commission, Dr. N. Srinivasan, announced Sept. 19 that the government will build seven new heavy-water production plants by 1986.

The decision to build the nuclear fuel-producing plants was taken in anticipation of a U.S. Congress vote to overturn President Carter's executive order for enriched uranium supplies to the U.S.-built Tarapur nuclear plant. Most significantly, it reflects Prime Minister Indira Gandhi's resolve to remove all obstacles to an intensified development of nuclear energy as the basis for an ambitious industrialization program.

The heavy-water CANDU reactor model is the main reactor system used by the Indian Atomic Energy Commission, and a step-up in heavy-water production will alleviate the serious problem of fuel supplies the program has suffered. The seven new plants, along with the five plants now in various phases of production and commissioning, will give India a capacity to install 10,000 megawatts of nuclear-generating capacity by the turn of the century.

Srinivasan projected that the percentage of India's energy produced from nuclear power would be approximately 12 percent by the year 2000, excluding a separate experimental fast-breeder program now underway. This assessment contrasts sharply with an energy study released by the Indian Planning Commission, which calculated a 6 percent component for nuclear power in its overall projections.

—*Paul Zykofsky*
New Delhi correspondent

FEF Program Widely Reported In India

The 40-year development program to turn India into an industrial power, put forward by the Fusion Energy Foundation and the weekly *Executive Intelligence Review* (*Fusion,* May 1980, p. 17), made headlines in India's national press in early September.

An article describing the FEF program in detail was published by the Press Trust of India, the nation's major news wire service. Versions of the Press Trust article were then picked up by three major daily newspapers—the *Patriot,* the *National Herald* (the unofficial paper of the ruling Congress I Party), and the *Hindustan Times,* the leading paper of southern India.

The *Hindustan Times* also reviewed the program favorably in its lead editorial Sept. 10.

"India will emerge as a superpower next only to the United States and Soviet Union if it pursues a well-defined economic policy laying emphasis on industry, atomic energy, and effective utilization of its third largest technical base in the world," the *Patriot* wrote.

"This prominent position for a Third World nation can be achieved by India in less than 40 years, according to an exhaustive advanced computer projection made by one of the world's front line economists, Mr. Lyndon H. LaRouche, Jr., a former U.S. presidential candidate, and other U.S. experts."

LaRouche-Riemann Model

LaRouche, a founder of the FEF, developed the LaRouche-Riemann economic model used to work out the India 40-year program. On a trip to India in early June, FEF director of research Uwe Parpart discussed the program widely with Indian scientists, planners, and government officials. (See *Fusion,* Oct. 1980, p. 33.)

The *Hindustan Times* editorial reports favorably on the program, criticizing it only for erring "on the side of optimism." The *Times* editorial reads in part:

Congressman McCormack: 'Yes' To Nuclear Fuel for India

In an interview with *U.S. News & World Report* on whether the United States should sell enriched uranium to India, Rep. Mike McCormack (D-Wash.) stated an unequivocal "yes."

"This fuel could not be used for weapons under any circumstances," he said. "It is physically impossible, and India does not possess the facilities to convert it to material that would work in a weapon."

"We are damaging the credibility of our own country and abandoning our role as leader in the peaceful use of nuclear energy by pursuing a policy of attempting to control India's nuclear program."

The congressman hit the media for their role in creating confusion on the issue: "Where there is confusion, it is because the media have not done their job of presenting the facts about nuclear fuel and nuclear energy."

"The program—entitled 'the industrialization of India 1980-2020, from backwardness to industrial power in 40 years'—comes down heavily against the kind of small thinking that characterized New Delhi's policies during the recent Janata interregnum.

"It warns India against dependence on the World Bank or Club of Rome-sponsored 'appropriate technologies'—so dear to the heart of our so-called Gandhian economists who mushroomed during recent years. Such a dependence, it feels, will not help to catapult India into the superpower bracket. In saying so, it echoes a suspicion long voiced in this country by Mrs. Indira Gandhi that, though 'appropriate technologies' may have a short-term relevance to our vast unemployment problem, an undue emphasis on them will tie us down to the Western desire to stymie our long-term efforts at industrial self-reliance."

World Energy Conference Backs Nuclear Power

The industrialized nations must move ahead with the development of nuclear power or suffer the penalty of economic catastrophe, potentially leading to world war. This was the dominant theme at the World Energy Conference in Munich, West Germany Sept. 8-12.

West German Chancellor Helmut Schmidt opened the international gathering by warning that the world now faces the risk of war because of the failure to develop new energy sources. "We must not close our eyes to the economic and political risks of a war for energy supplies," he told the 3,000 delegates assembled from 78 countries.

In a major address on the first day of the conference, Klaus Knizia, president of the *Vereinigten Electrizitaetswerke*—the United Electricity Works utility, stressed the critical role of nuclear energy in maintaining world peace and in meeting expanding global energy requirements. Knizia told the conference that the energy requirements of the developing counties will increase ninefold over the next 40 years just to ensure minimal living standards. This necessitates an ongoing dialogue between the developed and developing nations on energy, he said.

The industrialized states, Knizia said, should substitute nuclear power

Oil Shutoff

Making Synfuels 'Competitive'

Philippe Ledru/Sygma

Oil shutoff: The model for shutting down Mideast oil production is Iran, once the world's second-largest oil exporter. Abadan, Iran's largest refinery, is shown here in October 1978 when political chaos was beginning to paralyze production.

The *Washington Post* unabashedly attacked Saudi Arabia for trying to keep the OPEC oil price down in a Sept. 18 editorial—on grounds that by keeping production up and stabilizing prices, the Saudis were preventing synthetic fuels from becoming "competitive."

"The Saudis, excellent tacticians that they are, would probably prefer to keep the world price of oil just a little below that of the synthetics, to keep alive all those uncomfortable questions about the economic viability of a synthetic fuels industry," wrote the *Post*. "That's the way for the oil-exporting governments to maintain their market power into the next century."

The *Washington Post* is not alone in this logic. Economists at Chase Manhattan Bank are conducting a comprehensive in-house study on the global and domestic economic impact of a shutoff of Persian Gulf oil. Assuming a reduction of Persian Gulf production from 17 million barrels per day to 9 million barrels per day—a and coal for oil. The *"Schwellenlaender,"* the "threshold" or Newly Industrializing Countries with large populations and developed urban centers, must meet their growing energy needs with the necessary nuclear power. Knizia added that coal, although important, can supply only a limited part of the world's energy needs and that the soft energy alternatives can supply only a small percentage.

This year's World Energy Conference—the conference is held every three years—drew a large representation from Third World countries, and the proposal for using nuclear energy in the developing sector was strongly endorsed by a number of distinguished Third World delegates, including Mr. M.R. Srinivasan, director of India's Department of Atomic Energy. A speech by Hans Bandmann, director of the Fusion Energy Forum of West Germany, attacking the nonproliferation discussion as a political weapon for keeping the Third World under control, also drew congratulations from Indian delegates.

In its coverage of the conference, however, the Western press by and large chose to play up the presence of a group of Third World environmentalists who came to the conference demanding "dung power" and other energy alternatives that would not require dependence on "Western industrial culture." Ironically, these so-called appropriate technologies are the ones approved by the World Bank.

Chancellor Schmidt, who faces reelection this fall, showed signs in his speech of bowing to the continued pressures from antinuclear environmentalists in his own country. Schmidt said that the problems of energy supply can be resolved only by exploiting all resources, "not by playing a single card, as with coal yesterday, oil today and nuclear tomorrow." Coal represents the cheapest energy substitute for West Germany and nuclear power must be "limited," Schmidt said, in a departure from his usual statements on nuclear power.

Most of Schmidt's remarks were devoted to the plight of the Third World, where, he said, the average country spends one-quarter of its export earnings on oil imports. With no alternative energy capabilities to speak of, each rise in the oil price is measured in "more hunger, more thirst, more disease." Schmidt called on OPEC (the Organization of Petroleum Exporting Countries) and the Comecon (East Bloc) countries to join with the industrialized countries in providing more aid to the developing sector.

Another leading participant at the conference was Michel Pecqueur, chairman of the Atomic Energy Commission of France. The French AEC has the world's most ambitious nuclear program and projects that 80 percent of national electricity needs will be supplied with nuclear energy by the year 2000.

German Information Center

Schmidt: "We must not close our eyes to the economic and political risks of a war for energy supplies."

Pecqueur addressed the delegates region by region. "You have continued to play with fire," he warned the OPEC counties. The industrialized nations are doing what has to be done to develop coal, he said, "but are neglecting nuclear." Pecqueur called on the developing sector countries, "who cannot afford the luxury of a crisis or of zero growth," to push for international cooperation for energy and to join with French President Giscard in calling for a "trialogue" among Europe, the Third World, and the oil-producing nations.

The East Bloc countries, Pecqueur said, should become less secretive about the actual status of their oil resources to help eliminate a major unknown in world energy planning.

Soviets Propose Cooperation

The Soviet representatives who attended the conference came with offers of joint projects to develop Siberia's coal resources in exchange for coal exports to participating countries. This perspective, presented by Professor Styrikovich of the Soviet Academy of Sciences, was supported by a leading West German mining expert, Erwin Anderheggen, who stated in his remarks that the problems to be overcome in establishing an integrated East-West European energy grid were not technical but political.

—Dana Sloan

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very drastic decline in output—the Chase economists are now calculating the effects on world financial markets and on every American industrial sector.

The 17 million figure is the current combined oil output of Saudi Arabia, Kuwait, the United Arab Emirates, and Iraq—OPEC's leading producers.

"Only dramatic upsets will drive them down to the 8 to 9 million barrel per day level," a Chase officer told the weekly *Executive Intelligence Review* in August. The distinct impression is that Chase favors the upsets in order to make synthetic fuels economical.

Which Side Is the Gov't On?

Although rarely stated outright, the Carter administration's synthetic fuels program absolutely depends on an oil shutoff. Synthetic fuels are so expensive (currently $62 per barrel) that the Carter program is admittedly wholly uneconomical unless all alternatives—including nuclear and conventional petroleum sources—are rendered even more uneconomical.

An Interview with Alexander Sheindlin

Soviets Plan Several MHD Reactors

At the recent World Energy Conference in Munich, Fusion *correspondent Laurent Rosenfeld interviewed Soviet academician Alexander Sheindlin on the Soviet Union's magnetohydrodynamics (MHD) program. Academician Sheindlin is the director of the Institute for High Temperatures of the Soviet Academy of Sciences, located in Moscow.*

* * *

Question: Could you briefly outline the present MHD program and objectives in the Soviet Union?

A 20-megawatt natural gas-fired MHD unit has been working at the Institute for the past few years and is connected to the Moscow power grid. The first commercial-size MHD generator, the U-500, will be completed by the year 1985. This generator, whose power output will be 500 megawatts, will produce 250 megawatts with an MHD topping cycle, plus 300 megawatts with a conventional steam turbine cycle. Minus the losses, the net total energy will be 500 megawatts. It will be a natural gas-fired generator and will be installed in the town of Ryazan, 200 kilometers south of Moscow. We plan to have several reactors of that same design built by the end of the decade.

The second generation of MHD reactors, which will be coal-fired reactors, should see their first commercial operation around 1990–1995. Several reactors of this type could be operating by the turn of the century, for a total gross output of between 20 and 30 gigawatts.

Question: What do you think of the present collaboration between the Soviet Union and other countries, particularly Western countries such as the United States, in MHD work?

The collaboration between the Soviet Union and United States is at the government level, which is the reason for the good results we have had. We have been cooperating now for seven years, and we have achieved good results, among other reasons because we have deliberately decided to go further than just exchange of information and set up a really close cooperation; the United States has built some equipment for us, and we have built some for the United States.

Question: Could you specify what type of equipment?

The superconducting magnet built in the United States has functioned satisfactorily on the Soviet U-25 experiment for the past two years. On the other side, we delivered, five years ago, three devices designed to measure the physical properties of the MHD plasma. These diagnostic devices were used with success at the MIT research center near Boston, at the Pittsburgh Energy Research Center, and at the University of Tennessee Space Institute MHD program.

Question: What kind of measurements were they making?

They had to measure and control the electrical conductivity, the temperature, and the electron concentration in the plasma.

I must add, however, that the Soviet-American cooperation is presently stagnating, in spite of our efforts to push it further. I think it is now up to the United States to take the next step forward.

Question: What do you think is the cause of this stagnation?

We think that the causes are only political, and this is a pity. I am, however, absolutely convinced that the American scientists are willing to collaborate further. The only obstacles are political.

Question: With which other countries do you collaborate in MHD?

We have a high-level and every successful cooperation program with Indian scientists. In addition we co-operate with the other socialist countries, including Poland and Yugoslavia.

Ambitious R&D Program Announced By Japan

A vast research and development (R&D) program and investment in the frontiers of industrial technology will be the heart of Japan's economy in the 1980s, according to the proposal by the Ministry of International Trade and Industry (MITI), "Long Term Vision for the 1980s." Although well received by industry and government circles in Japan, adoption by the new government of Prime Minister Zenko Suzuki may be sabotaged by competing demands for increased military spending under pressure from the Carter administration and attempts to reduce the 30 percent budget deficit.

If adopted, the MITI proposal will double R&D expenditures to 3 percent of GNP by 1990 and encourage joint government-industry investment in the most advanced technology fields of nuclear fission and fusion power, superefficient gas turbines, industrial robots and computerized machine tools, computer-assisted design and production for industry, and agricultural application of the most advanced photosynthetic and genetic research.

MITI's perspective is that the energy crunch will limit Japan's average annual economic growth to 5 percent in the 1980s (somewhat better than the world average of 3 percent)—down from its growth rate of 10 to 15 percent in the late 1960s through early 1970s.

But after 1990, new techniques such as fission and fusion will restore cheap, abundant energy to allow resumption of high economic growth rates. At that point, Japan's success will hinge on its 1980s development of high-technology capabilities.

The Robotic Edge

Japan's robotic automobile plants of Nissan, whose automobiles are sold as Datsuns in the United States, have already given that company a competitive edge in the industry. At some plants, virtually all assembly work is performed by robots, with workers supervising, making adjustments to equipment, or performing white-collar work. According to one U.S. congressional staffer who visited a Nissan plant, "the U.S.'s most modern plants look primitive by comparison."

French Industry Ministry Director-General Jean Pierre Souviron proposed in late June that France and Japan cooperate in the fields of robotics, electronics, computers, aircraft, seabottom resources, and energy efficiency, and also that a joint consortium be formed to sell industrial plants to other nations.

—*Richard Katz*

USDA

The World Bank's idea of self-sufficiency: labor-intensive farming and labor-intensive energy.

World Bank Energy Policy: Little Energy, No Development

World Bank vice president Ernest Stern called a press conference Aug. 22 in Washington, D.C. to announce the release of the World Bank's first global energy study, "Energy in the Developing Countries." Purporting to chart a course that will make many Third World countries "energy self-sufficient," the report has attracted international attention because it calls for $500 to $600 billion in annual energy-related investment in the developing nations by 1990.

In respect to energy requirements, however, the report is a fraud. The bank has not changed from its traditional role as successor to the old British Colonial Office, and intends no substantive development of energy (or anything else). What is worthy of note is the political purpose of the fraud.

Mooting the possibility of "violent disruption" of OPEC production in the Persian Gulf and Middle East, the report proposes to replace OPEC with small-scale oil production projects in other parts of the Third World. The bank identifies 24 countries with potential for "oil self-sufficiency," which could be generating a financial surplus on oil exports of $25 billion annually.

Forty-seven other countries, it says, should begin production of more marginal resources. A total of 30 countries can look forward to "energy self-sufficiency," provided that $40 to $50 billion is invested annually, amounting to $500 billion over the next decade.

West German Dresdner Bank Asks $10 Trillion in Energy

Dresdner Bank, West Germany's second largest bank, issued a report in mid-September concluding that the Western World must spend about $10 trillion on energy equipment over the next 20 years to develop new energy sources. Dresdner specified that about one-half of this amount should go for developing nuclear power and nuclear-based electricity grids. More than a quarter of the total, about $2.8 trillion, could be spent by the oil industry on the development of more sophisticated oil recovery techniques. Another $805 billion could be invested in coal development.

Dresdner's report was first presented at the World Energy Conference held in Munich, West Germany Sept. 8-12.

Although this figure seems large, on closer examination it turns out that it includes investments by private corporations that run energy projects, including power generating stations, in the Third World. Also, it does not separate out qualitatively new investment from investment in the maintenance of existing facilities. Since the annual expenditure for Third World energy projects was already projected to be $34 billion in 1981, the World Bank's $40 to $60 billion figure at best represents a marginal increase.

When the Dresdner Bank of West Germany recently estimated global energy investment requirements, also maintenance and new investment by private and public agencies, it came up with a figure of $10 trillion over the next two decades or $5 trillion over the next decade (see article this section). Dresdner's estimate puts the World Bank figure in the proper light.

Yet something even more pernicious seems to be involved in the World Bank study. At the present time, the potential exists to deploy the $80 to $100 billion annual OPEC surplus through the agencies of the European Monetary System into high-technology Third World development, based on nuclear and hydroelectric power. The EMS-OPEC combination, by which the European nations would create development loans on the basis of OPEC deposits, could deploy $200 billion per year in credit for development of new Third World productive capacities in energy, industry, and agriculture.

The World Bank report reveals its contrary intention in two predictions: First, it predicts that the OPEC component of world oil output will dwindle substantially over the coming two decades—and, therefore, the OPEC surplus that forms the backbone of the potential EMS Third World development program will substantially disappear. Second, it predicts that the nuclear component of world energy *consumption will remain negligible* until well into the next century—which assumes that the EMS Third World development program will in fact collapse.

Going on the record of World Bank forecasts, which have proved to represent policy intentions not predictions, it is clear that the policy intention to prevent the OPEC linkup with the EMS explains the publicity given to the bank's fraudulent energy development program.

For the United States, the policy implications of the World Bank program are equally clear: skyrocketing energy costs and no nuclear exports.

—*Vin Berg and Renee Sigerson*

Africa: Producing for Debt Payment

The U.S. Department of Agriculture issued a statistical report in August revealing both the catastrophic situation of agriculture in Africa and, implicitly, the causes.

Food production dropped 3 percent in 1979 from 1978 levels. Compared to average production totals for the 1961-1965 period, food production was *90 percent lower* on a per capita basis.

The USDA report, titled "USDA Africa Agricultural Situation Report: A Review of 1979 and the Outlook for 1980," indicates further that despite the massive decline in food production, "total agricultural production" remained the same. The decline in food output was offset by an increase in the production of cash crops such as cotton, tea, and other products that earn foreign exchange needed to finance oil imports and service foreign debts. This shift to cash crops has been evident for several years and goes a long way toward explaining the catastrophic economic conditions in sub-Sahara Africa today, where 10 to 70 million people face starvation in the coming weeks and months, according to the best estimates available.

Kenya, for example, one of the nations threatened by famine, produced a surplus of corn in 1978 and even exported about 180,000 tons. The government subsequently cut prices paid to farmers from $11 for a 200-pound bag to $9, forcing about 20 percent of Kenya's farmers to switch to what was then a lucrative cash crop, sugar.

However, the prices of exports such as sugar, tea, and coffee have since been falling, depriving most of the African nations of the foreign exchange they need for imports, including food and fertilizer and other capital inputs for agriculture. As a result of this situation, economists at the World Bank and like-minded agencies are now saying that Africa cannot go on importing food and must become self-sufficient in food production—a recommendation that will only aggravate the starvation conditions in Africa.

UN Conference Calls Urban Growth 'Nightmarish'

The United Nations conference in Rome the week of Sept. 1 on what it called the "nightmarish growth" of the world's cities drew appreciative Malthusian press coverage. The conference was described in the Sept. 3 London *Times* as "one of the most awe-inspiring conferences ever held" in an article headlined "Great Wens (Warts) All Over the World." The "wens" are the world's urban centers

Fully caught up in the conference's purpose, the *Times* reported that the city today is becoming "a burdensome consumer of sickness and pollution." There are, it added, "no universally applicable remedies" to this urban overpopulation.

(At least one leading developing country—India—is not convinced. The Indian press has been running favorable reviews of the Fusion Energy Foundation's 40-year, urban-based industrialization program for India—see article, this section.)

Ph. Ledru/Sygma

Debre: "Let's have a grand design."

Debre Attacks Malthusians

Europe cannot accept any proposals to cut back agricultural production at à time when Third World populations desperately need food to survive, declared Michel Debre, the French presidential candidate who is former premier of that nation. Debre made this statement in an explicit attack on "Malthusians" in a guest article for the Sept. 4 edition of *Le Monde*.

"The agricultural Malthusianism that some want to impose on Europe goes directly against the authority and prestige of the European nations," Debre wrote. "Let us have a grand design for France, for Europe, for the agricultural development of the Third World. To our partners in the European Community we must address suggestions on the ways to expedite food relief and the development of our production. . . . Let us propose true contracts for long-term relief to the states where starvation or near-starvation reign, and let us create, if necessary, the needed food processing industries on our own territory."

The Lightning Rod

Continued from page 6

States for the past 110 years. Originally, it was used to pump water for homesteads on the prairies; at the windfarm, it is pumping water to create an artificial lake. The proprietor nobly confessed that he was having some difficulty with the lake. The sandiness of the soil, he explained, made it obligatory to use a plastic liner inside the lake cavity to prevent dissipation of the water, and the ducks sailing about the lake, apparently considered an aesthetic necessity, all too frequently poked holes in the plastic with their bills.

The pièce de resistance of our tour was a completely wind- and solar-powered two-bedroom house occupied by the proprietor, his wife, and son. The house was heated in the following manner: On command, an electrically powered Sears Roebuck winch (electricity supplied from an adjacent windmill) raised the roof over the living room, allowing the sun's healthy rays to strike a series of tanks built out of galvanized aluminum siding holding 24 tons of water and occupying a prominent position in the living room.

Although our guide forewarned that certain sacrifices were necessary to live in the establishment—for example, a strict limitation on the number of loads doable in the family washing machine each month—he pointed out that the wind-charged 12-volt batteries supplying the bulk of electricity to the house were entirely adequate to supply nighttime light for reading, "if you pull the lamp close to your book."

The price of the home, described as designed to be "affordable to the average American family," was estimated at $60,000.

Despite the *sotto voce* wisecracks of a couple of MIT scientists in the group who appeared *not* to despise electricity, the majority of those taking the windfarm tour appeared to welcome the vision of the future that they had been privileged to witness. Particularly enthusiastic was a fellow who looked remarkably like a prominent radio and television newscaster.

As for myself, I remain,

Yr. obt. svt.,

Benj. Franklin

Inside DOE

Backyard Grants

When the term appropriate technology was coined, even those pro-growth persons who looked askance at the Department of Energy's "soft" technology programs thought that perhaps it would be better for very poor, developing countries to have low technology rather than no technology. Even at that time, however, *Fusion* warned that a key target for 19th-century "appropriate technology" programs was the high-technology United States itself.

This target has come clearly into view since the Carter administration stepped up its friendship with the People's Republic of China. Suddenly the presidential science advisor and the secretary of energy began talking about saving energy here at home by adopting centuries-old agricultural methods from the Chinese.

At one press conference, the Washington press corps listened in amazement as DOE officials told the technology-proud farmers of this nation the advantages of using energy-saving methods to rid their crops of pests, instead of "inappropriate" pesticides. The "appropriate" technology suggested? Human bug pickers who manually collect bugs from plants.

Now the DOE, through its Appropriate Technology Small Grants Program, is encouraging what it calls innovative concepts so that people "can

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Suzanne Klebe/NSIPS

Sen. Paul Tsongas (right) at committee hearings on the Senate fusion bill in August. At left is Dr. Will Smith, Research and Development Subcommittee.

Fusion Bill Sure to Pass

Congressional sources are optimistic that the nation will have an Apollo-style fusion program signed into law before the year is out. Both the Senate and the administration are working to cut 15 years off the current Department of Energy timetable to prove commercial feasibility of fusion power and to commit the nation to an upgraded fusion effort.

The impetus for a redefined national fusion program was provided by the landslide passage of the Fusion Energy Research, Development, and Demonstration Act of 1980 by a 365 to 7 vote in the House of Representatives Aug. 25 (*Fusion,* Nov. 1980, p. 8). Now passage of a similar Senate fusion bill is likely and congressional sources expect it to be on the president's desk by early October. There is no indication at this time that President Carter would not sign such a fusion bill.

Tsongas Bill Revised

The Senate Committee on Energy and Natural Resources voted unanimously Sept. 10 to pass a revised fusion bill, sponsored by Senator Paul Tsongas (D-Mass.), out of committee and to the Senate floor. Committee sources expect the bill to be placed on the Senate consent calendar to be voted on without debate. Because it has been amended to make it compatible with the House bill, a conference committee will not be necessary and the bill will be ready for presidential action.

Senator Tsongas and the Energy Committee staff proposed five amendments Sept. 10 to bring the Senate fusion bill into close alignment with the House bill sponsored by Mike McCormack (D-Wash.).

Most important, the revised Senate bill calls for demonstration of commercial feasibility "at the turn of the 21st century" rather than by the year 2005, as the original version of the Tsongas bill read. This is the target date in both the McCormack House bill and in the DOE's fusion advisory panel report (the Buchsbaum Report), which has been accepted by the DOE Energy Research Advisory Board.

Second, the bill was amended to increase the funding in the next two fiscal years. The original Senate bill called for doubling the magnetic fusion budget within seven years, with no short-term or long-term guidelines for funding. At the Senate committee mark-up session Senator Tsongas explained that he did not include any funding for fiscal year 1981, which begins Oct. 1, because the budget has already been set by both Houses at a level of $396 million.

The committee staff did make a change, however, reflecting the concerns of Congressman McCormack and the fusion community, by adding to the proposed bill "a 25 percent increase in funding in each of fiscal years 1982 and 1983." This would mean an additional $100 million increase in fiscal year 1982 and $100 million or more the following year—increases that will allow serious engineering, design, site selection, and construction to begin on the next-step engineering test device in the early 1980s.

Senator Tsongas told committee members that these funding guidelines had been informally supported by the executive Office of Management and Budget, although the administration as yet has not taken a formal position on fusion upgrading.

(Sources in the fusion community report in fact that the Office of Management and Budget has indicated to the DOE that it will go along with a $100 million increase in fiscal year 1982, bringing the budget close to the $.5 billion mark.)

The third amendment was strongly requested by the fusion scientists present at informal hearings on the bill Aug. 5. The original bill required each fusion laboratory director to set up an advisory committee composed of industry, university, and scientific representatives. The general feeling was that this mandatory proviso might undermine the centralized leadership required to move fusion from the laboratory to commercial development.

Although the amendment offered by Senator Tsongas toned down the advisory committee recommendation, Senator Henry Bellmon (R-Okla.) objected. "They [the advisory committees] will complicate research efforts that are proceeding satisfactorily," he said. Bellmon suggested that the notion be stricken from the bill entirely so the legislation "doesn't shackle the brilliant scientists."

The compromise reached substituted the word "may" for "shall," leaving the matter to the discretion of the DOE secretary and the fusion program management.

Other changes included the request for a triennial review of the fusion program by the DOE's Energy Research Advisory Board, rather than an annual review, and a request that within one year, rather than two, the DOE submit a report to the president and Congress with recommendations for increased support for education in engineering and science.

Senator Tsongas made it clear that the Senate bill, which now has more than 20 cosponsors, has bipartisan support. As Energy Committee minority staff head Chuck Trabant put it, "the minority members fully support the bill with its amendments."

The senators present at the committee mark-up were John Melcher (D-Mont.), Dale Bumpers (D-Ark.), Spark Matsunaga (D-Hawaii), Ted Stevens (R-Alaska), James McClure (R-Id.), Henry Bellmon (R-Okla.), Pete Domenici (R-N.M.), Mark Hatfield (R-Ore.), and Malcolm Wallop (R-Wy.).

The administration is still weighing its response to the DOE's Buchsbaum Report on fusion, whose recommendations are in line with the legislative initiatives (see *Fusion,* Oct. 1980, p. 48). With or without a separate executive response to the Buchsbaum report, it appears assured that by the end of this legislative session the nation will have a fusion program that will commit the resources to answer the scientific and technological questions in magnetic fusion so an array of possible technologies to produce and use fusion energy will be available at the beginning of the next century.

Nat'l Press Ignore Fusion Bill

The McCormack fusion bill was termed "historic" by its sponsors and passed the House by a landslide vote, yet the nation's media for the most part ignored it. Although a story was carried on the major news wires and the Fusion Energy Foundation released a full packet of press information nationally, the press chose not to report this potential solution to the nation's energy problems.

The *Washington Post,* which had covered the Buchsbaum Report on its front page, to this date has not reported on the House bill's passage. The *New York Times* ran a factual wire story in the "Science Times" supplement, but then featured a lengthy letter to the editor attacking the bill as a "boondoggle" for scientists and fusion as "unfeasible."

The best coverage occurred in the local and regional newspapers, some of which are excerpted below. The

Senator Howard Baker:

'Time to Move Forward Aggressively'

Fusion Energy Foundation executive director Dr. Morris Levitt sent telegrams of congratulations to Congressman McCormack and other House sponsors after the passage of the fusion bill Aug. 25. Telegrams of encouragement were also sent to key Senate sponsors of the Tsongas fusion bill. Here are excerpts from a letter sent by Senator Howard Baker (R-Tenn.) in reply to the FEF telegram.

Thank you for your recent message. I certainly appreciate hearing from you.

The promotion of fusion energy has long been of interest to me. I have closely followed the recent promising results obtained from the various experimental centers throughout the country. The ELMO Bumpy Torus project in Oak Ridge has, of course, been of special interest to me, and is in my view characteristic of the creative diversity so essential to the fusion energy program.

Taken collectively, the results at these major fusion research centers support the conclusion that the time has come to move forward aggressively toward the engineering phase of the magnetic confinement fusion program. On December 6 of last year, I wrote the Ranking Minority Members of the House Committee on Science and Technology and the Senate Energy and Natural Resources Committee asking that they take steps to expedite legislation to develop a demonstration magnetic fusion power plant by the end of the century.

The House has passed HR 6308, which would encourage development of fusion energy research and demonstration in a time frame similar to that which I have advocated. In addition, S. 2926, a bill which is consistent with my recommendations, has been introduced in the Senate. I have cosponsored this bill and am working to ensure its passage by the Senate.

only television coverage to come to *Fusion*'s attention was an editorial Sept. 3 on the New York station WPIX, which encouraged the Senate to follow the House's lead on fusion.

WPIX editorialized: "We speak so often of bad news in the energy field that it is especially satisfying to be able to compliment the House of Representatives on an important and constructive piece of legislation. Last week, with very little notice or fanfare, the House approved a $20 billion commitment for the development of nuclear fusion over the next 20 years."

Other notable coverage was an editorial and news article in the *Seattle Times* and a feature story in the *Los Angeles Times*. In Congressman McCormack's area in Washington state, there was good local coverage, including a letter to the editor written by FEF representative Mark Calney that congratulated McCormack for his work in steering the bill through Congress.

FEF executive director Dr. Morris Levitt has urged *Fusion* readers to let their press and media know that they want fusion news to be covered.

Excerpts from the Press

The News American, Baltimore, Md., Aug. 26
"House Votes to Speed Nuclear Fusion Research"

The House, lured by the promise of a virtually limitless energy source, has voted to commit $20 billion to the effort to harness nuclear fusion by the end of this century.

St. Croix Avis, St. Croix, Virgin Islands, Aug. 28
"Nuclear Fusion Bill Goes to Senate"

Legislation is moving through Congress that might speed up the nation's development of nuclear fusion, potentially a large source of power. The bill is on its way to the Senate after approval in the House.

Knoxville Journal, Knoxville, Tenn., Aug. 30
"More 'Magic' "

Taking a cue from the White House, Congress has embarked on its own dreamland quest for a solution to the nation's continuing energy deficiency.

Oak Ridger, Oak Ridge, Tenn., Aug. 26
"Big House Majority Favors Fusion Speedup"

. . . While the total cost of developing fusion was estimated in the bill at $20 billion over the next 20 years, Rep. McCormack said this was reasonable, considering that the United States will spend $90 billion this year alone on imported oil.

Minneapolis Star, Minneapolis, Minn., Aug. 27
(in a *Los Angeles Times* syndicated story)
"U.S. Eyes Big Push for Fusion"

With virtually no public debate and little public attention, the United States is about to embark on a multibillion-dollar effort to convert the theory of atomic fusion into a technology for generating electricity. . . . While three decades of fusion research have failed to produce a single controlled fusion reaction, experimental successes in the past two years have led scientists to conclude that it is possible in the next two or three years.

Inside DOE

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solve their energy problems in their own backyards." Two examples will do.

First, the DOE proudly announced that students at Phillips High School in Wisconsin are selling apples and T-shirts to raise money to construct an experimental, wind-powered, electrical generating system for the local community.

As DOE program director Ann Hegnauer stated in a press release, "You start with a concept that is small in scale, simple to build and operate, and low in cost. . . . Then you employ local labor, materials, and skills and use renewable resources to respond to a community's needs."

Will the 3-kilowatt wind generator provide enough power even for the high school? Not really, and since it will only produce power when there is a strong enough wind, this "appropriate technology" can be used only if hooked up to the centralized power grid of the Lake Superior District Power Company!

Dust Bowl Power?

In a second case, the department proposes to produce energy by fostering dust bowls. This particular "appropriate technology" program will produce burnable biomass from Arizona tumbleweed. The advantage of this program, according to coordinators from the University of Arizona, is that 50 acres of farmland no longer suitable for cultivation because of dropping water tables will provide the tumbleweed.

It would seem that as one administration policy drives 2,000 farmers a week out of business, another administration policy makes sure that their land is never again arable.

The DOE advises that all those interested in applying for appropriate technology grants write to: Appropriate Technology, Department of Energy, 150 Causeway Street, Boston, Mass. 02114. We hope *Fusion* readers have some appropriate comments to forward to the DOE.

SCIENTIFIC AMERICAN GOES MAOIST?

For several years *Scientific American* has taken a middle-of-the-road position on many key issues in American science, such as the development of nuclear power. However, with its September 1980 special issue on economic development, the magazine has thrown its prestige behind the Club of Rome's program for dismantling science and technology in the advanced sector and exporting the Chinese economic model to the developing sector.

That the editorial intention of this special issue was to promote "redistribution-of-wealth" proposals and labor-intensive agriculture was made clear by publisher Gerald Piel in an interview on New York's radio station WQXR about the issue. Piel praised China and Tanzania, where the Chinese model is practiced, as alternatives to industrial methods of development.

This review will take up the two leading articles in the special issue of *Scientific American* that coincide with the antiscience aims laid out by Piel. A later review will analyze some of the specific proposals for Third World development and energy contained in other articles.

This issue of *Scientific American* is an intervention at a critical point in time. The series of articles on Third World development was intended as a contribution to the debate over international development strategy at the upcoming Special Session of the United Nations General Assembly. The introductory article was written by K.K.S. Dadzie, who has been director general for development and international cooperation for the United Nations since 1978. Dadzie is a Ghanian who was trained in economics at Cambridge University.

The unscientific and specifically Malthusian methodology that underlies the issue is established at the onset. Dadzie argues that Third World development can proceed only by redressing the "asymmetrical" relations that exist between developing and developed nations—that is, redistributing economic resources—and by allowing Third World nations, hitherto forced to orient to the world market, to establish more "organic" and "indigenous" economies.

This Malthusian bias is even more explicit in the final article in the series by economist Wassily W. Leontief. Here Leontief uses his fundamentally flawed input-output model of the world economy to prove that there must be a trade-off between advanced and developing sector prosperity. The model, however, is simply a static description of existing economic relationships, which is a far cry from analyzing the use of capital and technology to bring about economic growth and development, which alters all the relationships.

Both Dadzie and Leontief propose to *redistribute existing wealth*, instead of expanding wealth in both developed and developing sectors by scientific and technological advance. And since science cannot thrive without economic growth, they are proposing to end science as well.

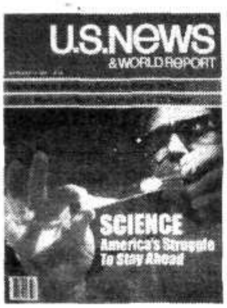
In actual fact, Third World development can take place only under conditions in which the advanced sector is generating an increasing reinvestable surplus through high rates of capital formation and rising living standards; and Third World development will provide the necessary stimulus for the realization of technological advances in the developed economies.

All the rhetoric Dadzie expends about the Third World's unequal access to technology turns out to be just that. Toward the end of his article, he lapses into references to "ill-considered uses of technology" and "imprudent recourse to technological inputs" in advanced-sector agriculture.

What model of economic self-sufficiency and self-determination does Dadzie hold up uncritically for the Third World to adopt? It is the labor-intensive Chinese economy, which has never recovered the production levels achieved before Mao Tse-tung imposed "self-sufficient," commune-based agriculture on the country during the Great Leap Forward, and where scientists and other educated individuals were paraded around in dunce caps during the Cultural Revolution.

—*Lydia Schulman*

* * *



PROMOTING FEAR OF SCIENCE

In a special section on "Science: America's Struggle to Stay Ahead," the Sept. 15 issue of *U.S. News & World Report* laments the decline of U.S. leadership in science. But after admitting that "Much of the nation's uneven economic record during the past decade stems largely from the decline in research and development," the report then attempts to demonstrate that this decline is caused by well-founded fears of the risks involved in technological society:

"Technological failures like that at the Three Mile Island nuclear plant and the fall of Skylab have created doubts in the public mind that science offers the seemingly unlimited promise for the future it once did."

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Fear of Science

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The argument that cost analysis must control basic medical decisions is presented in an article, "Is Modern Medicine Worth Its Price?" "Many health officials have concluded that the power of medicine to treat has outstripped the country's ability to pay," states the author, using as an example the $1 billion a year the government pays for renal dialysis to keep only 50,000 Americans alive.

As anyone who has had a loved one saved by modern medicine understands, this very method of balancing *numbers* of people against *numbers* of dollars is a hideous attack on human values. Furthermore, it ignores the fact that a healthy and productive workforce, maintained by high-technology medical care, more than "pays" for itself. This article ends by putting forward the "death with dignity" philosophy as the alternative to extending high-technology medical care to all.

Genetic engineering, high-technology inventions for consumers, and space exploration are presented in a science-fantasy fashion by other articles in the package. However, there is the constant declaimer that "critics see such efforts as a dangerous tampering with nature's processes." Overall, the report states that science has declined because the majority of people now fear high technology, with good reason.

The only realistic note comes in an interview with Philip Handler, president of the National Academy of Sciences. Handler attributes the attack on science to a small, vocal minority and insists that ". . . most Americans still trust science and continue to believe—as do I—that science and technology have done far more good than harm, and can continue to do so."

Although America is still the leader in science and produces one-third of the world's new scientific ideas and products, Handler noted, we produced three-fourths of this output in the 1950s. Compared with the Soviet Union, Handler said that although the United States is still ahead, the Soviets are increasing support for science while we are sliding downhill.

In reply to a naive question on whether scientists can assure the public that all major scientific ventures will be safe, Handler replied:

"Safe? The world has never been safe. But it is getting safer. . . . We are hyperconcerned about risk as no previous societies have been. Previous societies have not had the luxury of worrying about risk. They had to worry about survival, not risk. There will be no advances without risks.

"Consider nuclear energy. It is, so far, the safest major technology ever introduced into the United States. There's nothing comparable. . . . Nobody was injured at Three Mile Island. . . . If we deny ourselves nuclear energy, we are heading for real catastrophe down the road. . . . I suggest that that would be a much greater catastrophe than the kind the critics are talking about."

* * *

A. Keler/Sygma

Giraud: "We do not accept the law of minority."

NUCLEAR POWER AND DEMOCRACY

Ben Wattenberg's 1980, *one of the few protechnology series to be found on American television, presented an informative program in August on France's ambitious policy for nuclear energy development. The program was produced by PBS station WETA-TV 26 of Washington, D.C. with grants from the Dow Chemical Company, Conoco, Inc., and the LTV Corporation. Here are excerpts from Wattenberg's interviews with French government officials.*

French Reaction to TMI

Andre Giraud, minister of industry: Well, first, we thought that we had to be very careful in studying what it meant and not to think that anything similar would be impossible in our country.

Wattenberg: In fact, after Three Mile Island, is it correct that France actually accelerated its nuclear program?

Giraud: By the way, that's the case, yes. Because the oil crisis was developing at the same time and again we didn't see anything significant in the incident, and I wouldn't say accident, that occurred in Three Mile Island.

Michel Hug, of EDF, the nationalized utility: Well, what I say is that if you need a certain amount of energy and you may produce it by several means, one is in a nuclear plant. Other means involve, for instance, a coal plant; and people who have looked into the danger of both ways of producing energy state that a coal plant, as far as the waste problem and the danger that the public is exposed to, is at least several times more dangerous than a nuclear plant.

Opponents of French Nuclear Policy

Giraud: What we do not accept is the idea that an objection from one person or just a small number of persons would go against the opinion of the majority of citizens that are concerned by it. We do not accept the law of minority—that's a democracy.

It's not only because a few people are just yelling in the street that we accept that. We have a parliament to make the decisions. The law is determined in parliament, not in the streets.

Wattenberg: So, the case you would make is that in this instance, France is, in fact, more democratic than the United States by not allowing . . .

Giraud: I'm not making a comparison. I'm trusting that our country is a democracy.

Deindustrialization

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an interview with *Fusion,* Warren G. White, assistant to Governor Herschler of Wyoming and former natural resources coordinator for Nebraska, said that synfuels development "can pose a very significant conflict" for the state. A synthetic fuels plant requires about 30,000 acre-feet of water per year, or about the same amount of water as 10,000 to 15,000 acres of irrigated agricultural land. In a state like Wyoming, which gets only 12 to 16 inches of precipitation a year, each synfuels plant constructed will take 10,000 to 15,000 acres of agricultural land out of production.

Large-scale development of coal gasification is planned for the Powder River Basin by Atlantic Richfield (ARCO), the major leaseholder in the area. Coal gasification is potentially the most profitable of the synfuels, because it is cheaper to ship gas than liquid or solid fuels; it also has the highest water requirements. The Wyoming area of the Powder River Basin alone has a reserve base of 53 billion tons of recoverable coal.

The 'Sunset' Industries

The stated purpose of the Economic Revitalization Board created Aug. 28 is to help the "sunset" industries modernize and to stimulate investment in "sunrise" industries like computer technology and communications. However, congressional sources indicate that the main work of the ERB's tripartite board—led by Commerce Secretary Philip Klutznick, Dupont chairman and corporate leader Irving Shapiro, and AFL-CIO president Lane Kirkland—will be in securing labor-management agreement on cutting back capacity and holding down wages in the sunset industries.

In an unpublished report dated Aug. 4, the subcommittee on industrial policy of the Senate Democratic taskforce on the economy stated: "There is little justification, if any, for the bailout of industrial losers. The process of disinvestment, or freeing of resources tied up in low productivity industries, is essential for economic growth." The report, which was leaked to the *New York Times* in late August, even challenged the report on the steel industry released by the Office of Technology Assessment last June, which advocated a minimal modernization program for the U. S. steel industry.

An aide to Sen. Adlai Stevenson (D-Ill.), who heads up the industrial policy subcommittee and has sponsored a bill for fostering "technological innovation," told *Fusion* that Stevenson categorically opposes supporting "the geriatric industries."

Information culled from a variety of congressional and industry sources converged on these scenarios for the nation's steel and auto industries:

Steel. In the absence of major tax breaks and a protectionist policy against imports, the steel industry will reduce its capacity from the current 150 million annual tons down to 120 million tons by 1988. The resulting shortage in domestic steel-making capability will have to be alleviated by expanded imports, especially from Brazil, South Korea, and other of the so-called Newly Industrializing Countries.

Auto. The auto-making capacity of Chrysler and Ford will be cut in half over the next decade. As a result of the stringent conditions attached to the $1.5 billion federal loan guarantee package awarded earlier this year, Chrysler has been forced to reduce its capacity from 3 to 4 million autos per year down to 1.5 to 2 million. Ford's production capacity will be scaled down from around 5 million cars to 2.5 million. This means that 300,000 out of 900,000 autoworkers will be permanently laid off before the end of the decade, and another 300,000 out of 900,000 workers in the auto supply industries will be eliminated.

Deregulation

In his Aug. 28 policy speech, President Carter cited the deregulation of trucking, airlines, rail, banking, and communications as "the most fundamental restructuring of the relationship between industry and government since the New Deal."

The restructuring has indeed been dramatic but in ways that the president was not anxious to emphasize. Airline deregulation left the major carriers with shattered profits and a combination of mergers and liquidations in the offing, and resulted in pared down routes and dangerous cutbacks in standard maintenance procedures. Trucking deregulation has claimed a half-dozen major common carriers and will disrupt service to rural areas formerly protected by the now abandoned route authorization system.

The railroad deregulation bill sponsored by Rep. James Florio (D-N.J.), which passed the House 337 to 20 Sept. 9, will have a similar impact on the railroads and rail service. The bill gives the railroads flexibility on setting rates and abandoning routes that are deemed unprofitable.

Questioned about the impact of the bill, one industry analyst predicted an accelerated abandonment of branch lines, especially in the farm belts: "This could be traumatic for some little farm towns in Iowa, but it will be good from the macro point of view. It will free up financial resources for other investment."

The major anticipated growth area is coal freight. Coal freight has jumped from around 400 million net tons in the early 1970s to 473.7 million net tons in 1979, because of the enormous escalation of petroleum prices since the 1973 Mideast war. As of 1979, coal tonnage comprised 32.3 percent of the railroads' tonnage, from a level of 26.9 percent in 1970.

The further growth of coal freight—to the detriment of agricultural and other types of freight—and major investment in new track needed to open up the Western coal industry for domestic use and export has been held back by one thing: lack of "rate flexibility." The deregulation of rates is now expected to spur a railroad boom linked to coal development.

Science and Law

Continued from page 28

preme Court had ruled against giving Chakrabarty his patent, the decision would have been an incalculable setback for future scientific work on the synthesis of insulin, nitrogen-fixing bacteria, interferon, and other synthetically produced life forms the development of which is crucial for the enhancement of life.

A Partial Victory

The victory, however, was only partial. The Supreme Court decision was 4 to 5, with the Court's liberal block acceding to the antiscience arguments. The conservative block, on the other hand, took a self-effacing position and proceeded from merely a traditionalist defense of existing law:

"We are without competence to entertain these arguments—either to brush them aside as fantasies generated by fear of the unknown, or to act upon them," the majority opinion stated.

The irony here is that in drafting

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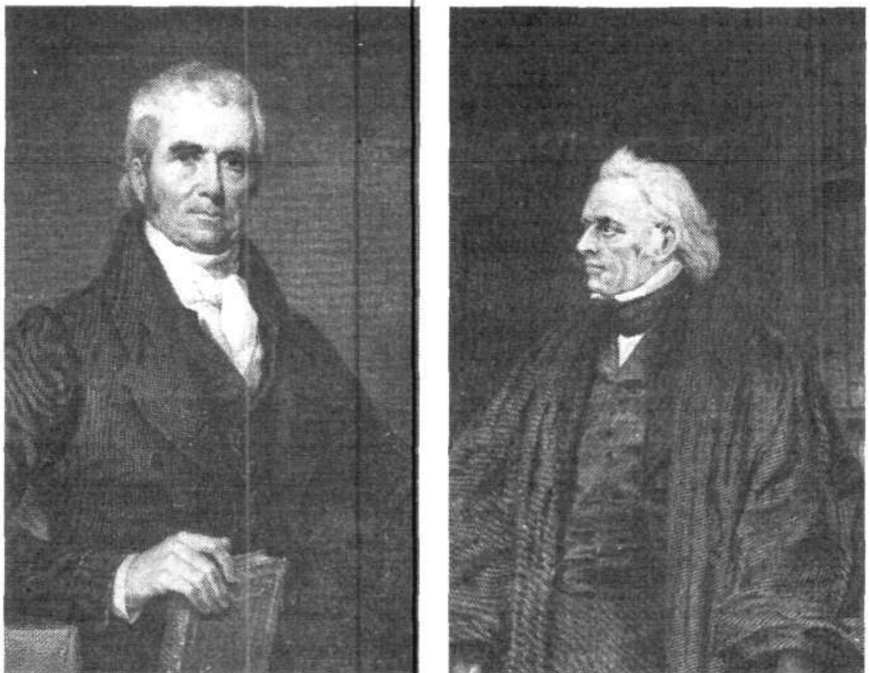
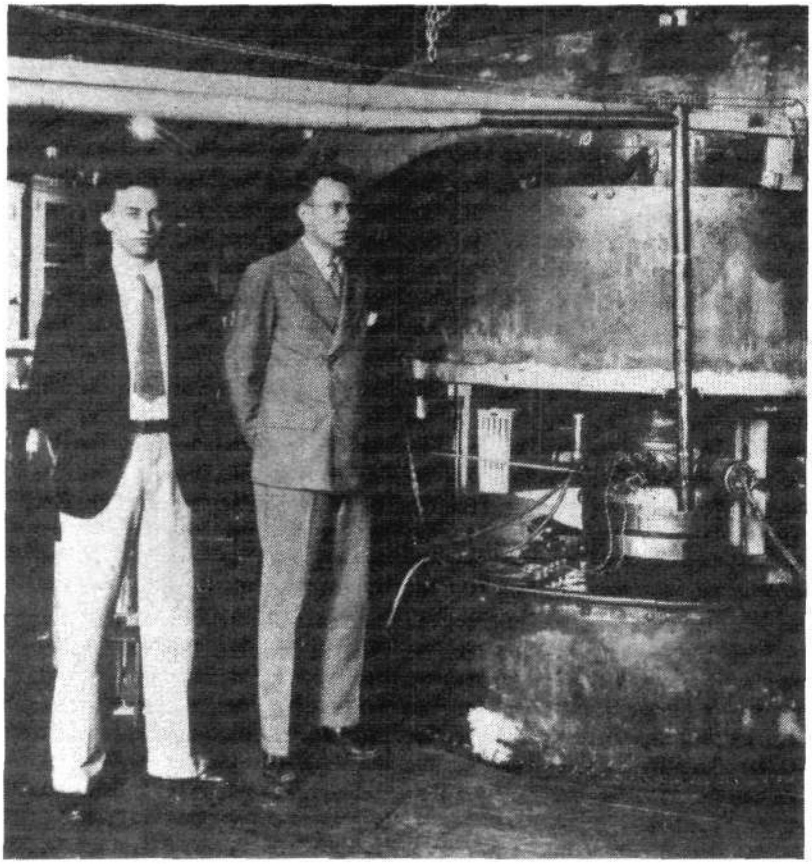


The Constitution, as the founders of the republic understood it, was the working approximation of the universal law by which all particular laws had to be measured. Here, Chief Justice John Marshall (left) in an engraving of a painting by Henry Imman. At right, Justice Joseph Story in an engraving of a painting by Chappel.



Golden Anniversary of Particle Accelerator

A celebration to mark the 50th anniversary of the development of the high-energy physics particle accelerator was hosted in Washington, D.C. July 22 by Congressman Mike McCormack (D-Wash.).

Attending the affair to honor what McCormack described as "outstanding accomplishments for all mankind" were members of the House Committee on Science and Technology, the directors of major accelerator programs here and around the world, and a number of particle accelerator pioneers. The event took place at the Smithsonian Institution's Museum of History and Technology, which opened an exhibit on accelerators, "Atom Smashers: Fifty Years," last December.

Among the guests was Dr. Stanley Livingston, shown in the 1930 photograph above with Dr. Ernest Lawrence beside the magnet built by the Federal Telegraph Company that they used as a cyclotron magnet.

The introduction of particle accelerators in the 1930s permitted physicists to create beams of atomic particles with uniform energy all moving in the same direction. These beams were used to bombard other particles in a continuation of the nuclear experiments that had begun using naturally radioactive materials like radium.

In addition to the discovery of subatomic particles, accelerator research has led to the understanding of phenomena required to build nuclear reactors and the production of radioactive compounds used in the treatment of cancer.

Science and Law

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the Patent Act and the relevant sections of the Constitution, the Founding Fathers were guided by a conception of *natural law*. In brief, this principle of law maintains that if the universe is governed by discoverable laws rather than random effects, and *if human life and society are the product of these laws*, it follows that the laws by which humans govern their society must be coherent with universal law or be invalid in an essential way.

This is the proper concept of natural law. These same words are more often used to proclaim the existence of a certain irreducible area of anarchy that should be free from law; but the United States, of all the countries of this world, was the one most explicitly founded on the former, proper conception.

The Constitution, as the founders of the republic understood it, was the *working approximation of the universal law* by which all particular laws had to be measured. As Chief Justice John Marshall put it "It is a *Constitution* that we are interpreting"—an attempt to formulate for practical use the means by which a republic must orient its laws to be in agreement with the universal laws of science.

In making the "right" decision for reasons that reflect an abandonment of that understanding, the present court denigrates the Constitution, treating it as no more than a sort of start-up law code. This case-by-case blindness leaves the nation prey to opponents of universal law in science—progress—who plan to "impose on us this restraint [on domestic manufacture] as a badge of dependence and a sacrifice of sovereignty," to use the words of Justice Joseph Story.

Whether that assault is carried on by siege (as with nuclear power) or by scare tactics (as with Chakrabarty's invention), the real target is the American dedication to the improvement of the laws of nature.

—*David S. Heller*

The Georgetown Version of 'Controlled' Fusion

The scientific ethic and the notion of progress espoused by the nation's scientific community is in direct conflict with the values of society. This is the message of a recent article in the Georgetown *University Law Review* by Professor Steven Goldberg.

Although the population enjoys a euphoric enthusiasm about scientific breakthroughs, it becomes dramatically opposed to many applications or commercial developments that result from scientific research, Goldberg says.

As a solution, Goldberg's article, "Controlling Basic Research: The Case of Nuclear Fusion," calls for social control via increased oversight and review of research beginning at the basic research level. The vehicle he proposes is a committee of persons who are not prejudiced by the notion of progress, but rather are concerned with the social implications of science. Goldberg proposes going far beyond the existing assessment agencies that have already chopped research to shreds—a proposal which by its very nature would suffocate research and technology development in this country.

Ironically, Goldberg selected the U.S. nuclear fusion research program as an example of research that has proceeded with insufficient social control. The reason, he suggests, is that fusion has been shielded from public scrutiny because of its distant applications as an energy source. The momentum that has built up behind the program, Goldberg argues, will be impossible to stop at the point of commercial feasibility and will result in the probability of a socially unacceptable technology in the future.

Goldberg recommends that of the two approaches to fusion, magnetic and inertial confinement, the more socially acceptable approach may be

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Science and Law

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to promote inertial confinement because of its alleged lower radiation levels. U.S. scientists, he says, would necessarily choose the magnetic approach, regardless of the social consequences, simply because it is closer to realization.

The ludicrousness of this "insufficient social control" argument is then heightened by Goldberg's pointing out that the government's classification program is one of the main obstacles hindering faster progress in inertial fusion research.

Some Facts

It is well known that the fusion program has been one of the best managed programs in U.S. history. It has proceeded by investigating numerous research options, amid voluminous evaluations and assessments.

To understand why Goldberg might acknowledge the importance of science and its constitutional imperative yet end up with the idea that the needs of science and society are in opposition, one must look at Georgetown University.

Not only does Georgetown house every antidevelopment geopolitical figure from James Schlesinger to Henry Kissinger, but Goldberg's professed idols include C.P. Snow and Karl Popper. These are two British-intelligence-linked academics who, respectively, coined the idea of the "two cultures"—the idea that science has drifted away from the liberal arts and must be "humanized"—and the notion that progress is just a figment of someone's imagination (or what an Oxford Aristotelian who does not know how to use philosophical terms properly calls "metaphysical").

This science versus society conflict was used quite successfully to kill the U.S. space program (as documented in the Sept. 1980 issue of *Fusion*) as well as its ancillary economic and technological benefits. Is this what Georgetown has in mind for the fusion program?

—*Patricia Levitt*

Resurrecting Kleinian Mathematics

History of Mathematics, Vol. I: *The Development of Mathematics in the 19th Century*
by Felix Klein
Translated by M. Ackerman with an introduction by Robert Herman
Brookline, Mass.: Math Sci Press, 1979, $50
(first published in German in 1928 by Springer-Verlag)

I am indebted to Robert Herman for making available an English translation of the first volume of Felix Klein's *History of Mathematics.* The volume, titled *The Development of Mathematics in the 19th Century,* was translated by M. Ackerman and contains an appendix by Herman, "Kleinian Mathematics from an Advanced Standpoint."

Herman expresses his admirable purpose in the introduction to his appendix: "I am particularly interested in Klein's work that follows the Erlangen Program, since one of my main goals in this series is to resurrect the best work of 19th century differential geometry."

It is no exaggeration to say that every leading physicist in the field of hydrodynamics today has been influenced by Felix Klein's masterful defense of the Riemannian standpoint. Klein put forth his famous Erlangen Program for the unification of geometry when he was 23, in a lecture at Erlangen University where he was al-

A Valuable Primer On Nuclear Waste

A Nuclear Waste Primer
League of Women Voters Education Fund
Washington, D.C., 1980, $1.25

The League of Women Voters Education Fund, publishers of *A Nuclear Waste Primer,* should be commended for its attempt to educate people on this important issue. The *Primer* provides a thorough presentation of the historical facts, technical descriptions, and definitions and reviews the current status of the official U.S. nuclear waste program.

It also presents what other nations are doing about nuclear waste—programs very different from those being proposed for the United States.

Anyone reading the pamphlet will understand what nuclear waste and radiation are, where waste comes from, what the current administration is planning to do with it, and what the alternatives are.

However, it's important to note that the booklet does not give the full story on the waste issue and therefore could be quite misleading if used as the sole source of information. The single, most important issue left unaddressed is the question of fuel reprocessing and its effect on the nuclear fuel cycle and waste. The *Primer*

AIP Niels Bohr Library, Lande Collection

Felix Klein

ready a full professor. Most of Klein's life, however, was spent at Göttingen University, the home of Gauss and Riemann before him, where he took over direction of mathematical physics.

In the early period of his life Klein showed great promise as a mathematician with significant original contributions in the field of autonomic functions. After suffering a breakdown in 1885, he reorganized his professional life to concentrate on what became his major mission—education. Klein did not confine himself merely to establishing a top faculty at Göttingen University or to establishing the hegemony of Riemannian mathematical physics (which included the spirited defense of Georg Cantor). He also took on the task of reorganizing the whole of German school mathematics in order to introduce a high conceptual level from the earliest grades.

But Klein's new math, unlike that of the evil Bertrand Russell, was based upon a thoroughly geometric-construction approach that emphasized the unification of geometry and algebra. It is an effort like Klein's that is urgently needed today in order to sharply reverse the present trend toward miseducation and diseducation.

The *History* was never actually completed by Klein. It was published posthumously from notes by two of his students. Perhaps, therefore, it was not Klein's own intention in this volume to offer high praise to the British science tradition. Nonetheless, as it now stands the work gives undue credibility to the claims of James Clerk Maxwell for himself and on behalf of Michael Faraday, whose independent discoveries are completely overshadowed by any unbiased consideration of the work of the great Gauss and his collaborator Weber, as well as the work of the French school of specialists in electricity.

Aside from this, the book is a fascinating account of the history of mathematics. Beginning with Gauss's discoveries, the volume concludes with Klein's own contributions to the theory of groups. Of value to the layman and advanced mathematician as well, this is a book that should receive wide circulation. It is to be hoped that Volume II of Klein's *History* will quickly follow.

—*Carol White*

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dismisses this question in one paragraph by stating that "while it is true that recycling spent fuel does extend fuel resources, some experts question the desirability of making reprocessing a basic part of waste management."

The Reprocessing Question

The *Primer* then goes on to support the position that reprocessing is not important to waste management—a position that the Carter administration has been advocating since it came into office and one that is based entirely on a political, not scientific issue.

In fact, dismissing reprocessing (as well as the breeder) reflects the political view that nuclear power should be limited as an energy source, that the present nuclear plants should be allowed to run their course for the next couple of decades, but that the nation will need no more nuclear plants and therefore no more fuel. (This, by the way, is the content of the Democratic Party's platform statement on nuclear energy.)

Prior to President Carter's election, waste management and fuel reprocessing were considered interrelated, and reprocessing was an integral part of the U.S. waste program. This is the case for other nations, except Canada, which has vast supplies of uranium and builds a reactor, the CANDU, that operates on natural rather than enriched uranium, and therefore does not require reprocessing.

The reason for reprocessing is simple. Ninety-six percent of the material in spent fuel can be recycled back into new fuel; only 4 percent of the spent fuel is actual waste material that has to be disposed of. For an administration whose primary energy policy is conservation and efficiency, throwing away such a valuable resource makes no sense at all.

The policy of the nuclear industry since the beginning of nuclear power has been to separate the waste from the reusable fuel by reprocessing, and then to treat the waste separately by solidifying it and permanently burying it.

Furthermore, the fast breeder reactor depends for its fuel supply during the initial start-up phase on the reprocessing of spent fuel from current light water reactors.

Alternative Waste Plans

One alternative to the Carter waste policy was introduced into the House of Representatives by Congressman Barry Goldwater, Jr. in June. The bill would move up the timetable of waste depository operation to 1986-1987 compared to the administration's program of a 1997-2006 start-up date (see *Fusion*, Aug. 1980, p. 49). The proposed legislation also calls for immediate site selection and the implementation of construction—two basic requirements to meet the conditions of various state moratoria on nuclear power. Certainly this alternative program should have been mentioned in the *Primer*.

The *Primer* can be obtained for a donation of $1.25 from the League of Women Voters, 1730 M Street NW, Washington, D.C. 20036.

—*Jon Gilbertson*

Magnetized Targets

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imizes the power density required for ignition.

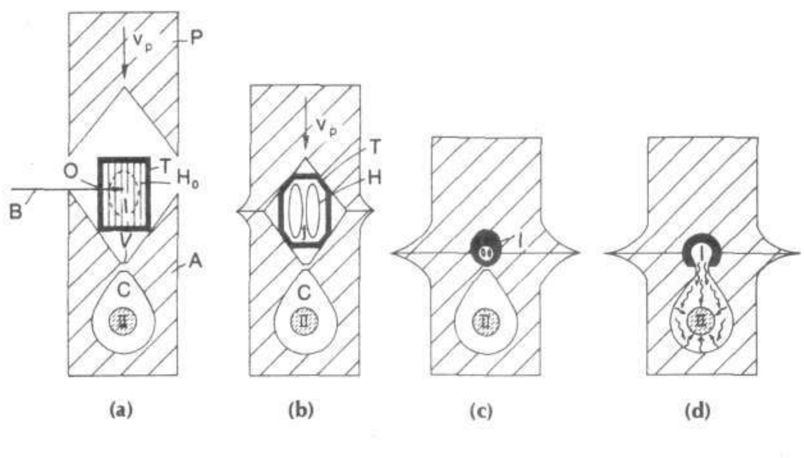
For example, conventional non-magnetized inertial confinement requires power levels of several hundred trillion watts in the laser or particle beams that drive the implosion. This could be decreased by almost two orders of magnitude using the Winterberg proposal.

The figure illustrates the Winterberg concept: In part (a) a laser or electron beam B initiates a low-density magnetized pinch plasma H_0. Simultaneously, a projectile P traveling at a velocity v_p between 20 and 40 km/sec collides with the chamber T containing the low-density pinch plasma.

As shown in part (b), the implosion of the chamber caused by the impact of the projectile compresses the magnetized plasma to higher densities. The interaction between the plasma and the imploding wall of the chamber leads to induced currents in the wall, which causes the pinch magnetic field to close (c). Thus a closed magnetic configuration is generated, providing the most efficient compression and heating of the trapped plasma to fusion temperatures and densities.

The burst of fusion energy generated in this way now burns a hole through the wall of the chamber as shown in part (d). Most of this fusion energy will become soft X-ray radiation, generated through the interaction of the thermonuclear plasma and the chamber wall. Soft X-rays are ideal for driving high-gain conventional inertial-confinement targets, as pointed out by the Soviet fusion scientist L. Rudakov. The soft X-rays pass through the burned-out portion of the wall, or "window," to a second chamber cavity C containing a conventional target II, which is then imploded by the soft X-rays.

The method thus uses a low-power driver to produce high yields of energy from the conventional target in this staged use of magnetized targets.



TWO-STAGE MAGNETIC BOOSTER IMPACT FUSION TARGET

Parts (a), (b), (c), and (d) show the configuration and sequence of events occurring in the two-stage magnetic booster impact fusion target. I is the booster target of magnetized plasma, which is separated from the high-yield target II by a wall. P is the incoming low-power projectile, moving at velocity v_p, which impacts on the booster target chamber T, containing the initial magnetic field H_0. O is the opening that lets the laser, charged-particle, or projectile beam enter T. V is the conical vertex position, A the anvil, and B is the beam that creates the low-density magnetized target plasma. The projectile implodes the chamber, compressing the magnetized target in (a) and (b). Soft X-rays created from the wall-plasma interaction in (c) pass through the hole now burned in the wall between I and II, imploding the conventional target in (d).

Rochester Laser Lab Signs $39 Million Contract with DOE

The University of Rochester Laboratory for Laser Energetics (LLE) signed a $39.2 million contract with the Department of Energy Sept. 15 for research in laser fusion. The money will be used to expand their work in laser fusion using the 24-beam, 12-TW Omega system, as well as increase use of the National Users Facility, which is the only laser research facility open to use by academic and industrial scientists.

An additional $4.7 million beyond the $39 million is expected from DOE for the users facility alone.

"The contract recognizes the laboratory's contributions to the science of laser fusion and clearly establishes Rochester as a major participant in the national fusion program," commented Dr. Moshe J. Lubin, director of the Laboratory for Laser Energetics.

The annual operating budget of about $12 million will allow LLE to continue its groundbreaking work on developing commercial laser fusion target pellets and converting laser light to efficient, shorter wavelengths. Crucial laser-matter interaction studies can be made with these converted short-wavelength beams, which should enhance the coupling of the laser beam energy to the fusion target pellet.

Under the contract, which runs to Sept. 1984, particular emphasis will be placed on experiments at the 50 to 100 million degree temperatures leading to thermonuclear energy release and on the development of new techniques and instruments to measure thermonuclear events that occur in less than billionths of a second.

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Letters

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In nuclear fusion, what breakthroughs do we expect in the next 10 years?

Joseph Rogozinski
Mineola, N.Y.

The Editor Replies

Although we could certainly develop a fusion rocket by the 1990s if we now had a program to get it done, the United States won't have one by the 1990s because we're not doing it.

There was a project in the 1960s called Orion to build a fusion-propelled lunar shuttle. It was being done largely by the military with some input from NASA. But there was an argument over the project and it was canceled in 1965. Orion used nuclear warheads for propulsion and was designed to reach the moon in 24 hours. See *Fusion*, Oct. 1980 for a description of fusion-propelled spaceships.

We should have a lunar base by the first decade of the 21st century, with a fusion rocket like Orion to serve as a shuttle supply ship.

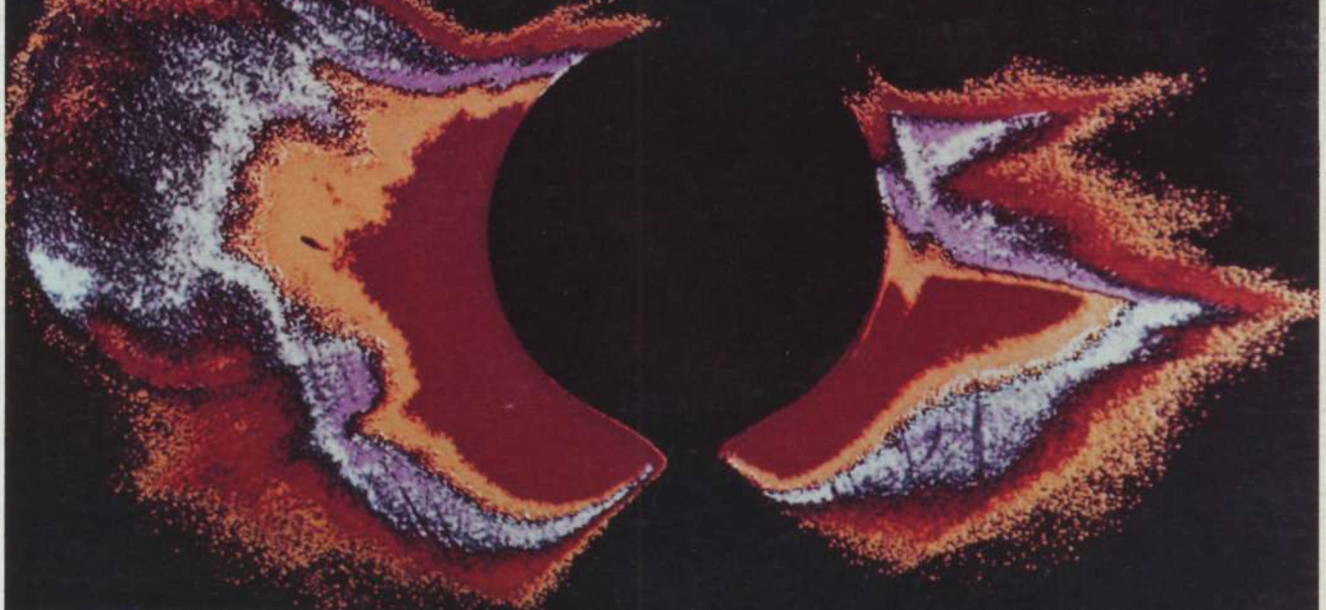
As for breakthroughs expected in nuclear fusion in the next 10 years, we expect them in two major areas of fusion work: magnetic and inertial fusion. In magnetic fusion, we expect a demonstration of actual energy generation through various magnetic confinement schemes, including the tokamak, the tandem mirror machine, the stellarator, and various compact combinations of these systems called "tori" and "spheromacs."

In the area of inertial confinement, we fully expect that combined types of inertial fusion will demonstrate ignition and burn and that there will be novel inventions for high gains.

As for a manned mission to Mars before the year 2000, this is possible only if we revive the Nerva program, which was canceled in 1969. Nerva called for a "grand tour of the outer planets," using fission rockets. That's a bottom-line necessity for a Mars program. We could build such fission rockets right now with existing technology.

Charles B. Stevens
Fusion Technology Editor

In This Issue



THE SPACE PROGRAM AND FUSION— PARTNERS IN PROGRESS

The breakthroughs in fusion research over the past decade that have brought the nation so close to tapping this unlimited source of energy go hand in hand with the successes of the U.S. space program. The NASA program has made a tremendous contribution to our knowledge of how the universe works. It is only through NASA satellite observatories, for example, that we have made basic scientific advances in understanding the magnetic structure of the Sun and the formation of stars—advances that directly relate to the laboratory study of plasma physics and fusion.

ANNOUNCING THE YOUNG SCIENTIST

The Fusion Energy Foundation is proud to announce the publication of a new magazine for children 10 to 14 years old that is dedicated to science and progress. *The Young Scientist* will be published bimonthly during the school year, and the premier issue has been mailed to each *Fusion* subscriber as a holiday bonus. *The Young Scientist* includes news and features on today's scientific frontiers, the latest in fusion power development, physics, and biophysics, crucial experiments, great inventions, photographic tours of scientific and industrial facilities, interviews with today's leading scientists, stories from yesterday's scientists, and puzzles and games that challenge children to re-create the breakthroughs in mathematics and theoretical science.

Subscriptions are $8 for 5 issues, with special group rates.

The cover: Front cover photograph of a solar flare, courtesy of NASA. Above, NASA's Skylab space observatory (left); a computer-colored photograph of the Sun's corona, courtesy of NASA; and the Tandem Mirror Experiment (right), courtesy of Lawrence Livermore National Laboratory. Below, a scene from *The Young Scientist* "On Tour" feature, photograph courtesy of the Alabama Space and Rocket Center.