FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION
January 1981
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Fusion Extra
McCormack Fusion Bill Signed into Law

NASA's Boost to the Economy

An Apollo Fusion Program Can Top It

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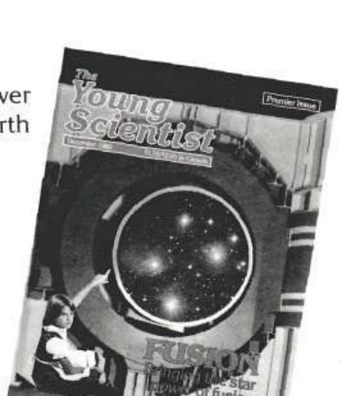

- The tokamak: bringing the star power of fusion down to earth
- A tour through the Alabama Space and Rocket Center
- Experiments with magnetic fields and moving charges
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- An interview with Dr. Stephen Dean —how a fusion scientist got his start as a young man

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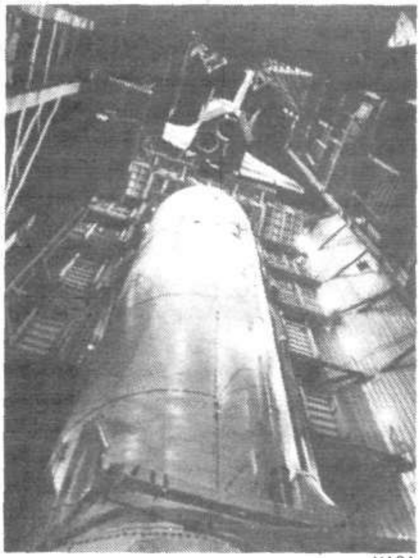


NASA

The space program: from technology spinoffs to advanced education an incalculable payback. See page 29.

Features

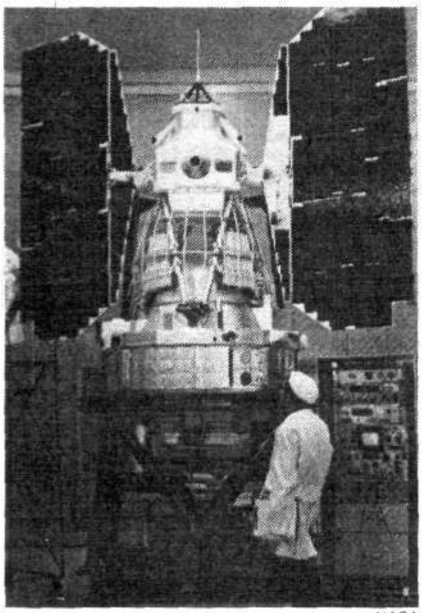
Carlos de Hoyos

With a new law mandating construction of a fusion engineering device by 1990, the national laboratories and private industry have an exciting decade ahead. Here Ebasco executive vice president Leonard Reichle (l.) chats with the FEF's Charles Stevens and Morris Levitt at the FEF press conference Oct. 9. See page 14.

Fusion Extra

Vol. 4, No. 3
January 1981

News



NASA
An early warning system for crop conditions? NASA's AgRISTARS program is doing it now with Landsat-3. See Research, page 80.

Departments

Regional press said the FEF was their best source of information on the fusion legislation.

From the Editor's Desk

As Ben Franklin says in his Lightning Rod column, what better gift at this holiday season than the signing into law of the McCormack fusion bill? This issue's special Fusion Extra section tells you all about it—and asks readers to make sure their local press and media get the necessary information to report on the new legislation. Especially exciting is the article on industry's role in the new fusion program, a subject we'll be covering in more detail in 1981.

Of special interest in this issue is the question of Third World development, the subject of an interview with Uwe Parpart, FEF research director, who just returned from Mexico. The high-technology path is described in the Conferences article on the FEF's seminar in Mexico City, featuring the LaRouche-Riemann economic model, while the opposite route is debunked in two reviews of case studies in *Scientific American*'s special issue on economic development found in our new section, Science Press Review.

Marjorie Mazel Hecht

Marjorie Mazel Hecht
Managing Editor

The McCormack Fusion Bill: Victory and Challenge

The enactment into law of the McCormack fusion bill with President Carter's signature on October 7 is a great victory for scientific progress in America. It caps a tremendously rich process of scientific and political developments over the past decade and simultaneously poses a clear-cut challenge to America for the last decades of this century.

Every American should know what the McCormack bill says and the scientific achievements it is based on:

(1) The United States is now officially committed to building a prototype magnetic fusion reactor by the year 2000—just as definitively as the Atomic Energy Act of 1954 opened the way to commercialization of nuclear fission power, and President Kennedy's space program budgets of the early 1960s committed the nation to putting a man on the moon by the end of that decade.

(2) The harnessing of fusion power will provide an economical basis on which to meet *all* the world's energy needs for millions of years in all possible forms, including electricity, heat, and hydrogen. This is the best way to avoid scarcity and war and it opens the way to full use of existing energy resources.

(3) The construction of a magnetic-confinement fusion reactor is based on a series of basic theoretical and experimental advances in plasma physics that have permitted the achievement of net energy "breakeven" conditions and technological breakthroughs such as neutral-beam heating for reaching fusion ignition temperatures.

(4) Because of these scientific advances, the nation is now committed to developing the full engineering requirements for a fusion reactor. This will be pursued by setting up the first national fusion engineering center to conduct and coordinate technological R&D, ranging from superconducting magnets to reactor materials and full-scale plasma heating systems. As a start, the legislation specifies that the present magnetic fusion budget of $400 million will be increased by at least $100 million for each of the next two years.

The Battle Ahead

Now there is a new set of problems to overcome. It is not simply that we must meet many complex and difficult engineering requirements, or that we must develop a plasma and heating configuration that is pure enough, dense enough, and stable enough to produce large amounts of net energy cheaply. We have to wage the same fight that went into passage of the McCormack bill to make sure that the ultimate objective of the fusion program becomes possible: a fusion-based economy.

In reviewing what this will involve, it is useful to take a quick look back at fusion history.

Fusion research budgets in the 1960s were a paltry few million dollars at most, and the results were accordingly unspectacular, although important scientifically. This began to change in the late 1960s as significant new results from the Soviet tokamak machine were quickly reproduced in the United States. As in future experiments, the lesson was that a combination of bigger, more powerful machines and ingenuity could overcome the host of plasma instabilities.

Then, under the aggressive leadership of Dr. Robert Hirsch (now at Exxon) and Dr. Stephen O. Dean (now with Fusion Power Associates), fusion budgets in the early-to-mid-1970s moved quickly to the tens and hundreds of millions level. Correspondingly, the results improved dramatically, and fusion was on the map. During this period also, there were parallel developments in laser fusion and other forms of inertial fusion, which are part of military, rather than civilian, research agencies.

The FEF Role

In the early 1970s, the noted economist and recent presidential candidate, Lyndon H. LaRouche, Jr., along with his associates, was advocating the upgrading of the U.S. fusion program. As part of this effort, in November 1974, joined by several scientific collaborators, they formed the Fusion Energy Foundation, which from the outset actively promoted a crash fusion effort of Apollo program dimensions. Three years later, the FEF launched *Fusion* magazine.

The complementarity of the national research program and the FEF activities was most crucial in 1978, when Princeton scientists achieved fusion ignition temperatures and improved plasma confinement for the first time in a large-scale experiment. Despite all attempts by the Malthusian energy secretary James Schlesinger to downplay the result, the FEF put the story on the front pages of the world press.

Then, as the military and scientific decline in the United States reached crisis proportions after three years of the Carter administration's economic and energy policies, the fusion issue was decisively put forward by the extraordinarily capable Congressman Mike McCormack. He was backed by a broad scientific, industrial, and defense grouping centered around the national laboratories and represented by the findings of the Foster, Hirsch, and Buchsbaum panels, respectively.

Prerequisites for Success

Now, as we look to the future, there are three prerequisites for the success of the national fusion effort.

First, we must properly reindustrialize America by ending the antinuclear policies and gearing up around the massive domestic use and export of nuclear power, at the same time that we combine advanced aerospace and electronic capabilities with technological renovation of basic industries. Otherwise, the nation will not have the adequate industrial and engineering base for fusion.

Second, we must launch a broad-based research and training program that explores every possible dimension of plasma physics theory and experimentation and produces tens of thousands of scientists trained in the most advanced areas of mathematics and science. Otherwise, we will not produce the minds and by-product breakthroughs in plasma physics and all the other branches of science that are required for perfecting fusion as an economical source of energy.

Third, we must create an educational renaissance in the schools by recreating and expanding the highest classical tradition in literature, music, and science. At the same time, this demands that we end the chaos, crime, and adulterated curricula that now prevail. Without such a renaissance, we won't have a population in number or quality capable of building or assimilating the industrial and scientific requirements of a fusion-powered economy.

Can the nation meet all the requirements posed by the McCormack fusion bill? That is the real challenge—and the tremendous opportunity—now before America.

FUSION
MAGAZINE OF THE FUSION ENERGY FOUNDATION

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.

ISSN 0148-0537
USPS 437-370

The Lightning Rod

My dear friends,

Recently I received a letter from that venerable gentleman, Mr. Kris Kringle, the same who was having so many difficulties with the Department of Energy last year. You may remember that Mr. Kringle's North Pole manufacturing establishment had come under attack for operating in what the DOE considered a non-energy-efficient location, and that his reindeer had been cited repeatedly for ignoring the 55-mile-an-hour speed limit.

"Ben, it took a passel of lawyers, and I lost so much weight worrying that I'll be carrying a parachute this year to avoid slipping down the chimneys at an unhealthy rate," wrote the old fellow, "but thank goodness we're still in business at the old stand."

It seems the Energy Department finally agreed to permit Kringle Enterprises to continue its traditional operations, with one or two conditions. A corner of the reindeer shed has been turned over to a DOE staffer "to enable him to procure samples for studies on the combustibility of certain waste products produced by said Kringle's transportation systems," as a DOE memorandum puts it.

"I just hope they're not thinking of an afterburner," Kris commented.

"Mr. Kringle has also submitted a signed statement pledging in perpetuity never to permit the employment of Japanese reindeer in the conduct of his business," according to an election eve White House press statement.

"The only good thing to come out of the whole *mishugas*," according to Kris, was that "Ralph Nader finally decided I was a consumer fraud dreamed up by the multinationals, and started holding press conferences to announce that 'Santa Claus does not exist.' Since then business has never been better."

By the way, Kris has asked me to pass on to all of you his thanks for the way you pitched in to help pass the McCormack fusion bill, which he said was "the nicest Christmas present this Santa ever had."

With best wishes for the New Year, I remain,

Yr. obt. svt.,

Benj. Franklin

Letters

Perils of a Propagandist

To the Editor:

As you noted in the December issue of *Fusion* [p. 75, Science Press Review], *Scientific American* devoted its September issue to economic development, with various articles on developing nations' efforts in that direction. One such article was on China, written by a Chinese economic official from Shanghai, Ding Chen.

Given *Scientific American* publisher Gerald Piel's warm praise for the "Chinese model," perhaps readers should have been prepared for a less than disinterested effort by a Chinese official. However, one should always be wary of the perils of a propagandist, particularly one from China where every day now the miracles and models of Mao's models are being denounced by the present regime as evils of the past.

Scientific American's propagandist, it seems, had a particularly perilous task in trying to tell the story of Chinese successes. One success he dwelled on with great pride is that of agriculture and the model commune of Dazhai, a celebrated triumph of Maoist will over the land.

Ding Chen tells how they "moved mountains" in this "self-reliant communal enterprise" and accomplished such feats as getting yields of 8.4 tons of grain per hectare. Mr. Chen, however, failed to anticipate the next propaganda line coming from Peking. About the time his article appeared, the official media in Peking opened a campaign attacking Dazhai, revealing it to be a sinkhole of investment that was a massive loss for the regime and a fraudulent model for which statistics on yields, acreage brought under cultivation, and harvest tonnage were regularly falsified and greatly overinflated. The head of the commune, a top figure in the official hierarchy, has been ousted.

As to our propagandist's other claims, I leave that to your imagination.

Daniel Sneider
Asia Editor
Executive Intelligence Review

Editor's Note: This issue's Science Press Review Section reviews two other articles in Scientific American's *special on economic development.*

There Is No 'China Syndrome'

To the Editor:

I read with some interest the article entitled "Nuclear Power: The Safest Energy Around" in the September issue [by Jon Gilbertson].

The one problem I have in trying to convince others of the soundness of nuclear energy is not so much that nuclear plants are safe, but what happens when that ultimate failure occurs. One can argue that air travel is safe, but we know that airplanes are going to crash, and when they do hundreds of people are killed.

People believe that nuclear power plants are inherently safe, but when that ultimate disaster occurs, no one seems to be able to define the total impact on the people and environment. It seems possible that a nuclear reactor could overheat resulting in a steam explosion or a meltdown which would breach the containment shell and spew radioactive material into the atmosphere. If this is not a possibility, perhaps someone could explain to me why it isn't. If it is a possibility, is there any agreement among the experts as to what the ultimate damages would be?

Gary D. Jones, P.E.
Vice President Marketing & Sales
Illinois Water Treatment Co.
Rockford, Ill.

The Author Replies

You are right, there is considerable confusion. This primarily stems from the false and misleading information that has flooded the news media from antinuclear environmentalist groups, particularly since the Three Mile Island incident and the "China Syndrome" film, which was released at the same time as the TMI incident.

The public has been led to believe that the "China syndrome" is real, or that radioactive fission products in a reactor core can somehow escape from the containment building, contaminating densely inhabited areas.

Neither event is possible. Nor are many other "dangerous" scenarios. These are "hypothetical" events; that is, events that have no known physical means of occurring, but that have been analyzed by nuclear safety engineers who design plants so that those plants could withstand the effects of such hypothetical events.

The core meltdown or China syndrome: Analysis has shown that, even if the fuel did somehow melt through the reactor vessel—in itself an "hypothetical" event—there is no way that it could penetrate the floor of the containment building after dripping onto it. The water that would have accumulated on the floor—for example, 8 feet deep at TMI—would completely cool and disperse the decay heat.

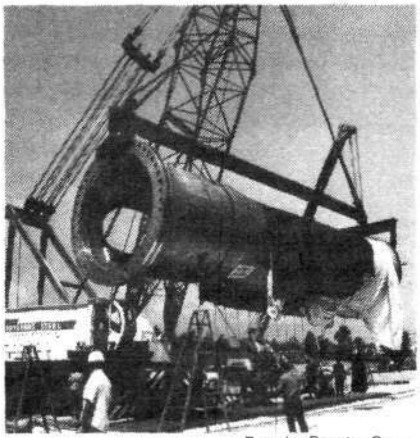
Let us go even further and assume the physical impossibility that no water were on the floor. In that case, the concrete floor itself would conduct the decay heat away before the fuel could penetrate more than a few inches or a foot at most. The concrete floor slab is 12 feet thick. *In short, the China syndrome is impossible.*

Suppose, however, that a primary coolant system rupture resulted in the generation of steam pressure within the containment building. But the maximum building pressure possible is that which would result from a double-ended pipe rupture loss-of-coolant accident (LOCA). This, in fact, is the "design basis accident," as discussed in the September article. All reactors are designed to withstand the effect of this development with large safety margins to boot, including the pressure generated as water flashes to steam during the blowdown phase. This is done, even though there is no known physical way that such a double-ended rupture could ever occur.

I hope this aids in defending and promoting nuclear power even more

Continued on page 13

News Briefs


Breeder Reactor Corp.

The Clinch River breeder: Slated for postelection demolition? Here the second intermediate heat exchanger is delivered in Sept. 1980.

CARTER PLANS TO KILL U.S. BREEDER PROGRAM AFTER THE ELECTION

Idaho Senator Jim McClure and Congressman Steve Symms called a press conference in Rigby, Idaho Oct. 21 to expose a top-secret administration plan to kill the U.S. breeder reactor program entirely after the Nov. 4 presidential election. The two Republicans revealed the existence of a National Security Council memorandum dated June 12, 1980 titled "Recommendations for Post Fuel Cycle Evaluation Implementation of the President's Non-Proliferation Policy." The memo has been circulated to all members of the top-level policy committee of the White House, including the vice president, the secretaries of state, defense, and energy, the joint chiefs of staff, and the CIA.

The NSC memorandum reportedly spells out detailed plans for closing down the U.S. breeder program, a development that would cap President Carter's four-year-long efforts to cut off funding to the Clinch River project. The top-secret memorandum is the administration's response to the final evaluation produced by the International Fuel Cycle Evaluation (INFCE) conference in Vienna last Feb. 25-27, which recommended that the advanced fuel cycle and reactor concepts can and should be developed and made available to all nations. INFCE, ironically, was initiated by President Carter in 1977 in the hopes of containing the development of the breeder reactor internationally.

According to McClure and Symms, the administration plans to make its final decision on the breeder policy at a meeting on Nov. 14. They also reported that officials in Washington have confirmed that a special taskforce is now at work on plans to implement the NSC memo and that the taskforce is directed by Gus Speth, chairman of the White House Council on Environmental Quality, and Kitty Shirmer of the Office of Management and Budget, two of the most ardent antinuclear spokesmen in the Carter administration.

FAST BREEDER UNDER DEVELOPMENT IN INDIA

India will be completing the design of a 250 to 500-megawatt commercial fast breeder reactor by 1986-87, G. Venkataraman, chief physicist at the Kalpakkam Research Facility, reported in early October. A 15-megawatt test reactor, which is based on the design of the French Rhapsodie Reactor and converts thorium into a fissile material, will start operating at Kalpakkam by the end of the year. The larger size, commercial fast breeder reactor will utilize the scientific information on the irradiation of thorium gained from the test reactor.

At the same time that the breeder reactor news was reported, India's Atomic Energy Commission announced that its site selection committee has decided to locate India's fifth nuclear power station at Kakrapar in the state of Gujrat.


NASA

Frosch: A hard job

NASA ADMINISTRATOR FROSCH RESIGNS

Dr. Robert Frosch, the administrator for the National Aeronautics and Space Administration, handed in his resignation effective Jan. 20, 1981. Frosch, who has headed the space agency since 1977, will become the director of a new federation of engineering societies created last year. Although Frosch cited personal reasons for his resignation, Washington sources report that Frosch and other top NASA scientists have become increasingly frustrated in trying to ensure that the space program has enough funding to complete projects in progress and to begin new ones. In congressional hearings this summer Frosch disagreed with President Carter's science advisor, Dr. Frank Press, who stated that there were no major new projects on the agenda for NASA in the next decade. As one spokesman for NASA commented on the Frosch resignation, "if you care about the program, it's a hard job."

DEUTCH BACKS OFFICE OF STRATEGIC TRADE

Former deputy secretary of energy John Deutch testified before the Senate Government Affairs Committee Sept. 24 in favor of legislation that would create an Office of Strategic Trade as an independent executive agency. The bill, S2606, which was introduced by Sens. Jake Garn (R-Utah) and William Cohen (R-Maine), would transfer to the new office functions now performed by the Commerce Department under the Export Administration Act, which provides for controls on commercial goods or technologies which have dual, military applications. Deutch's remarks indicated that such a new office could rapidly expand its scope beyond exports and be used to inhibit domestic scientific investigations under the guise of protecting them from the Soviets. In particular, Deutch singled out the problem he used to have with scientists who wanted to participate in public conferences on issues such as "inertial confinement fusion," claiming that such open conferences would provide secrets to the Soviet Union.

FEF CONFERENCE CHARTS 'SECOND INDUSTRIAL REVOLUTION'

"We can't send man to the planets with chemical or fission rockets, but we can send him with fusion. Then we shall colonize space and industrialize the solar system," pioneer fusion scientist Dr. Friedwardt Winterberg told a Fusion Energy Foundation-sponsored conference on reindustrialization at Los Angeles's Concord Hotel Oct. 15. The Los Angeles conference was the first of a series of six conferences this fall organized by the FEF to call attention to the enormous potential leverage for economic growth represented by the recently enacted McCormack "Apollo-style" fusion legislation.

The conference was also addressed by FEF research director Uwe Parpart and by Dr. N.W. Snyder, designer of Parsons Engineering Company's North American Water and Power Alliance plan. Dr. Snyder described Parsons's NAWAPA plan as a single water grid functioning like a power grid in shifting water and power resources throughout North America. "In order to make agriculture and cities viable, it is necessary to find water and move it," he said.

Parpart outlined a 25-year global economic boom, beginning with capital goods exports to the Third World. He said that the ambitious proposals for economic development that he and other speakers were presenting amounted to nothing less than a "second industrial revolution, founded on the vast resource base and superhigh temperatures of fusion energy."

Richard Iaria/NSIPS

Participants at the Los Angeles conference, from left: Nick Benton, Uwe Parpart, F. Winterberg, Sandy Baldanado, N.W. Snyder, Art Wilson, Dr. Plummer, and William Wertz.

The scientists were joined on the rostrum by Art Wilson, president of the California State National Farmers Organization, and Dr. Plummer of the Medical Mission to Africa. In attendance were a representative of California Congressman James Lloyd, as well as staff members of Lockheed, Hughes Aircraft, Litton Industries, McDonnell Douglas, and 30 smaller firms.

FEF NEW JERSEY FORUM DRAWS 75 MEMBERS

FEF executive director Dr. Morris Levitt addressed an FEF forum Oct. 21 on the broad implications of the new fusion legislation for the U.S. economy. The forum drew 75 area businessmen, engineers, teachers, and trade union and government officials, and received greetings from Democratic Congressman Robert Roe and Mayor Thomas Dunn of Elizabeth. Discussion centered on industry's role in the development of commercial fusion and on the need to use the nuclear industry's political muscle to ensure the implementation of the fusion legislation.

The FEF is sponsoring similar events in regions across the country. Interested members should contact the foundation's New York office.

LOUSEWORT LAURELS WON BY VENEZUELAN GOVERNMENT

This month's lousewort laurels award goes to the government of Venezuela for its "free market" approach that closed the nation's only tractor factory Oct. 3. The government shut down the factory, stating in an official communiqué: "no enterprise whose products will mean a rise in the costs for the farmer can be kept functioning. For this reason it was not recommendable to maintain the company producing tractors."

Viewpoint

A New Form Of Innovation

by Dr. Harold M. Agnew

What we should be experiencing today is a completely new form of innovation, a main portion of which should be the introduction of new techniques to complement the more mechanical and technical innovations that my colleagues have provided and hopefully will continue trying to provide for mankind, our premise being that most technical innovations are beneficial, or at least could be. I believe the difficulty today is that the technical community worldwide has been bringing into fruition all sorts of applications of clever scientific discoveries, but the social and political so-called scientific world has been standing still.

Where we have been innovating we have for the most part been doing it on the micro scale. This is to be expected if one is profit motivated and wants a short-term assured return on any investment. With interest rates what they are today, any outfit with cash that can afford to stand still can make more money on straight interest than it can on long-term risky developments associated with most innovations. We haven't been introducing new social and economic changes to take full advantage of the technical innovations.

Let me give you an example of innovation that is a combination of technical and social. The big defense problem today is the MX dilemma. Why do we need an MX? The stock answer is because Minuteman's survival is at stake. If you think about it, building the MX really doesn't help Minuteman. It simply would provide, if there were a limit on the number of Soviet and Chinese and French and British reentry vehicles, that if Minuteman were to be targeted and attacked MX might survive for a retaliating strike. Not Minuteman! If I were a Minuteman, the MX contribution to my survival, or actually nonsurvival, wouldn't satisfy me very much.

I don't believe that anyone would disagree that the function of our Minuteman is one of maintaining a credible deterrence. If we have to build MX so that we can fire it after Minuteman has been destroyed, we really haven't got much for our $100 billion, and we haven't helped Minuteman.

Now how about a little political and social innovation in this situation? It seems to me the first decision a president has to make upon being sworn in is if he'll ever order a retaliating ICBM launch against a foreign power. If the answer is no, then we really don't need an MX or anything else during his tenure of office. If the answer is yes, then the question is simply, "When?" One could ask, "Will he retaliate after, say, 100 foreign detonations on the United States?" He would probably say, "Yes." Your next question should then be, "How soon after?" He would probably say, "Immediately." So what we have done is narrow down the decision time to something like a half an hour between when the foreign missiles are launched and when they arrive.

So then an innovator might proceed with a question along the following line. "Would they have to hit the ground before you would launch?" I suspect the answer from Carter would be, "Yes"; from Senator Thurmond, "No." Thurmond might say we can't afford another Pearl Harbor, either by accident or contrived.

Well, the technology is available today to determine whether an appreciable fraction of Minutemen is at risk from any foreign ICBM launch. The key words here are "appreciable fraction." The key to this, however, would be the ability to guarantee that the information one is receiving is valid and cannot be interrupted. Instead of having just a couple of satellites and a few ground stations monitoring foreign ICBM launchings, one would need them in the tens. Many of them would have to be silent, only talking to each other, and being appropriately monitored. Some might be decoys, but I suspect that the launching cost would dictate that all space hardware be operable. The shuttle could be the answer to cutting costs in putting this hardware in space.

I'm convinced that such a redundant system would provide absolute information with regard to the question as to whether Minuteman was at risk, and, if it were, Minuteman could be launched so that it would no longer be at risk. With proper information, Minuteman could even be launched at other than empty foreign silos. Moreover, the whole Minuteman force would be available. Such an innovative system would serve as a much more credible deterrent than any MX, which would always be vulnerable to an increased number of foreign RVs [reentry vehicles], which could be built in a shorter time period. Such a system would be cheaper, could be in place sooner, and would help put a cap on the arms race because not one new offensive system would be required.

The MX missile if built could even be placed in the present Minuteman configuration or hopefully be associated with a small offshore submersible system. And if, alas, a completely new MX is needed, the information that such a redundant satellite system would provide could be available to assess the vulnerability of even that system. I doubt that this alternative solution to the vulnerability of Minuteman will ever become a reality, and that's too bad.

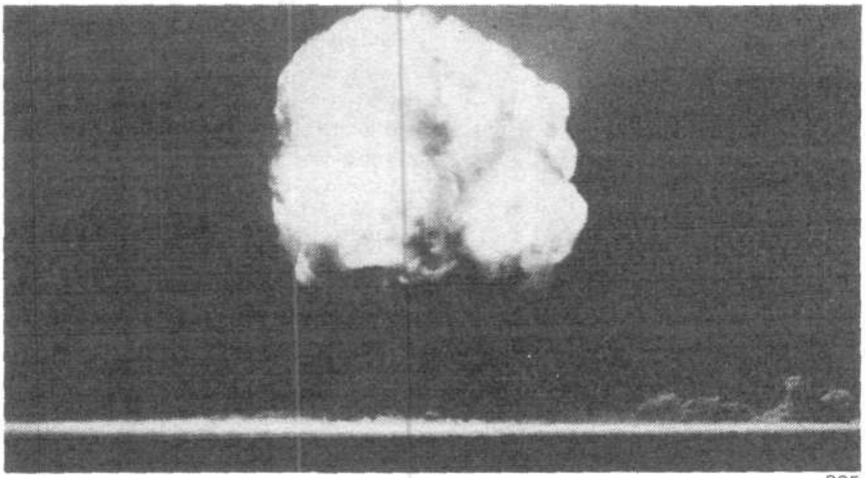
Nuclear Baptism

Another area where a little social and political innovation is needed has to do with how you make world leaders, who soon will have never witnessed a nuclear explosion, understand what these things are really like. If you've ever stood 30 miles from a multimegaton air or ground burst, I believe that you would be very, very reluctant to order the launching of such a device against anyone, knowing that with high probability you'll get one right back. With the present atmospheric test ban, only the French and the Chinese have the opportunity to have their political and military leaders feel the heat and witness the power of a nuclear explosion. I suspect few have witnessed a megaton explosion or a kiloton explosion. Pictures don't suffice.

A little innovation to dampen the enthusiasm for the use of nuclear weapons by the new leaders of the nuclear power states might be to witness such an explosion clad only in their shorts, within one month of assuming office. The present nuclear powers could take turns in providing the nuclear source so that no technical or military advantage would accrue to any power through this "limited testing." In fact, I would submit the best way to phase out strategic weapons and lessen the possibility of a first attack by anyone would be to make the decision makers upon entering office be baptized, so to speak, under nuclear fire. Again, a little political innovation.

The Reprocessing Question

We have been worrying about proliferation of nuclear weapons, and this administration adopted a policy of nonreprocessing of spent nuclear fuel. They even tried, very unsuccessfully, to convince the rest of the world to follow our nonleadership. The results have been just the opposite of those desired. The rest of the world is well on its way to becoming independent of U.S. technology and suppliers, primarily because of our unreliability as a nuclear supplier in a world of very unstable Mideast oil suppliers.



DOE

'Pictures don't suffice': The first atomic bomb, July 1945.

A little early innovation, such as requiring that the nuclear power or whoever provides nuclear fuel for reactors would never sell but always lease the fuel based on its energy content and the fraction used, would have eased today's problem. After the contracted amount of energy has been delivered, the spent fuel would be exchanged for credit toward new fuel. We lease computers, and we really lease tires in the same way. After 40,000 miles you need new tires. You don't keep the old ones. You turn them in for credit and get new ones. During the last war you couldn't get a new tire without turning in the old one. Nuclear fuel could be handled the same way.

The nuclear suppliers could then reprocess the spent fuel or not, depending solely on the economics. Since they all eventually have their own spent fuel to handle, the return would promote little additional burden, and the price charged for the new fuel would include the cost of handling the spent fuel. Eventually the reprocessing, fabrication, and waste storage could be handled on a multinational or international basis to ensure proper storage, credit, and utilization of the spent fuel. These to me represent just a few of the areas needing innovation today in the area of national security.

Questions have been raised with regard to Japan and the rest of the world with respect to innovation. I would say as long as ideas may be pursued and not stifled by overregulation, innovation will survive. Let me take Japan as an example of a very innovative philosophy. Many of you may be too young to appreciate that before the 1950s and certainly before World War II, the phrase "Made in Japan" was not a compliment. Japanese products were very junky, no matter what they were.

Sometime after the war someone in the Japanese government decided that from that time on no product for export or internal consumption would be allowed unless it passed a quality test. This was a very innovative concept. Here was a nation that had been devastated by a war, was occupied by its conqueror, and decided without fanfare to change its complete industrial production philosophy.

We first noticed it on optical equipment. A little tag appeared on every

Continued on page 86

Letters

Continued from page 7

effectively than you have done in the past.

The more interesting question now posed is why the people who calculate these catastrophic, impossible scenarios, at places like Princeton University, refuse to quantify and make public with equal vigor the readily available data on how many people are suffering and dying as a result of the failure to make nuclear power available throughout the world. Could it be that they hypocritically have compassion only for the victims of hypothetical catastrophes, not real ones?

Jon Gilbertson

The DES Controversy: Science Vs. Scare

To the Editor:

I have just read the article entitled "Beef Herds Jeopardized by Hormone Scare" in the October issue of *Fusion*. You appear to take rather lightly a medical discovery which has profoundly affected my life. Let me offer my perspective on the DES "scare."

My mother took DES while she was pregnant with me. I can't say that I have lost sleep over the prospect of developing cancer from this exposure, but I will admit that the concern is never too far from my thoughts. We are, after all, talking about vaginal cancer, one of the most difficult to diagnose and one of the most fatal types of cancer.

Fortunately, being now 30 years old, I am probably past the threat of DES-induced cancer. In fact, the researchers aren't sure that a DES daughter is ever free from the cancer worry, but the initial evidence indicates that, past the age of about 25, cancer is not of immediate concern.

There remain for me, however, the less publicized horrors of the DES "scare." I may never have a normal pregnancy or deliver a child. The researchers aren't even guessing now what will happen to me and my DES-

Continued on page 84

In This Section

A New 'Apollo' Program

McCormack Fusion Bill Becomes Law

President Carter signed the McCormack fusion bill into law Oct. 7 as the Magnetic Fusion Energy Engineering Act of 1980. The landmark legislation commits the nation to develop a commercial demonstration fusion reactor by the year 2000, preceded by a fusion engineering device (FED) in 1990. The act also mandates the establishment of a new national fusion laboratory to oversee the design and construction of the FED.

This historic legislation, which sets into motion a national effort as far-reaching as the space program of the 1960s, so far has been prevented from the public celebration it merits. The president signed the bill so quietly, in fact, that not even the White House press staff knew about it until late that day, and then only after an inquiring reporter supplied the bill number and insisted that the staffer check it out.

This White House secrecy seems quite deliberate. The near-unanimity with which the bill had passed Congress—a unanimous voice vote in the Senate and a 365 to 7 vote in the House—made it impossible for Carter to veto the bill. Yet because fusion promises an inexhaustible, cheap energy supply, it ruins the administration's Malthusian arguments for conservation, synfuels, and solar energy as well as political maneuvers to jack up the price of imported oil. Therefore, the administration did not want the fusion program to capture the spirit of the nation the way the Apollo program did.

FEF Mobilizes

Breaking through the media and administration "gray-out" of the news of the fusion legislation was one of the immediate tasks the Fusion Energy Foundation undertook. The foundation sent out the president's statement on the signing of the fusion bill to hundreds of national press and informed the wire services and major media of the news. A press packet was compiled with background information on how fusion works and statements by scientific experts as well as legislators on the importance of the bill.

In addition, the FEF held a press conference and background briefing Oct. 9 at its New York headquarters, which included a slide presentation on the progress of the U.S. fusion program. At the same time, *Fusion*'s Washington news editor Marsha Freeman made a whistle-stop tour of southern California, Oregon, and Washington state, holding dozens of press conferences and radio and television interviews on the fusion legislation.

"If we develop fusion now, we have no need to assume a policy of scarcity. It allows us to use our available oil and coal resources now," Dr. Morris Levitt, executive director of FEF,

Carlos de Hoyos

"If we develop fusion now, we have no need to assume a policy of scarcity." Charles B. Stevens (l.) and Dr. Morris Levitt briefing press Oct. 9 on the signing of the McCormack fusion bill.

stated as he opened the press conference.

Levitt stressed the economic impact of the bill: "The NASA program put 14 dollars back into the economy for every dollar spent on the program—in terms of jobs, factories, and new products. Fusion promises to do even better."

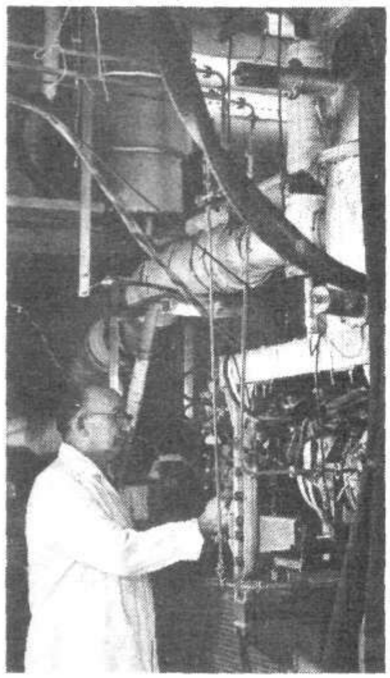
Levitt also noted that the McCormack fusion program would not solve all the nation's problems. "We need similar legislation," Levitt said, "to reindustrialize the nation, in particular to gear up our nuclear power efforts. Nuclear power is crucial here and in the developing sector in providing the energy and industrial base for the coming fusion economy."

"The ultimate challenge of the McCormack bill, especially in light of the Wirszup report on the decline of American science education compared to the Soviet system, is to gear up a massive program in education and science. We need tens of thousands of new scientists, hundreds of thousands of new engineers, and millions of the general population who become part of a thriving scientific culture. That's what we have to accomplish in the spirit of the McCormack bill."

Levitt and Charles B. Stevens, *Fusion* magazine's fusion technology editor, then used slides to show how fusion works, the various fusion machines, and the progress in the U.S. and world programs since the 1950s.

Among the press present were the *Newark Star Ledger*, the *News World*, United Press International, and Tass, the Soviet news agency. Also represented were the International Atomic Energy Agency and several industries and research centers involved in fusion work. The question period covered queries on alternative funding concepts, the specific industries that would be involved in the new fusion effort, the safety of fusion, and the international implications of the legislation.

—*Marjorie Hecht*



PPPL

An early U.S. stellarator experiment at Princeton.

"This is the nearest thing to landing man on the moon that this country has undertaken since the Apollo program."

The Signing Of the Fusion Bill

Carter

As soon as the McCormack fusion bill was signed into law, the Fusion Energy Foundation reproduced the official White House statement and sent it out as a press release. The foundation also solicited the statements below from the key congressmen involved in getting the bill through the House and the Senate.

* * *

What the White House Said

Press Release from the White House, Oct. 7

Oct. 7—President Carter today signed HR 6308, the Magnetic Fusion Energy Engineering Act of 1980, a bill authorizing a magnetic fusion research, development, and demonstration program within the Department of Energy. The bill establishes as a national goal the successful operation of a magnetic fusion demonstration plant in the U.S. by the year 2000.

The scientific results of magnetic fusion experiments have been highly encouraging so far and there is considerable confidence that controlled fusion reactions can be achieved.

Congressman McCormack and Senators Church, Tsongas, Baker, and Domenici are to be commended for their foresight in obtaining enactment of HR 6308.

Fusion power offers the potential for a limitless energy source with manageable environmental effects. And HR 6308 represents a bipartisan effort to develop fusion as a viable energy option for the United States. Our nation is the undisputed leader in developing this advanced technology, and HR 6308 will help us keep it that way. This bill represents a reasonable approach to the broad advancement of fusion research and technology. I sign it into law with pleasure.

Rep. McCormack

Statement by Rep. Mike McCormack, Oct. 7

I am excited and very pleased that the president has signed the fusion bill. There is no doubt in my mind that this is the most important energy project ever undertaken by anybody anywhere. This is the nearest thing to landing man on the moon that this country has undertaken since the

Apollo program. The new law establishes a national commitment to fusion energy as a mainline energy source for this nation in the 21st century and sets a goal of having a magnetic fusion electric-generating demonstration plant operating successfully by the year 2000.

Sen. Baker

Press Release from the office of Senator Howard Baker, Oct. 8

It gives me great pleasure to see that the Congress has spoken with forcefulness and near unanimity in this statement of confidence in American technology. I view the magnetic fusion engineering act as an affirmation of the belief that despite our short-term energy problems the future is bright with the promise of unlimited energy derived from abundant, inexpensive, readily available fuel.

Fusion energy holds that promise. While it will not contribute to the solution of our serious short-term energy supply problem, we must investigate and explore and develop all possible energy options if we are to ensure that our children will not live in a world of peril because energy is running out. In a time when we are spending almost $100 billion a year for foreign oil, we must be willing to make the commitment and take the chances that are necessary if this nation is ever again to achieve energy independence.

I believe we will achieve that independence and I was proud to be an original cosponsor of the fusion energy act as an important element in assuring a secure energy future for America.

Wide World

Baker

McCormack Klebe/NSIPS

Sen. Tsongas

Press Release from the office of Senator Paul Tsongas, Oct. 8

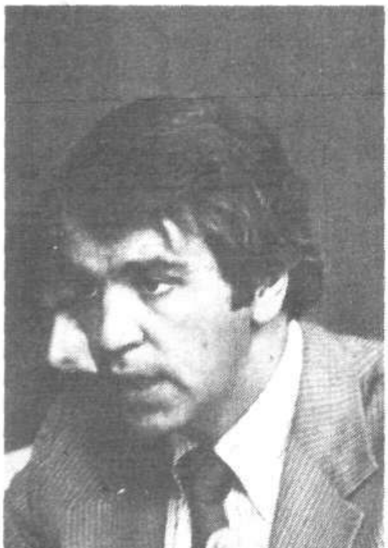
Fusion holds great promise as an inexhaustible energy resource and has the potential for achieving a high degree of safety with an acceptable level of social and environmental impact. Its fuel is low cost and abundant; it does not have the accident potential or the nuclear waste problem associated with nuclear fission.

This does not mean that we can afford to devote less attention or fewer resources to near-term energy options. But even though a demonstration plant is 20 years away, this energy source is being taken seriously because we recognize the need to invest in our energy future today.

Dr. Levitt

Statement by Dr. Morris Levitt, executive director, FEF, Oct. 7

The signing of the Magnetic Fusion Energy Engineering Act of 1980 is an historic development. It represents a victory for the political and scientific forces who have worked hard for this bill. It puts before this country now three major tasks to implement the legislation: a reindustrialization program based on nuclear energy, development of a basic research and training program using the Riemannian method, and the revamping of our educational programs.



Tsongas Klebe/NSIPS

The fusion bill, printed here in full, passed the House Aug. 26 by a vote of 365 to 7 and the Senate Sept. 23 by a unanimous voice vote. President Carter signed it into law Oct. 7.

The Magnetic Fusion Energy Engineering Act of 1980

That this Act may be cited as the "Magnetic Fusion Energy Engineering Act of 1980."

Findings and Policy

Sec. 2. (a) The Congress hereby finds that—

(1) the United States must formulate an energy policy designed to meet an impending worldwide shortage of many exhaustible, conventional energy resources in the next few decades;

(2) the energy policy of the United States must be designed to ensure that energy technologies using essentially inexhaustible resources are commercially available at a time prior to serious depletion of conventional sources;

(3) fusion energy is one of the few known energy sources which are essentially inexhaustible, and thus constitutes a long-term energy option;

(4) major progress in all aspects of magnetic fusion energy technology during the past decade instills confidence that power production from fusion energy systems is achievable;

(5) the United States must aggressively pursue research and development programs in magnetic fusion designed to foster advanced concepts and advanced technology and to develop efficient, reliable components and subsystems;

(6) to ensure the timely commercialization of magnetic fusion energy systems, the United States must demonstrate at an early date the engineering feasibility of magnetic fusion energy systems;

(7) progress in magnetic fusion energy systems is currently limited by the funds made available rather than technical barriers;

(8) it is a proper role for the Federal Government to accelerate research, development, and demonstration programs in magnetic fusion energy technologies; and

(9) acceleration of the current magnetic fusion program will require a doubling within seven years of the present funding level without consideration of inflation and a 25 percent increase in funding each of fiscal years 1982 and 1983.

(b) It is therefore declared to be the policy of the United States and the purpose of this Act to accelerate the national effort in research, development, and demonstration activities related to magnetic fusion energy systems. Further, it is declared to be the policy of the United States and the purpose of this Act that the objectives of such program shall be—

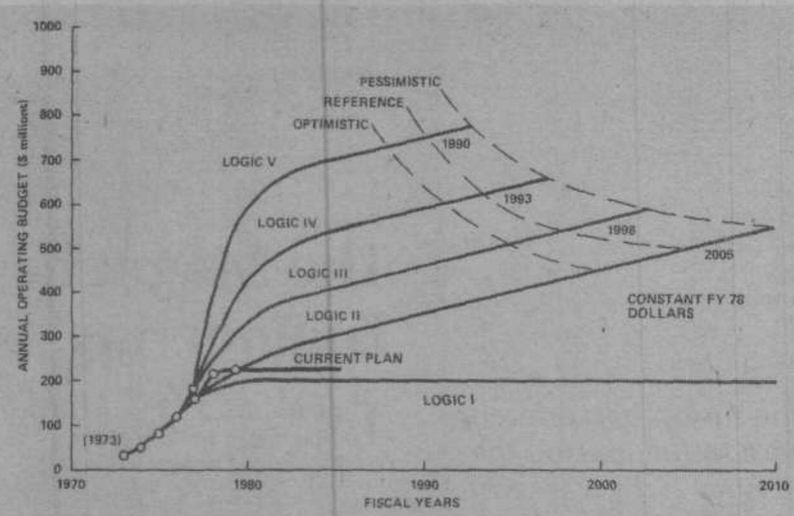
(1) to promote an orderly transition from the current research and development program through commercial development;

(2) to establish a national goal of demonstrating the engineering feasibility of magnetic fusion by the early 1990s;

(3) to achieve at the earliest practicable time, but not later than the year 1990, operation of a magnetic fusion engineering device based on the best available confinement concept;

(4) to establish as a national goal the operation of a magnetic fusion demonstration plant at the turn of the twenty-first century;

(5) to foster cooperation in magnetic fusion research and development among government, universities, industry, and national laboratories;



FUSION R&D PROGRAM OPERATING BUDGET AND LOCI OF DEMO OPERATING DATES FOR LOGIC I THRU V

FIGURE II-9

This 1978 Department of Energy projection for magnetic fusion shows five funding paths, called Logics. The dashed curves indicate when fusion reactors would be achieved for each Logic path. The dashed curve labeled reference is a conservative projection. As shown, the then-current DOE funding level put off a demonstration reactor until the year 2010, while accelerated funding levels could achieve a demonstration reactor by as early as 1990. The McCormack fusion bill would push the funding level up to somewhere between Logic III and Logic IV.

(6) to promote the broad participation of domestic industry in the national magnetic fusion program;

(7) to continue international cooperation in magnetic fusion research for the benefit of all nations;

(8) to promote greater public understanding of magnetic fusion; and

(9) to maintain the United States as the world leader in magnetic fusion.

Definitions

Sec. 3. For the purposes of this Act—

(1) "fusion" means a process whereby two light nuclei, such as deuterium and tritium, collide at high velocity, forming a compound nucleus, which subsequently separates into constituents which are different from the original colliding nuclei, and which carry away the accompanying energy release;

(2) "magnetic fusion" means the use of magnetic fields to confine a very hot, fully ionized gas of light nuclei, so that the fusion process can occur;

(3) "energy system" means a facility designed to utilize energy released in the magnetic fusion process for the generation of electricity and the production of hydrogen or other fuels;

(4) "fusion engineering device" means a magnetic fusion facility which achieves at least a burning plasma and serves to test components for engineering purposes;

(5) "demonstration plant" means a prototype energy system which is of sufficient size to provide safety, environmental reliability, availability, and ready engineering extrapolation of all components to commercial size but which system need not be economically competitive with then alternative energy sources; and

(6) "Secretary" means Secretary of Energy.

Program Activities

Sec. 4. (a) The Secretary shall initiate activities or accelerate existing activities in research areas in which the lack of knowledge limits magnetic fusion energy systems in order to ensure the achievement of the purposes of this Act.

(b) (1) The Secretary shall maintain an aggressive plasma confinement research program on the current lead concept to provide a full measure of support for the design, construction, and operation of the fusion engineering devices.

(2) The Secretary shall maintain a broadly based research program on alternate confinement concepts and on advanced fuels at a sufficient level of funding to achieve optimal design of each successive magnetic fusion facility using the then best available confinement and fuel concept.

(3) The Secretary shall ensure that research on properties of materials likely to be required for the construction of fusion engineering devices is adequate to provide timely information for the design of such devices.

(c) (1) The Secretary shall initiate design activities on a fusion engineering device using the best available confinement concept to ensure operation of such a device at the earliest practicable time, but not later than the year 1990.

(2) The Secretary shall develop and test the adequacy of the engineering design of components to be utilized in the fusion engineering device.

(d) The Secretary shall initiate at the earliest practical time each activity which he deems necessary to achieve the national goal for operation of a demonstration plant at the turn of the twenty-first century.

(e) The Secretary shall continue efforts to assess factors which will determine the commercial introduction of magnetic fusion energy systems including, but not limited to—

(1) projected costs relative to other alternative energy sources;

(2) projected growth rates in energy demand;

(3) safety-related design limitations;

(4) environmental impacts; and

(5) limitations on the availability of strategic elements, such as helium, lithium, and special metals.

Comprehensive Program Management Plan

Sec. 5. (a) The Secretary shall prepare a comprehensive program management plan for the conduct of the research, development, and demonstration activities under this Act. Such plan shall include at a minimum—

(1) a presentation of the program strategy which will be used to achieve the purposes of this Act;

(2) a five-year program implementation schedule, including identification of detailed milestone goals, with associated budget and program resources requirements;

(3) risk assessments;

(4) supporting research and development needed to solve problems which may inhibit or limit development of magnetic fusion energy systems; and

(5) an analysis of institutional, environmental, and economic considerations which are limiting the national magnetic fusion program.

(b) The Secretary shall transmit the comprehensive program management plan to the Committee on Science and Technology of the House of Representatives and the Committee on Energy and Natural Resources of the Senate not later than January 1, 1982.

Magnetic Fusion Engineering Center

Sec. 6. (a) The Secretary shall develop a plan for the creation of a national magnetic fusion engineering center for the purpose of accelerating fusion technology development via the concentration and coordination of major magnetic fusion engineering devices and associated activities at such a national center.

(b) In developing the plan, the Secretary shall include relevant factors including, but not limited to—

(1) means of saving cost and time through the establishment of the national center relative to the cost and schedule currently projected for the program;

(2) means of providing common facilities to be shared by many magnetic fusion concepts;

(3) assessment of the environmental and safety-related aspects of the national center;

(4) provisions for international cooperation in magnetic fusion activities at the national center;

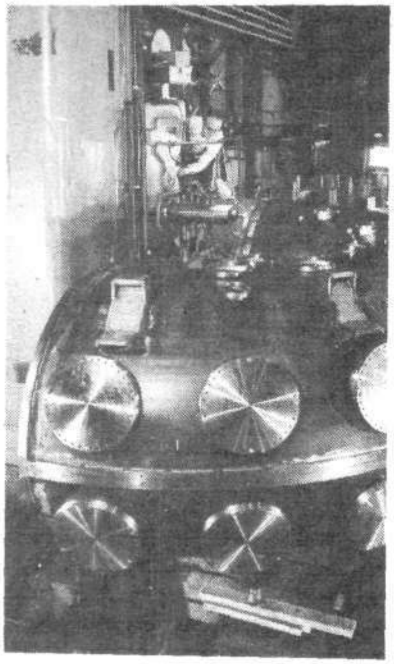
(5) provision of access to facilities for the broader technical involvement of domestic industry and universities in the magnetic fusion energy program;

(6) siting criteria for the national center including a list of potential sites;

(7) the advisability of establishing such a center considering all factors, including the alternative means and associated costs of pursuing such technology; and

(8) changes in the management structure of the magnetic fusion program to allow more effective direction of activities related to the national center.

(c) The Secretary shall submit not later than July 1, 1981, a report to the House Committee on Science and Technology and the Senate Committee on Energy and Natural Resources characterizing the plan and setting forth the steps necessary for implementation of the plan, including any steps already implemented.



PPPL

Building the vacuum vessel of Princeton's PLT, the tokamak that achieved record temperatures in July 1978.

Technical Panel on Magnetic Fusion

Sec. 7. (a) A technical panel on magnetic fusion of the Energy Research Advisory Board shall be established to review the conduct of the national magnetic fusion energy program.

(b) (1) The technical panel shall be comprised of such representatives from domestic industry, universities, government laboratories, and other scientific and technical organizations as the Chairman of the Energy Research Advisory Board deems appropriate based on his assessment of the technical qualifications of each such representative.

(2) Members of the technical panel need not be members of the full Energy Research Advisory Board.

(c) The activities of the technical panel shall be in compliance with any laws and regulations guiding the activities of technical and fact-finding groups reporting to the Energy Research Advisory Board.

(d) The technical panel shall review and may make recommendations on the following items, among others:

(1) the preparation of the five-year program plan prepared pursuant to section 5;

(2) the type of future facilities needed to meet the goals of this Act along with their projected completion dates;

(3) the adequacy of participation by universities and industry in the program;

(4) the adequacy of international cooperation in magnetic fusion and any problems associated therewith; and

(5) institutional, environmental, and economic factors limiting, or prospectively limiting, efforts to achieve commercial application of magnetic fusion energy systems.

(e) The technical board shall submit to the Energy Research Advisory Board on at least a triennial basis a written report of its findings and recommendations with regard to the magnetic fusion program.

(f) After consideration of the technical panel report, the Energy Research Advisory Board shall submit such report, together with any comments such Board deems appropriate, to the Secretary.

Sec. 8. The Secretary may direct the director of each laboratory or installation at which a major magnetic fusion facility is operated for, or funded primarily by, the Federal Government to establish, for the sole purpose of providing advice to such director, a program advisory committee composed of persons with expertise in magnetic fusion from such domestic industry, universities, government laboratories, and other scientific and technical organizations as such director deems appropriate.

International Cooperation

Sec. 9. (a) (1) The Secretary in consultation with the Secretary of State shall actively seek to enter into or to strengthen existing international cooperative agreements in magnetic fusion research and development activities of mutual benefit to all parties.

(2) The Secretary shall seek to achieve equitable exchange of information, data, scientific personnel, and other consideration in the conduct of cooperative efforts with technologically advanced nations.

(b) (1) The Secretary shall examine the potential impacts on the national magnetic fusion program of United States participation in an international effort to construct fusion engineering devices.

(2) The Secretary shall explore, to the extent feasible, the prospects for joint financial participation by other nations with the United States in the construction of a fusion engineering device.

(3) Within two years of the enactment of this Act the Secretary shall transmit to the House Committee on Science and Technology and the Senate Committee on Energy and Natural Resources the results of such examinations and explorations with his recommendations for construction of a national or international fusion engineering device: *Provided, however,* That such examinations and explorations shall not have the effect of delaying design activities related to a national fusion engineering device.

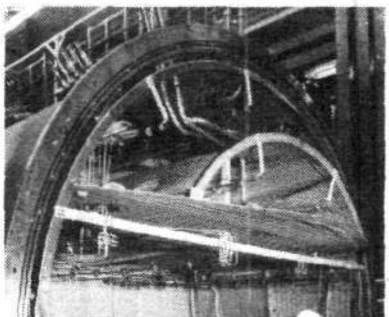
Technical Manpower Requirements

Sec. 10. (a) The Secretary shall assess the adequacy of the projected United States supply of manpower in the engineering and scientific disciplines required to achieve the purposes of this Act taking cognizance of the other demands likely to be placed on such manpower supply.

(b) The Secretary shall within one year of the date of enactment of this Act submit a report to the President and to the Congress setting forth his assessment along with his recommendations regarding the need for increased support for education in such engineering and scientific disciplines.

Information Dissemination

Sec. 11. (a) The Secretary shall take all necessary steps to assure that technical information relevant to the status and progress of the national magnetic fusion program is made readily available to interested persons in domestic industry and universities in the United States: *Provided, however,* That upon a showing to the Secretary by any person that any information or portion thereof provided to the Secretary directly or indirectly from such person would, if made public, divulge (1) trade secrets or (2) other proprietary information of such person, the Secretary shall not disclose such information and disclosure thereof shall be punishable under section 1905 of title 18, United States Code.



LLL

Final cleanup on the tandem mirror experiment at Lawrence Livermore, a promising magnetic confinement alternative to the tokamak.

(b) The Secretary shall maintain an aggressive program in the United States for the provision of public information and educational materials to promote widespread knowledge of magnetic fusion among educational, community, business, environmental, labor, and governmental entities and the public at large.

Reports

Sec. 12. As a separate part of the annual report submitted pursuant to section 801 of the Department of Energy Organization Act (Public Law 95-91), the Secretary shall submit to Congress an annual report of activities pursuant to this Act. Such report shall include—

(a) modifications to the comprehensive program management plan for implementing this Act;

(b) an evaluation of the status of the national magnetic fusion energy program in the United States;

(c) a summary of the findings and recommendations of any report of the Energy Research Advisory Board on magnetic fusion;

(d) an analysis of the progress made in commercializing magnetic fusion technology; and

(e) suggestions for improvements in the national magnetic fusion program, including recommendations for legislation.

Authorization of Appropriations

Sec. 13. (a) There is hereby authorized to be appropriated to the Secretary, for the fiscal year ending September 30, 1981, such sums as are provided in the annual authorization Act pursuant to section 660 of Public Law 95-91.

(b) In carrying out the provisions of this Act, the Secretary is authorized to enter into contracts only to such extent or in such amounts as may be provided in advance in appropriations Acts.

Industry's Role in the

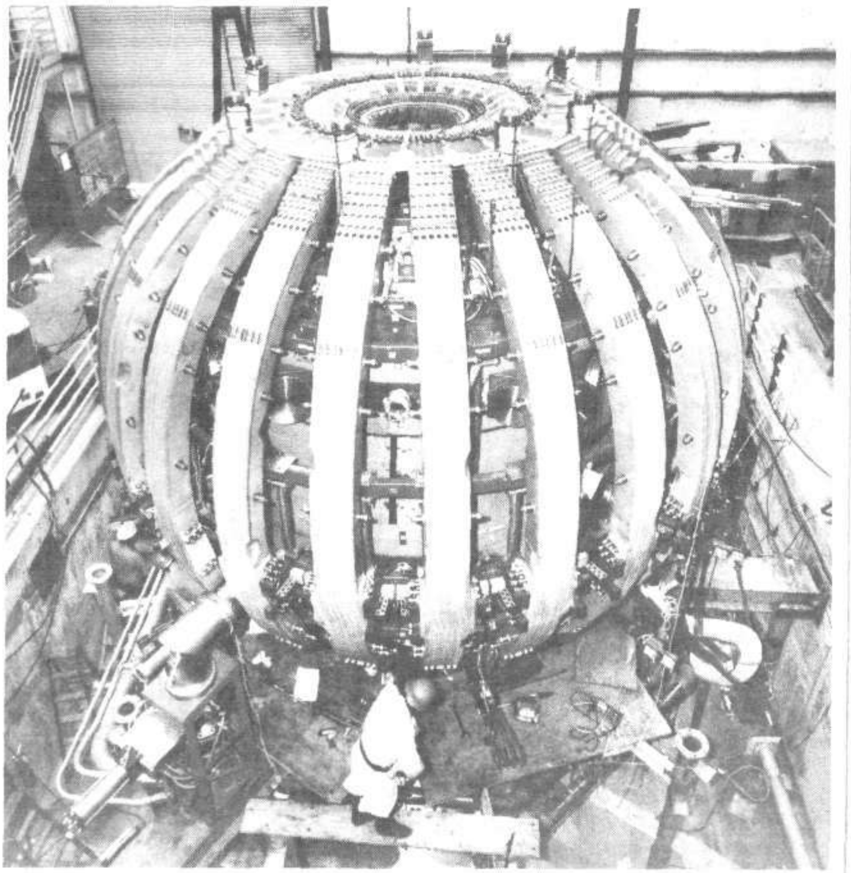
"The special expertise of the nuclear industry, aerospace and electronics concerns, computer firms, all the way to milling and metallurgical companies, will be required to develop and build power systems, special materials, superconducting magnets, special diagnostic equipment and instrumentation, and other technologies."

The government efforts to meet the goals of the McCormack fusion bill will require a large and continually growing involvement of industry in fusion research and technology development, said fusion scientist Dr. Stephen O. Dean in a recent interview: "All the engineering technology needed means getting programs going in the private sector."

Dean was formerly director of the Department of Energy's magnetic fusion confinement programs. He now heads Fusion Power Associates, a consortium of industrial and engineering firms that promotes fusion development.

Today, the U.S. magnetic fusion program is by far the largest and most rapidly progressing advanced research effort in the country. Small advanced-technology firms as well as large aerospace corporations are already essential components of the program. There is also a great deal more involvement of industry that is less conspicuous, according to Dean. In the next 10 years, during which the United States is to complete construction of a fusion engineering device, he forecasts the involvement of both small and large companies from a variety of industrial sectors and the revival of many industrial research and development capabilities that are now idle.

The special expertise of the nuclear industry, aerospace and electronics



General Atomic Co.

The Doublet III tokamak, built by General Atomic Co. in San Diego, an example of private industry's role in the fusion program.

Fusion Program

concerns, computer firms, all the way to milling and metallurgical companies, will be required to develop and build power systems, special materials, superconducting magnets, special diagnostic equipment and instrumentation, and other technologies the need for which only becomes clear in the course of the program's development.

Moreover, as in the NASA program of the 1960s, most of the technologies and materials required for the fusion program will have immediate applications in other areas.

Industrial involvement in the fusion program is nothing new, reported Dean. The first stellarator device in the late 1950s was built by Allis-Chalmers and RCA. United Technologies, predominantly an aerospace firm, just completed construction of a tokamak device at the University of Texas, and has the capability right now to "build a slew of tokamaks if there were a demand for them, here or abroad," he said.

Similarly, the Tokamak Fusion Test Reactor now under construction at Princeton Plasma Physics Laboratory—the first industrial-scale fusion device—is wholly contracted out to private industrial and engineering firms under Ebasco Services, a leading U.S. architectural and engineering design company and a member of Dean's consortium.

In a similar way, Dean indicated, the construction of the Fusion Engineering Device or FED specified in the McCormack bill will "involve many pieces of hardware to be contracted out, through government disbursement directly or subsystem pieces put out on bid by a prime contractor like Westinghouse." By the end of the year, the Department of Energy will have laid out a policy for the next decade, he said. Beyond that, into the year 2000 and the realization of an actual commercial fusion reactor, the requirements are difficult to foresee at this time.

"It is not clear yet how many fusion test devices may be needed," said Dean. "We may require two or three generations of such devices, operating in parallel, rather than going directly from the FED to a reactor."

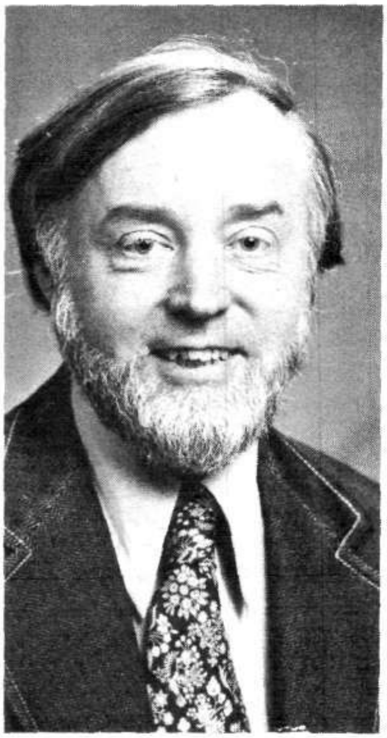
The Status of the Program

At present, the magnetic fusion program, funded by the Department of Energy at $350-$400 million, involves more than 2,000 engineers, scientists, and technicians primarily located at four national laboratories: Los Alamos Scientific Laboratory in New Mexico, Lawrence Livermore Laboratory in California, Oak Ridge National Laboratory in Tennessee, and Princeton Plasma Physics Laboratory in New Jersey.

Major experiments are also being conducted at General Atomic Corporation in San Diego and the Plasma Fusion Laboratory at Massachusetts Institute of Technology in Boston. Smaller efforts are supported at scores of universities and companies that either maintain separate small-scale fusion programs or are contractors for the major experiments underway at national labs.

Involved is frontier research and development in superconducting magnets, high-power microwave generators, large vacuum and refrigeration systems (cryogenic systems), diagnostics, computer control, and advanced materials including metal alloys, composites, and insulators.

Two of the largest and most complex industrial-scale projects in the United States are now being constructed for the fusion program. One is the Tokamak Fusion Test Reactor (TFTR) under construction at Princeton, scheduled for completion in 1982, and the second is the Livermore tandem mirror (MFTF-B) facility to be completed in 1984. The TFTR is being constructed by the Grumman Corporation, the aerospace-defense firm that played a major role in NASA's moonshot program. Ebasco is the primary designer.



Dean: Industry's role in the fusion program is not new.

The Elmo Bumpy Torus is a major alternative confinement concept for which McDonnell Douglas, another aerospace firm, has just won the contract. Most of the funds for this device will go to a score of subcontractors involved in advanced technology areas such as microwave generators. Other major projects, such as the Engineering Test Facility, the Large Coil Project, and the Blanket and Shelf Test Facility, will involve or already involve industrial corporations as the primary contractors.

As this indicates, two-thirds to three-quarters of the $400 million fusion budget goes to industry, either directly or indirectly. To obtain a commercial reactor by the year 2000, approximately $20 billion 1980 dollars will have to be spent, with a higher percentage going to private companies than currently and a greater private industry input and management role, according to Dean.

The Power Supply Industry

Dean gave an example of what would be needed from industry: "Fusion systems require ultralarge power systems. But right now reliability is a major problem. Blowouts, shorts, and all kinds of things can shut down an experiment for weeks or even months. The reason for this is simply that the power heaters or magnets, neutral beam heaters involving 100 kilowatts and up, are now beyond the state-of-the-art.

"If the fusion program's experiments are to progress at the pace required, we need a power supply that works every day for years at a time, not one or two days a week as at present. Industry must develop a power supply that works."

At present, he pointed out, the major companies like General Electric and Westinghouse are "booked up" producing conventional power systems. They do play a role in the fusion program's power systems, which are staged such that a motor generator will produce power for a more power-intensive device, and so forth. The big companies now produce only the first-stage motor generators, while smaller, specialized, high-technology entrepreneurial firms like Universal Voltronics produce the specialized power-generating devices down the line.

The Metallurgical Industry

In other technologies, like cryogenic or super-refrigeration systems, needed to cool superconducting magnets and vacuum systems, the national labs have developed working experimental types, but scaling these up to the size required for a reactor will depend on industrial expertise.

"Whole new alloys must also be developed," said Dean. "Experiments at the national labs will determine the specifications of the needed material. But then, the labs will have to go to the traditional milling and metals manufacturing firms to explain those specifications. They must help us learn how to fabricate the needed materials in a cost-effective way, meaning contracts for research and development."

Dean defined three special contributions that the U.S. nuclear industry could make. First, the industry's developed ability to do "neutronics calculations." High-energy neutrons are the primary, energy-bearing product of fusion reactions, and complex calculations will be required at every stage of fusion experiments to determine how they behave.

Second, the materials used in nuclear plants are precision-made and of higher quality than ordinary construction materials. This will be doubly the case in fusion device construction.

Third is remote handling of intensely irradiated materials. Special capabilities in this area have been developed by both the nuclear utilities and the aerospace firms, the latter for remote handling of objects in space.

The Aerospace Industry

As in NASA's space program, many primary-contractor functions in the fusion program will fall to aerospace firms.

The aerospace and electronics industries spread across the United States represent both a concentration of technology and a strategically located pool of manpower for the expanded U.S. fusion program. In the past, aerospace and electronics have engaged in 50 percent of all the research and development activities of U.S. industry, and have employed nearly 50 percent of the scientists and engineers in all U.S. industry.

Because of the importance of these firms to the economies of a number of regions of the country, their redeployment into the development of fusion power could have obvious, dramatic benefits in terms of employment opportunities in all skill categories in these regions.

Aerospace and electronics have key contributions to make in special materials, superconducting technology, and switching and power storage techniques demanded by the high-pulse energy requirements of fusion reactors. Second, these industries can aid in building the large-scale test reactors for the 1980s and 1990s.

This involves the rapid construction of complex, one-of-a-kind machines—dictated by test results and theoretical work. The experience of the aerospace and electronics firms in the space program makes them ideally suited for this kind of contractual work.

The Computer Industry

As Dean pointed out, "The fusion program at present has the biggest, fastest computer system in the entire country—with all labs hooked up by satellite." Instrumentation and diagnostic equipment must be computerized for high precision in fusion experiments. Computers also play a key role in simulations of plasma behavior.

"To date, the national labs have developed the software for the specialized needs of fusion experiments," said Dean. "The computer firms will have to develop the hardware."

Dean summarized: "Over the next 10 years, the fusion development program will require a lot from the aerospace industry and a lot from the power supply industry. Then there is the vacuum industry, the gyrotron and electronics industry, the high-power tool industry, and the instrumentation and computerized control industry. We'll need a lot from the existing nuclear industry, too. And of course, metallurgy and milling."

In addition, the construction of fusion reactor plants will readily incorporate the present manufacturers of fission reactors, heat exchangers, steam and turbine generators, and related equipment. Some of these industries will have to develop new technologies for manufacturing new magnet and vacuum systems. The chemical extraction and mining industries will be involved in reactor fueling and fuel supply, on-site fuel processing, and special alloys and materials—all told, an unprecedented development of existing industries and the creation of new ones.

—Jon Gilbertson and Vin Berg

A Report on the FPCC Meeting

The Next Step for the Office of Fusion Energy

Edwin Kintner, director of the Department of Energy's Office of Fusion Energy, opened the Sept. 23 meeting of the Fusion Power Coordinating Committee (FPCC) with the statement that "the most significant thing to occur in fusion in the last six months was the release of the Buchsbaum ERAB report." The FPCC is an advisory board to the Office of Fusion Energy composed of national laboratory heads and consultants.

The Energy Research Advisory Board (ERAB) of the DOE, led by Dr. Solomon Buchsbaum of Bell Labs, released its fusion review this past August recommending that the magnetic confinement fusion program under Kintner "is now ready to embark on . . . the engineering feasibility of fusion."

Suzanne Klebe/NSIPS

"This is a hunting license. Now we have to go out and catch something." Fusion Office director Edwin Kintner shown here at hearings on the Senate fusion bill in August.

After reviewing the ERAB conclusions, Kintner reported that the Office of Fusion Energy is responding to the Buchsbaum report "by setting up a fusion engineering device technical management board; we are reviewing the entire program according to the ERAB recommendations, and we are initiating the process to set up a new center for fusion engineering."

Kintner continued: "We will enlarge our university fellowship program, which now includes five students per year."

A point raised by Kintner and stressed by other representatives of the Office of Fusion Energy is that the office is initiating "a basic program parallelism" in which it will undertake "engineering experimentation and analysis" while simultaneously continuing a "broad-based program in plasma confinement" to pursue alternative nontokamak fusion concepts. These include the magnetic mirror, the Elmo Bumpy Torus, advanced tokamaks, and new concepts.

Kintner reported that the "cohesion in the program" among fusion scientists had been a crucial factor in all the initiatives of the past year, moving fusion to the engineering phase.

"Ken Fowler [director of the Livermore mirror program] could have thrown the program by insisting that the Mirror Fusion Test Facility [now under construction] catch up to the tokamak program" as earlier DOE reviews had recommended, Kintner said. Instead, Fowler insisted in his testimony before congressional committees that an accelerated engineering tokamak program could only *help* his mirror effort.

Kintner also made clear that this accelerated fusion program plan still has to be approved by the energy secretary and the money appropriated. "This is a hunting license; now we have to go out and catch something."

The Overall Strategy

Dr. Mike Roberts, director for planning and projects in the Office of Fusion Energy, presented a picture of how the overall strategy for reaching the commercial demonstration of fusion has changed over the past year. Most significant is the acceleration of the fusion timetable from the year 2015 to the year 2000, and a focus on a major assessment of progress in all magnetic fusion devices in 1990.

This 1990 date corresponds to the operation of the Fusion Engineering Device (FED), which is expected to "advance fusion technology" and develop a generic base of engineering/technology that will be applicable to future advanced scientific concepts as well as today's mainline tokamaks. The new program plan outlined by

Roberts would assess progress in 1990, at which time a decision would be made to advance to a demonstration reactor, proceed to an intermediate engineering power reactor, or revert back to more research and development.

It is expected that a variety of magnetic fusion concepts will continue to converge and there is optimism that in 1990 a decision will be made to go ahead with a demonstration power plant.

The Next-Step FED

Dr. John Clarke, deputy director of the Office of Fusion Energy, focused his presentation on the management and definition of the projected $1 billion FED. Clarke reported that he has organized a Technical Management Board, which will "make the overall priority determination for the FED and Intor [International Tokamak Reactor of the International Atomic Energy Agency] efforts and major technical tradeoff decisions affecting the direction of the FED concept evolution."

Clarke outlined a brisk schedule in which the Technical Management Board would screen concepts for the FED, evaluate the engineering and physics questions, and select and present a final FED concept by October 1981. In addition to Clarke, board members include Drs. John Gilliland from General Atomic Company, Lee Berry of Oak Ridge National Laboratory, Robert Conn of the University of California at Los Angeles, and Bruce Montgomery from the Massachusetts Institute of Technology.

Decisions will be made on physics and engineering, parameters for the new device including auxiliary plasma heating, magnetic coil configuration, temperature, and magnetic field parameters.

John Baublitz, Klaus Zilsky, and Gregory Haas, from the Development and Technology Division of the Office of Fusion Energy, gave a detailed picture of the frontier technologies that will need support if the FED is to be realized. Certain components such as superconducting magnets and heating systems (neutral beam, radiofrequency) will need to be designed, fabricated, and integrated into the device. Materials development will be key in aspects of reactor engineering.

In other cases, entire subsystems will have to be developed. These will include systems for controlling impurities, fueling the device, handling tritium, instrumentation, blanket, and shielding systems, maintenance and safety. All three speakers presented very detailed program plans that made clear the pace the work must have in order to be operational by 1990.

Dr. Ann Davies, director of the Tokamak Division, then reviewed the advanced tokamak program. Dr. William Ellis reviewed the important decision to go ahead with the Elmo Bumpy Torus proof-of-principle device (or EBT-P) and to upgrade the Livermore mirror fusion test facility to a more advanced tandem mirror design. Ellis directs the Mirror Systems Division.

Dr. Marshall Rosenbluth, the director of the Institute for Fusion Studies, reported on the progress made to set up this new theory center at the University of Texas and invited those present to consider what questions in the fusion program the new theory center might help tackle.

During the open section of the FPCC meeting, Dr. Al Mense, who is on the staff of Congressman Mike McCormack's Energy Research and Production Subcommittee of the House Science and Technology Committee, stressed that only fusion would solve our energy problems in the long term. Mense remarked that it is important to inform the public of the technological spinoffs from fusion research in the fields of accelerators, magnetic-forming techniques, medical diagnostics, and new materials.

Overall, the excitement of the House's passage of the McCormack bill, the favorable review from ERAB, and the announcement during the meeting that the Senate had passed the bill as well, gave a forward-looking spirit to the meeting and ambitious goals to the fusion community.

—Marsha Freeman

Carlos de Hoyos

Technicians fabricating the coils for the reactor-size Tokamak Fusion Test Reactor under construction at Princeton Plasma Physics Laboratory.

Fusion Press Coverage: Good News Is No News?

Why would so many of the press and media ignore what Congressman McCormack has termed "the most important energy bill passed by this or any other country" while solar energy, conservation, and synfuel schemes still command front-page headlines? One Washington reporter for a national daily newspaper that did cover the signing of the bill offered two explanations:

First, he said about the bill, "maybe it's too good to be true. It's hard for an editor to take seriously something that's going to revolutionize the world tomorrow." Second, he said: "If the *New York Times* doesn't write a front-page article on it, then the Today Show doesn't see it. Then people in St. Louis don't pick it up."

The reporter was half right. The *New York Times* did cover the signing in a surprisingly straightforward article. (Usually the *Times*'s science editor Walter Sullivan reports some version of "many scientists think fusion won't work.")

But the *Times* buried the story on the business page—and neither "St. Louis" nor the Today Show picked it up. In fact, "St. Louis," or, to be more precise, reporters in regional areas across the country that the Fusion Energy Foundation has been in touch with, had no place to get the news except the FEF.

Fusion magazine Washington news editor Marsha Freeman, who toured southern California and the Northwest, reported that local newsmen wanted everything she had on the fusion legislation and complained bitterly that United Press International had nothing but the briefest factual release on the legislation and no background material. Associated Press apparently did not report on the signing at all.

The Coverage

Because the more independent regional press have no real source of information, the national press coverage of the legislation tends to fall into two categories—favorable and unfavorable—with very little in between. The *Christian Science Monitor*, the *Washington Star*, and the *Flint (Mich.) Journal*, for example, applauded the national fusion effort editorially. "This applies a timely spur to the quest for an energy source whose attainment has aptly been compared to the control of fire," the *Monitor* wrote in an upbeat editorial Oct. 9 titled "Forward on Fusion."

The *Washington Star*, in an Oct. 15 editorial called "Power for the Future," notes McCormack's characterization of the importance of the fusion bill and says, "to the extent that the U.S. commitment is genuine—and that the nation understands that the rewards of nuclear fusion depend upon a large, sustained investment of brains and money—the congressman has it right."

As for the bad coverage, the source for such opinions is either gross misinformation ("Fusion would, in fact, pose some major waste disposal problems," wrote the *Toledo Blade*) or zero-growth antiscience thinkers of tne Schlesinger variety who prefer the known energy source of conservation to what they term the "unproved" fusion.

Science magazine, for example, the weekly of the American Association for the Advancement of Science, spent two pages in the Oct. 17 issue snidely denigrating both the energy source ("fusion remains entirely unproved as a source of commercial power") and the bill's chief sponsor McCormack ("he has accepted this dogma since he first began work with nuclear issues on the Hill").

The Schlesinger-style argument was put succinctly by John M. Deutch, former undersecretary of energy, in a *Christian Science Monitor* energy commentary: "It is quite possible that overly enthusiastic proponents will adversely affect the technology. It's being pushed too fast."

The Fusion Energy Foundation has a complete press packet of fusion, the legislation, and what other press have had to say about the bill. If your local newspaper, radio station, or television station has not covered fusion and wants to report some "good" news, tell them to call the FEF at (212) 265-3749.

The Press on Fusion

Yakima Herald Republic (Wash.), Oct. 17, article by Nick Provenza

"Fusion research has the potential 'to revolutionize' agriculture by creating a more efficient fuel for farming," the news editor of *Fusion* magazine said in Yakima Thursday.

"The energy crunch of the future won't be in electricity," said Marsha Freeman, Washington news editor of *Fusion*.

"We have enough coal and nuclear plants for electricity generation until fusion energy comes on line in the next 10 to 20 years," she said.

"The problems will come with liquid fuel. . . . And fusion is going to be the first economical way to produce hydrogen for fuel."

* * *

Oregon Journal, Oct. 16, article by Paul Manley

The Tri-Cities area of southeastern Washington stands an excellent chance of becoming the multi-billion-dollar proving ground for a "Buck Rogers" form of energy development just approved by Congress, a spokeswoman for the Fusion Energy Foundation said Wednesday in Portland.

Marsha Freeman, Washington, D.C. editor of the Fusion Energy Foundation's magazine, said at a press conference that superheated hydrogen, obtained from seawater, is envisioned as a major energy source for many uses by the middle of the next century. . . .

* * *

Tri-Cities Herald, Hanford, Wash., Oct. 10, article by Peter Gomena

The economic importance of the $20 billion fusion energy bill signed by President Carter Tuesday will not immediately be apparent, the Washington, D.C., editor of a national science magazine says. Calling the bill the first piece of positive energy legislation passed by Congress this session, *Fusion* Magazine editor Marsha Freeman said the fusion bill gives the nation's future energy programs direction.

* * *

The *Star-Ledger*, Newark, N.J., Oct. 10, article by Wes Dvorak

A new $20 billion national program to harness nuclear fusion energy holds out the promise that the country will have a source of clean, safe, and nearly unlimited power in 20 years, say scientists at the nonprofit Fusion Energy Foundation.

The New York-based group held a press conference yesterday on the impact of new legislation signed this week by President Carter. . . .

"If we develop fusion now, we have no need to assume a policy of scarcity," said Morris Levitt, director of the foundation. "It allows us to use our available oil and coal resources now."

* * *

TASS news agency, "Outlook for Development of Thermonuclear Fusion in the USA," Oct. 9, article by Vladimir Smirnov

Today in New York the leading scientific research organization, the Fusion Energy Foundation, held a press conference on the signing by President Carter of a bill for the development of thermonuclear energy in the USA. The FEF director, Doctor Levitt, noted at the press conference that by 2000 the USA will be in a position to create an inexhaustible source of energy that will meet the country's energy needs and free it from dependence on imported fuels.

* * *

The New York Times, Oct. 9, article by Robert D. Hershey, Jr.

With little fanfare, the United States has adopted a national plan to develop over the next 20 years a nuclear fusion technology that it hopes will provide an almost inexhaustible source of energy for future generations. . . . Although the bill creating the new United States fusion drive passed by a lopsided 365-to-7 vote in the House and its companion passed by a unanimous voice vote in the Senate, fusion supporters worry about prying the necessary appropriations out of Congress each year.

* * *

Barron's, Oct. 6, article by Roscoe C. Born

Most of the world scientific community now is convinced that the impossible dream scientists have pursued for 30 years will really come true. Fusion power is achievable. It will take billions of taxpayer dollars and 20 years to do it, but it can be done.

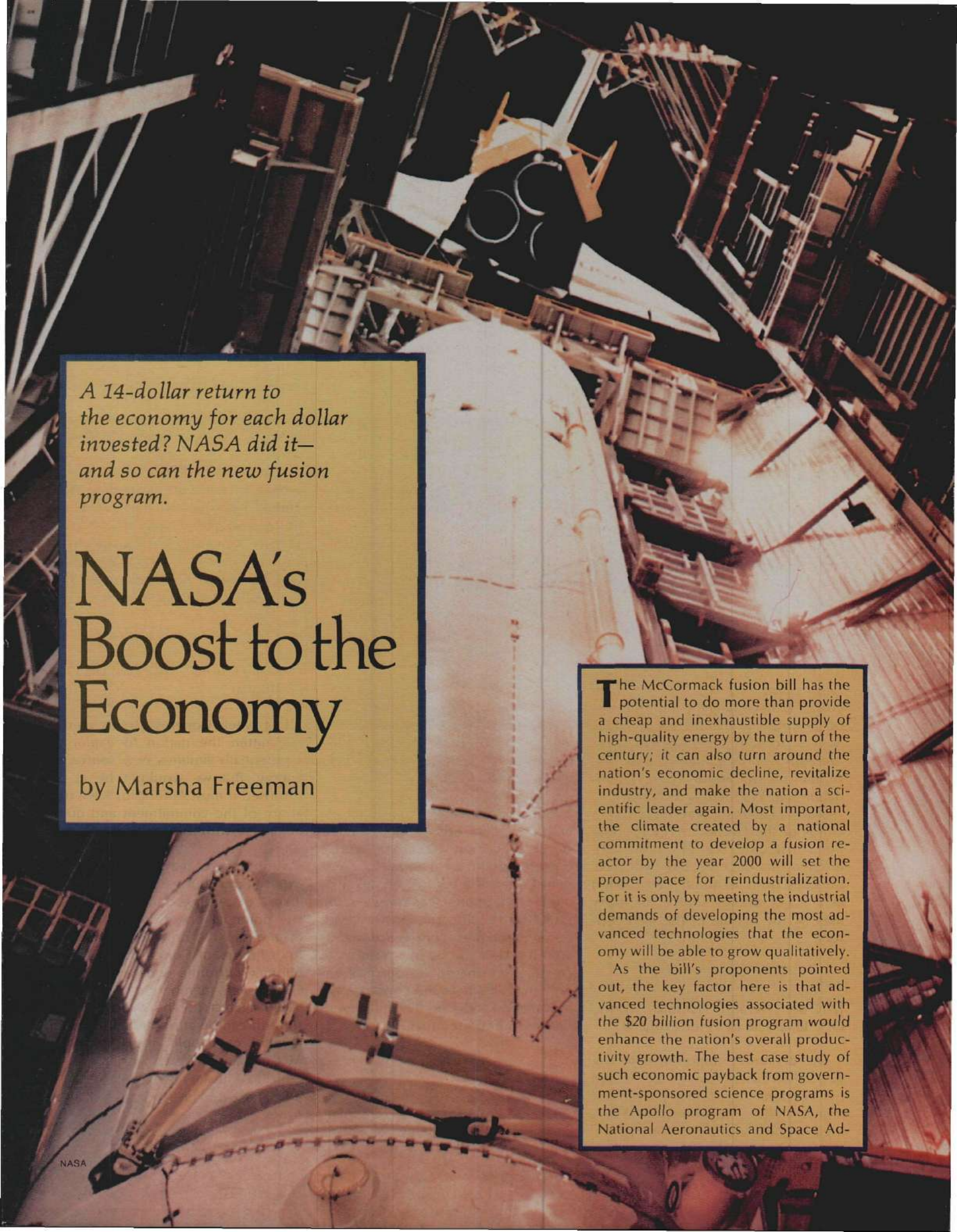
* * *

The *State Journal*, Lansing, Mich., Oct. 2, editorial

Last week Congress, to its credit, committed the nation to exploring a potentially limitless new source of energy. But we wouldn't be at all surprised if most Americans were unaware of the commitment and quite unfamiliar with this promising energy source. . . .

Fusion power may never live up to expectations, but we hardly have the luxury of putting off exploration of any potential energy source of this magnitude. We note that in passing both houses of Congress, the fusion bill met with little debate or dissent. Only seven members of the house voted against it. The overwhelming support can be attributed largely to a handful of people like Rep. Mike McCormack, D-Wash., who led the effort to educate his colleagues. Once educated, people at least will take fusion more seriously.

Continued on page 69



NASA

A 14-dollar return to the economy for each dollar invested? NASA did it—and so can the new fusion program.

NASA's Boost to the Economy

by Marsha Freeman

The McCormack fusion bill has the potential to do more than provide a cheap and inexhaustible supply of high-quality energy by the turn of the century; it can also turn around the nation's economic decline, revitalize industry, and make the nation a scientific leader again. Most important, the climate created by a national commitment to develop a fusion reactor by the year 2000 will set the proper pace for reindustrialization. For it is only by meeting the industrial demands of developing the most advanced technologies that the economy will be able to grow qualitatively.

As the bill's proponents pointed out, the key factor here is that advanced technologies associated with the $20 billion fusion program would enhance the nation's overall productivity growth. The best case study of such economic payback from government-sponsored science programs is the Apollo program of NASA, the National Aeronautics and Space Administration. A study conducted in 1976 by Chase Econometrics, a consulting firm associated with Chase Bank, estimated that for every dollar spent in the program, 14 dollars were returned to the economy in new jobs, factories, technologies, and other economic benefits. However, even this astounding rate of return is probably an underestimate, because the study did not take into account the full, qualitative effects on productivity of the advanced technologies that NASA developed. And despite the fact that the funding for the NASA program has gone downhill since the late 1960s, the enormous range of technologies developed to make manned space travel possible are continuing to have new applications throughout the economy.

Most of today's NASA critics probably have no idea of the tremendous advances made possible here on earth by space technology. The takeoff of the U.S. electronics and computer industries, two leading sectors of the U.S. economy today, for example, was sparked by the Apollo program, as was the development of a long list of advanced products such as remote sensors for monitoring infants in intensive-care units, artificial limbs, and all-weather tires.

But perhaps the single most important economic effect of the Apollo program was the upgrading of science training at all levels of the U.S. education system and the development of a new generation of American scientists. To take one area where this influence has been vital: many of the scientists working in the fusion program on the problems of advanced plasma physics, in materials development, and in other frontier areas got their education as a result of NASA-funded or NASA-inspired science programs. This process of educating future scientific discoverers and the long-term effects of the introduction of new technologies have an incalculable effect on society. As Dr. Lloyd Berkner, former chairman of the Space Science Board of the National Academy of Sciences and one of the leading scientists in the U.S. space program, put it:

> Each new technology derived from science has a permanence that continues to benefit society indefinitely in the future. Thus capital represented by discovery outlives all other forms. Consequently, the investment in basic research should be written off over an indefinitely long time against the permanent gains acquired by society.

The Payback from NASA

When the funding for NASA research and development began to stagnate and then decline in constant dollars starting in 1965, the U.S. economy lost its major source for the infusion of new ideas, new technologies, and new scientists and engineers. The dropoff in productivity growth that became noticeable in the early 1970s was the price paid for downgrading NASA and the nation's commitment to scientific research and development.

The study completed by Chase Econometrics in April 1976 found that federal dollars spent on NASA R&D were four times as effective as other R&D spending and that the applications of technological breakthroughs in the NASA program were visible in the economy within two years of their achievement.

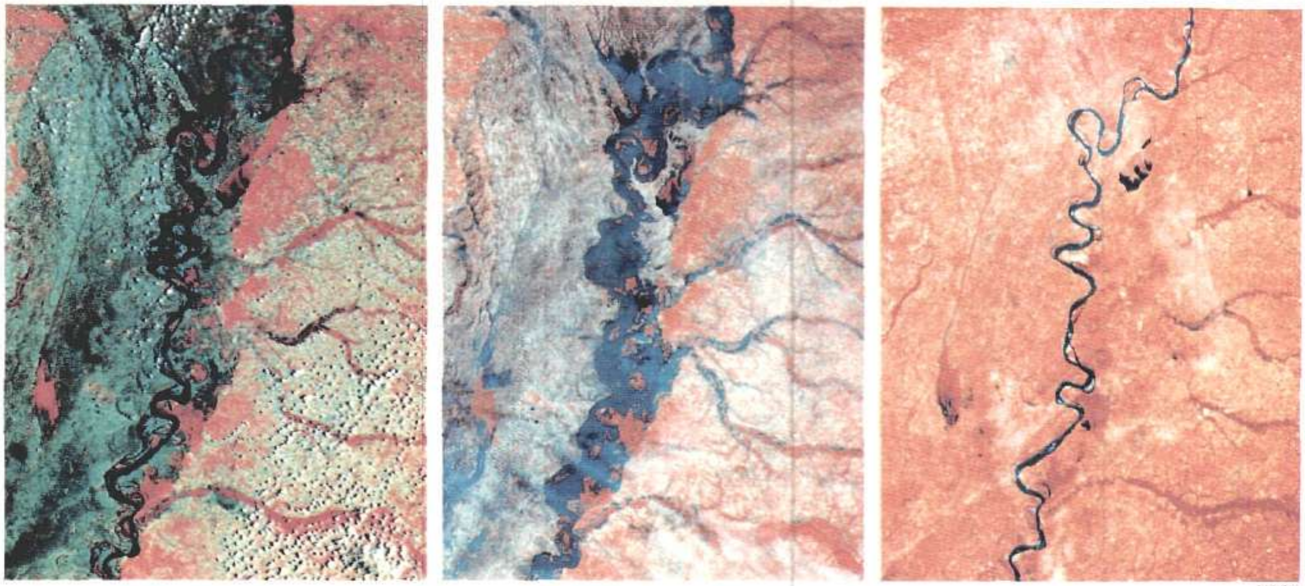
More impressive than any quantitative estimate of the economic impact of NASA spending is the fact that the space program has accounted for every important advance in industry, agriculture, and transportation in the United States from the mid-1960s to the present.

The U.S. edge in electronics and telecommunications stems directly from the miniaturization techniques and reliability standards instituted by NASA. In 1964, NASA established a reliability program and standards for microelectronic products for use in its own programs, which were subsequently adopted by the Defense Department and the industry as a whole. The production of components in accordance with NASA standards reduced the percentage of spoiled parts and increased production yields in the industry by about 20 percent. Today U.S. exports of microelectronic components continue to account for more than two-thirds of the world market.

The takeoff in a related field, the computer industry, was made possible

NASA

Frontispiece: The space shuttle Orbiter Enterprise is lowered into the 36-story test facility at Marshall Space Flight Center. Above: This sophisticated dispatch computer system operated by the Philadelphia Electric Company monitors and controls electric power throughout the company's network. Called SAMAC, System Automatic Monitor and Control, it incorporates technology developed for the Apollo program by Rockwell International and a separate spinoff by Philco-Ford.



NASA

The Landsat satellite program, a NASA spinoff, has the potential to revolutionize agricultural planning. Shown here are composite photographs of the Mississippi River flood in spring 1973, taken by Landsat I. Healthy crops, trees, and other green plants are bright red; suburban areas, light pink; barren lands, light gray; cities and industrial areas, green or dark gray; clear water, black. At left is the flooding near its maximum; the center image shows the extent of flood damage to the lowlands, where most of the farmland is water-logged; the final picture shows the remarkable recovery in the region by late summer.

by the cheapening of semiconductor components and solid-state technologies that resulted from NASA-funded research. There are now 1 million computers in the United States, operating in every aspect of business, industry, and agriculture.

The computer hardware and software developed for space systems have also had specific applications in manufacturing and industrial research. The multiplexer circuit developed for the Marshall Space Center for use in the Saturn rocket was installed in most U.S. textile weaving mills between 1968 and 1971, yielding productivity increases of an estimated 2 to 3 percent.

NASTRAN, a computer software package developed for analyzing the behavior of elastic structures under a wide range of conditions, was released for public use in November 1970. The system, which was developed at the Goddard Center between 1965 and 1970 at a cost of $3 million—an investment no individual firm could afford—is now being used in aircraft and auto production, bridge construction, and power-plant modeling studies.

In the course of producing spaceships that would take men and equipment through millions of miles of hostile environment, NASA researchers had to develop extraordinarily precise, nondestructive techniques for testing reliability and performance standards. An ultrasonic testing technique developed by NASA for $2 million has now turned into an industry with annual sales of $50 million. The testing equipment is being used for quality control in the production of steel, rails, aircraft, nuclear reactors, and automobiles. An infrared scanner and TV display screen developed for the Marshall Center are now being produced commercially by the NASA contractor, who founded a new company called Dynarad, Inc. The highly sophisticated equipment is being used for research in a large number of industries: steel, aluminum, petrochemicals, rubber, nuclear fuels, aircraft, and electrical power; it is also being used in the diagnosis of breast cancer.

Hundreds of materials have been transferred from the space program to industry, including high-temperature resistive alloys and ceramics and radiation-shielding materials for space and nuclear radiation protection. Or to take an example familiar to all automobile owners: The development of a type of rubber that does not become brittle at low temperatures led to the production of all-weather tires.

The technology spinoffs of the Apollo program have begun to transform a number of key sectors of the economy:

Transportation. The techniques developed for guiding and monitoring traveling spacecraft have, of course, been applied to aircraft of all types. They have also begun to be applied to the nation's outmoded and inefficient railroad system with extremely promising results. The most significant increase in productivity in the U.S. rail system in the past 20 years came from the installation of a computerized train dispatching and control system by the Southern Pacific Railroad. The system was originally developed by TRW as the Apollo Guidance System for the Johnson Space Flight Center in the early 1960s and was subsequently adapted for ground transport.

Agriculture. In agriculture, the introduction of remote sensing by satellites has given farmers an invaluable tool for determining the extent of crop damage, the spread of pests, ice accumulation in winter, spring water run-off, and soil condition. Landsat, for example, is revolutionizing agricultural planning.

Weather. Accurate weather forecasting and advances in meteorology, other spinoffs of the Apollo program, have alerted farmers to advancing hurricanes, tornadoes, and destructive rains. Global spot-checking of the growth of crops through meteorological equipment will one day enable farmers to coordinate planting on a worldwide basis.

Medicine. The applications of space-age technologies to medicine have been among the most extensive. NASA imaging technology, designed to develop pictures taken from satellites and spaceships from a distance of thousands of miles, is now used in developing medical X-rays. Artificial limbs were created by applying the remote handling technology developed by NASA and by the Atomic Energy Commission (AEC) for use in nuclear plants. Mass spectrometers preset to collect and analyze the atmosphere, a pilot's breath, the space environment, and the soil of Mars have been modified to measure eight critical components of a hospital patient's breath and emit a signal when any of them fall below critical levels. These spectrometers are being used in 200 intensive-care units worldwide.

In 1968, NASA's Office of Technology Utilization collected reports on the new technologies that NASA had developed with its contractors in order to computerize and index them for further use. Five hundred thousand were cataloged at that time, and new technologies were coming in at the rate of 6,000 per month.

In 1961, at the beginning of the Apollo project, no one dreamed that once the project's goal was accomplished—the landing of a man on the moon—the United States would not continue the manned quest of the rest of the solar system. To go farther than the moon, NASA would need propulsion systems that did not rely on chemical propellants, but on advanced nuclear and fusion plasma systems, and NASA began to develop these. In 1963, NASA and the AEC launched the ROVER project to develop an in-flight nuclear reactor and the Nuclear Engine, Rocket Vehicle Application Program (NERVA) to develop a nuclear-powered engine.

The joint programs were canceled in 1972, even though the initial work showed that the difficult problems of nuclear-powered space flight could be overcome, because no plans were being made for continued manned space exploration.

Both programs had important spinoff applications for the ground-based nuclear industry, however. Work done on compact, high-temperature nuclear fuel arrays led to the development of composite fuel elements, which have been used in safety experiments in the liquid metal fast-breeder program. Advanced reactors in the NERVA program incorporated "beaded" fuel particles—highly enriched uranium cores coated with pyrolytic graphite—embedded in a graphite structure. This approach to fuel fabrication has been applied to use in high-temperature gas-cooled nuclear reactors.

When the NERVA program was discontinued, many of the 450 Westinghouse employees who had worked on the program applied the analytical techniques developed to maintain high reliability and safety in space travel to the Clinch River breeder reactor program, for which Westinghouse was the lead manufacturer.

DOE

The spinoffs from the U.S. fusion program are likely to surpass those of NASA. An immediate technology for development is superconducting magnets. Here a U.S. Air Force C-5 Galaxy transports a huge superconducting magnet fabricated by the Argonne National Laboratory in Illinois. The magnet was sent to Moscow for use in a cooperative program in magnetohydrodynamics.

From the beginning of the space program, NASA scientists were involved in the development of plasma-based systems for space propulsion and direct conversion systems for on-board electrical power. Conferences on plasma propulsion sponsored by NASA through the 1960s drew together scientists from fusion, magnetohydrodynamics, and related fields, and played a significant role in the subsequent progress of both the U.S. fusion and MHD programs.

MHD, a technology for directly converting a hot, ionized gas from fossil fuels, nuclear energy, or fusion to electricity, has used actual rocket engines for testing components of the energy production system. The main laboratory used by the Department of Energy for experimental research on liquid metal MHD systems is NASA's Lewis Research Lab, and all of the work on MHD has benefited greatly from the high-temperature materials developed for space exploration. In addition, NASA's management skills have been applied to the MHD program—NASA's Lewis Lab is managing the next-step Engineering Test Facility for the Department of Energy program.

NASA

NASA's major contribution to upgrading U.S. science education was felt from the top levels of advanced education down to the elementary school level, where the principles of rocketry and space science became classroom topics. Here astronaut candidates are shown in a course at Vance Air Force Base in Oklahoma on what to do if ejected from an aircraft.

When both the space program and the nuclear energy effort were going full throttle, joint work by the AEC and NASA attacked scientific problems and engineering challenges in fusion, MHD, superconductivity, and other frontier areas to create the technologies for the future. This type of cooperative research, which waned with the downgrading of the space effort and the escalating attacks on nuclear power, is a crucial prerequisite for relaunching U.S. R&D to bring whole new energy and industrial technologies into being in the 1980s.

Another crucial prerequisite is building the necessary scientific manpower through upgraded educational programs. The most important effect of the space program—the one with the least measurable but most lasting impact—was the creation of a new generation of scientists. In 1962 NASA set up its Sustaining University program.

The aims of the program were to help finance postgraduate training for young scientists and engineers, to build new research facilities or improve existing ones at colleges and universities, and to distribute funds for space science research.

At the height of the program more than 200 educational institutions were receiving money for space research; 1,500 faculty members and more than 2,000 graduate students in the sciences were engaged in space science and technology research in 1967.

Grants awarded by NASA for research in colleges rose from $3 million in 1959 to $128 million in 1968. Between 1959 and 1969 NASA distributed more than $700 million to university programs. Of this, about $500 million went for direct work on space science projects, and $200 million went for student grants and the upgrading of teaching facilities.

By 1964, NASA was spending $20 million per year just for predoctoral training programs, and 3,600 students were working on space-related problems in 30 academic disciplines under NASA sponsorship.

NASA was simultaneously working closely with the National Science Teachers Association (NSTA) to improve public and parochial school science curricula. In 1960, the NSTA began publication of a series of 13 paperback science books for children. NASA later gave NSTA a grant of $19,000 to develop a science curriculum for kindergarten through grade six called Investigating Science with Children.

Both NASA and the science teachers felt it would be of immeasurable value to give the nation's brightest science students the opportunity to meet and talk with scientists in the space program. From 1963 to 1971, Youth Science Congresses were held at 10 NASA regional laboratories, where the students presented their own papers, heard critiques of their work from NASA scientists, their peers, and science teachers, and visited the NASA labs.

The AEC was also involved in this educational process, and in 1960 initiated a series of National Youth Conferences on the Atom. Financed by 60 investor-owned utilities, the program drew significant interest. However, the change of the title to National Youth Conference on Science and the Environment in 1972 was symptomatic of the bowing of industry to environmentalist pressure.

NASA and NSTA recently revived their program for directly involving the nation's youth in the activities of the space program and are requesting ideas from high school students for experiments to be flown on the NASA Space Shuttle in the mid-1980s. But the momentum behind science education in the United States waned by the late 1960s and has yet to recover.

It will not be possible to move forward in the development of fusion without turning around the decline in science education during the last decade. Recognizing this, the DOE Office of Fusion Energy has established a program for supporting graduate education. Beginning in the coming fiscal year, the program will support the graduate education of a total of five students.

Under the guidelines of the McCormack fusion bill, the DOE must submit to Congress within one year an assessment of the scientific manpower requirements for meeting the goal of commercial demonstration of fusion energy by the turn of the century. The number of scientists in the United States working on the problems in fusion today is not significantly different from what it was two decades ago. Whatever the specific findings and recommendations of the manpower assessment, it is clear that a new generation of young scientists must be created to realize commercial fusion.

The development of commercial fusion power by the year 2000 will have a similar reordering effect on the entire economy as the NASA Apollo program did before it. The job is tougher, for the nation's basic industries—steel and machine tools, to take two examples—have declined precipitously in the last 20 years. But the promise for the economy is even greater, as the combination of an unlimited energy source and myriad new technologies bring the economy to qualitatively new levels of growth and development. In terms of reindustrialization, fusion will be setting the new frontier.

Even before fusion gives the nation the energy required to revolutionize materials processing and every aspect of energy production, the program will have major spinoff applications throughout the economy. A key example is the area of cryogenic technologies:

Commercial-scale magnetic fusion reactors will use large superconducting magnets. Such magnets, made of materials that are kept at a few degrees above absolute zero and operate with almost no energy losses through electrical resistance, are used today in scientific experiments but not commercially. (The exception to this is that Los Alamos Scientific Laboratory has just begun a project to build such a magnet for commercial long-distance electricity transmission.)

Since there has been no large-scale demand for the equipment, no mass production industry has developed to provide it. The special wire for superconducting magnets is fabricated on a made-to-order basis with the magnets wound by hand. But with commercial fusion power plants on the horizon, a whole series of superconducting industries will be required.

The importance of developing industries that can fabricate superconducting wire and cable, produce the cryogenic equipment to store and transport the liquid helium needed to keep the magnets cold, develop the insulation required for all parts of the technology, and integrate and control such a delicate technology is not merely that it will make the large-scale production of magnets economical. All aspects of power production, transport, conditioning, handling, and distribution will be revolutionized through the commercial availability of superconductivity.

Superconducting power transmission systems, laid in underground cables and cryogenically cooled, can eliminate the up to 10 percent loss of electricity now common in electrical transmission lines. Superconducting electrical components such as generators can eliminate losses and extend the life of such components.

The superconducting magnets themselves are also needed for other advanced energy systems, such as magnetohydrodynamics conversion.

Smaller magnets are already being used in advanced no-wheel train systems in Japan, called magnetically levitated trains. Using the electromagnetic fields generated by strong superconducting magnets, rather than wheels and petroleum-based diesel engines, these trains are running at 300 miles per hour and causing no noise or pollution.

Applications of superconductivity have been under development in industry and government laboratories for years. What is needed is the "push" from a government-sponsored research program, which will pay for an accelerated R&D effort—the way NASA did in the fields of computers and electronics.

A fusion-based revitalization of the nation's research and development program will affect every high-technology field in the economy. It will pose the immediate need to get the sagging U.S. nuclear industry back on its feet to make sure the nation can meet the electrical demands posed by a growing economy. This, in turn, will require modernized, efficient steel and machine-tool industries as well as a transportation grid that can carry the new load. The success of the fusion program will also require that we set new timetables for the commercial deployment of advanced nuclear technologies and MHD.

The way to solve economic problems has always been from the top. The NASA program created more jobs than any succeeding government make-work program. It brought more income to American families than any social welfare program. It created a pool of scientists and engineers unmatched by any other peacetime mobilization.

An Apollo-style fusion program, along with an upgraded and revitalized space effort, can provide the basis for an economic boom in the 1980s—and fusion energy in the 1990s.

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

Note

1. For a full discussion of how high technology is essential for real economic growth, see *Fusion*'s special report "The Great Reindustrialization Debate" in the Oct. 1980 issue. The 64-page report is available in reprint from the FEF at $1.25 postpaid. Especially of interest is Uwe Parpart's article "Recovering World Industrial Leadership: The High Technology Path."

Blackbody radiation from magnetized plasmas may turn out to be the ideal driver for inertial confinement fusion.

Combining Magnetic And Inertial Fusion

Winterberg Proposal Opens New Research Directions

by Charles B. Stevens

A KEY TECHNOLOGICAL difficulty in inertial confinement fusion has been in generating the tremendous driver powers required to initially implode the fusion target. Now a radically new method proposed by Dr. Friedwardt Winterberg of the Desert Research Institute in Nevada offers a solution to this problem by approaching it from an entirely different perspective that supersedes earlier methods (Winterberg 1980a, 1980b).

Winterberg proposes using photon compression from a magnetized plasma target to implode a second target of conventional fusion fuel. This offers not only a specific technique (which may or may not prove practical), but an overall concept that could be applied in a variety of ways combining favorable features of both magnetic and inertial confinement in staging configurations. Rather than seeing fusion simply as one form of energy producing another, in the Winterberg concept the fusion process is viewed as a hierarchy of *forms* of organized energy, in which a small magnitude of energy "at the bottom" is amplified and transformed by stages into greatly increased fusion energy "at the top."

Especially if combined with the fast magnetic-liner approach of Soviet fusion researcher Leonid Rudakov, the Winterberg method has tremendous potential for bringing much closer to realization the date at which practical forms of cheap, clean fusion energy could be economically produced on a large scale—that is, if sufficient resources are mobilized to pursue this goal.

The Winterberg concept opens up an entirely new regime of inertial confinement to include crucial elements from magnetic-confinement fusion systems. Conventional inertial-confinement systems use the energy output by a driver (for example, a laser or electron beam) to implode a target pellet containing fusion fuel to the high temperatures and pressures at which fusion reactions occur. But these approaches require a very large power output from the initial driver.

What Winterberg has proposed is the introduction of an intermediate step in which a magnetized plasma target generates blackbody radiation, leading to implosion of a second target pellet of conventional fusion fuel. The intermediate magnetized-plasma step, by generating large amounts of blackbody radiation in the form of soft X-rays, serves as a power-amplifying and transforming phase. The soft X-rays, in turn, compress and heat the target pellet.

Moreover, if the initial target implosion fails to achieve significant energy gain, the soft X-rays generated by that target implosion could be channeled, in turn, as an amplified power source to implode a second, larger target; this method could be carried on in series indefinitely. By *staging* the inertial-confinement process in this magnetized-plasma fashion, therefore, the technological difficulties inherent in the enormous power requirements of the initial driver can be greatly reduced.

Interestingly, there is growing evidence that the Soviet Union is devoting significant research resources and a large part of its fusion research effort along the very lines Winterberg has proposed. At least, Soviet scientists have generated all of the component elements to apply such a method. In particular, certain aspects of the public proposals of a leading Soviet fusion scientist, Rudakov, proposals that have puzzled American researchers, begin to make sense from the standpoint of Winterberg's concept.

In its broadest features, inertial-confinement fusion is based upon the same concepts used in the H-bomb. Hydrogen bombs consist of fusion fuel that is ignited by a nuclear fission atom bomb. Since an atom bomb generates sufficient heat to produce the 50-million-degree Celsius temperatures of fusion ignition, one might simply place an atom bomb next to an assembly of fusion fuel, like placing a match next to dry tinder to start a fire.

In practice, however, this does not work. The very deposition of the heat energy of the atom bomb onto the fusion fuel would simply blow the fuel away long before it could be heated to fusion temperatures. This is especially troublesome because the rate at which fusion reactions proceed is directly proportional to the density of the fusion fuel. Simply heating the fusion fuel leads to its diffusion, with resulting low densities at which the fusion reactivity rate is very low.

The solution is to use the atom-bomb energy output to compress the fusion fuel to high densities before it is ignited so that it will *burn up* before it *blows up*. Furthermore, if we significantly compress the fusion fuel, we need only ignite a small portion of it in order to burn all of it. The reason is that the fusion energy output from this small ignited region is trapped in the cold, compressed fuel, heating it to fusion levels.

This bootstrapping approach actually makes use of a fusion energy-driven burn wave. The fusion products move with a velocity of about 10^9 cm/sec and readily escape from the burning region with virtually no loss of energy. Eventually they stop in the cold, compressed fuel, depositing their energy there.

Taken as a total process, a burn wave moving at up to 10^8 cm/sec through the cold fuel and heating it to fusion ignition temperatures is thus formed. Since the fuel assembly blows up at the speed of sound, or 10^7 cm/sec, the fuel is heated and burned prior to disassembly, given sufficiently high initial densities.

The primary energy output from an atom bomb is ideally suited for efficiently compressing matter to high densities because it takes the form of soft X-rays. The most efficient way of compressing matter is to do it isentropically; that is, the compression process is not allowed to heat the material before it has arrived at the desired density. If the material is preheated, then significantly larger amounts of energy must be invested to achieve a compression to a given density.

Generally speaking, isentropic compression works as follows: shock waves are directed inwardly at a sphere of fusion fuel, compressing it to high densities. When the shock waves converge on the center of the sphere, their energy is transformed into thermal energy, which heats a small core region of the compressed fuel to fusion temperatures. The resulting fusion energy then heats the remaining fuel, and a large portion of the total compressed fuel is burned up.

One of the best methods of generating shock waves for compression of matter is that of a rocket: ablative acceleration. That is, a surface layer of the sphere of fusion fuel is burned off, and the ablative outward expansion of the hot gases acts like the exhaust gases in a rocket to generate an oppositely directed force, which is directed inward in this case. If done with sufficient power, this inward force or pressure is transformed into convergent shock waves, which act in the same manner as a cylinder compressing gas.

The primary soft X-ray energy output from atom bombs is therefore ideal for driving isentropic compression of matter to high densities. Soft X-rays are electromagnetic radiation—photons—whose energy is sufficiently great that they are able to penetrate the low-density blow-off plasma generated during the ablative implosion without losing their energy. At the same time, since soft X-ray photons do not have enough energy to actually penetrate the solid-density fuel, they do not preheat the fuel (preheating would prevent an efficient isentropic compression). As a result, the energy of soft X-rays is deposited at the solid surface of the fusion fuel, the precise place where it will best continue the ablative implosion process.

A second, more complex aspect of the absorption of radiation for ablative rocket acceleration of matter demonstrates the efficacy of soft X-rays for this purpose. Electromagnetic radiation at lower frequencies (that is, longer wavelengths than X-rays, such as the 1.06-micron, neodymium-doped glass laser light), which consists of lower-energy photons, tends to be absorbed (or reflected) by plasmas it strikes at much lower plasma densities.

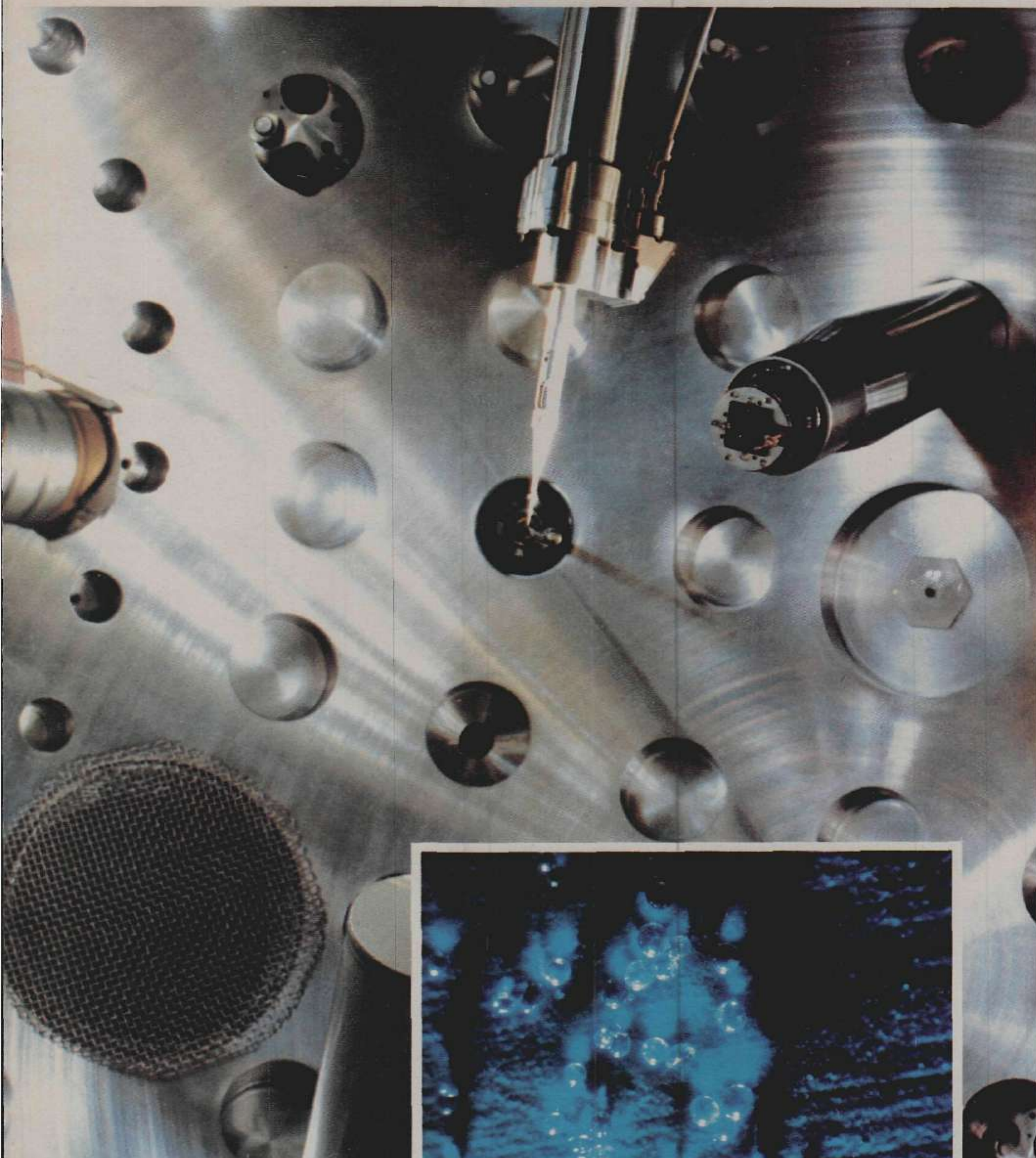
Absorption of radiation at these low densities involves highly complex collective interactions with the plasma. This is because plasmas at low densities become dominated by collective effects and are essentially collisionless. These collective interactions lead to numerous types of plasma instabilities and waves whose net effect is to generate highly organized energy outputs.

Thus, instead of the simple heating produced by short-wavelength, soft X-rays, longer-wavelength photons lead both to greater reflection (loss) of the incident radiation and to the generation of intense forms of energy (either very-short-wavelength, hard X-rays or high-energy electrons). As a result, the efficiency of the ablation process is significantly degraded, and preheating of the interior fuel by the penetration of hard X-rays and "hot" electrons prevents isentropic compression.

From the above, it would appear that to generate inertial-confinement fusion on the microscopic scale would first require replicating the soft X-ray energy output of nuclear fission devices on a small scale. This, in fact, is the key to the new Winterberg concept.

In laboratory inertial microfusion, beams of laser light, electrons, light and heavy ions, or microparticles are used to drive ablative implosions of small pellets of fusion fuel. The projections for these conventional approaches are that the required energy output for the drivers ranges from 10^6 to 10^7 J at a power level from 10^{14} to 10^{15} W, focused down to a target spot size from 0.1 to 1 cm^2. Table 2 summarizes these driver projections for both low and

A needlelike target positioner protrudes from above in this view inside Lawrence Livermore's Shiva laser target chamber. Laser fusion targets about the size of a grain of sand (see inset) are mounted on the tip of the positioner and located precisely in the chamber's center. Shiva's 30 trillion watts are focused from the top and bottom onto the tiny target containing fusion fuel.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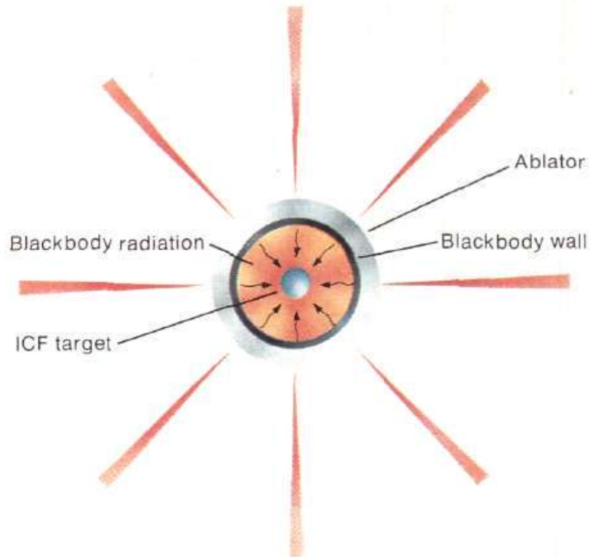
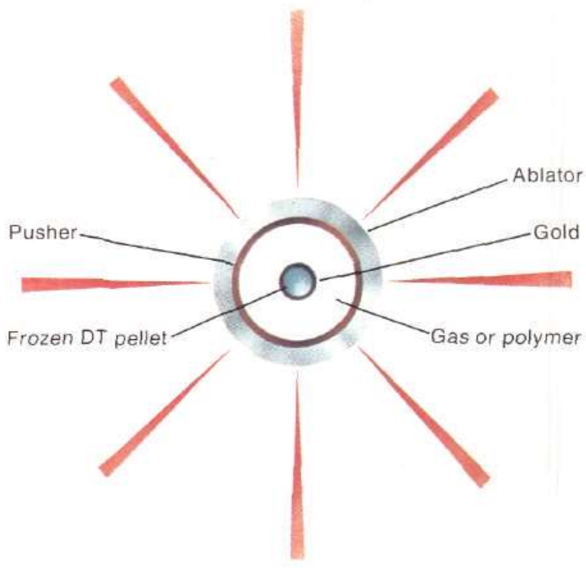


(a) Winterberg blackbody target



(b) Conventional target

Figure 1
COMPARISON OF WINTERBERG BLACKBODY
TARGET WITH CONVENTIONAL ICF TARGET

In a conventional inertial-confinement target, the driver must be powerful enough to directly implode the target pellet. But in the Winterberg photon compression target, the blackbody radiation generated by compression shock waves in a low-density uranium fluoride gas is compressed to great energy densities, which allows for efficient implosion of an ICF target.

high confidence levels for achieving net fusion energy outputs in these systems. Table 1 gives the main advantages and disadvantages of these different driver concepts.

A useful comparison of these different beam drivers can be derived from their energy density ϵ and energy flux density ϕ, which are related to each other by

$$\epsilon = \phi/v,$$

where v is the average velocity of the beam particles moving in the direction of the energy flux; $\phi_{max} = 10^{23}$ erg/cm^2-sec for high confidence levels; and $\phi_{min} = 10^{21}$ erg/cm^2-sec for low confidence levels. Table 3 summarizes the values of ϵ for the different driver concepts for both maximum and minimum values. As can be seen, the largest energy densities occur for the lowest velocity driver, that is, for superconducting macroparticles.

Photon Compression

The Winterberg concept is based on interposing an intermediate step in the inertial confinement process that can decrease the necessary driver energy flux ϕ by a factor of up to 100, and in the process, gain all of the efficient absorption advantages of short-wavelength, soft X-rays. This new step consists of "photon compression."

Instead of directly compressing the fusion fuel, the *primary inertial-confinement fusion driver (projectile, or* laser or particle beam) is used to compress electromagnetic radiation (photons). Then the compressed photons are used to implode an inertial-confinement fusion target in a second stage. The photon compression step acts as a power amplifier and an energy transformer. The primary driver input energy is amplified to higher energy-flux levels and transformed into short-wavelength, soft X-rays.

The scientific parameters for photon compression were developed by Max Planck, the German physicist who discovered the quantum nature of energy at the turn of the century. Planck investigated the thermodynamics of what are now called "blackbody cavities."

The blackbody cavity consists of a hollow sphere of material that absorbs any electromagnetic radiation that hits its exterior (that is, it is *black*). If this sphere is thermodynamically isolated, its interior provides the ideal trap for confining radiation. The radiation energy is unable to escape and, therefore, interacts with the confining wall of material so that an "equilibrium" is set up between the two. The radiation in this equilibrium state has a spectrum covering a wide range of electromagnetic frequencies, *but with most of its energy contained in photons with* frequencies near a particular value. This peak radiation frequency for the blackbody-trapped radiation corresponds to the temperature of the blackbody cavity wall, called the blackbody temperature.

At higher temperatures, the peak value for the radiation frequency increases. The specific relation is given by

$$h\nu = kT,$$

Table 1
ADVANTAGES AND DISADVANTAGES OF PRINCIPAL INERTIAL-CONFINEMENT DRIVERS

Driver	Major advantage	Major disadvantage
Laser beam	Very good beam focusing	Low efficiency, very expensive
Relativistic electron beam	Can be cheaply generated	Poor coupling to target
Light ion beam	Can be cheaply generated	Difficult to focus
Heavy ion beam	Can be produced by conventional accelerator technology	Expensive, accelerator several kilometers long
Microparticle beam	Very good beam energy deposition	Unexplored, unproven accelerator technology
Superconducting projectile	Simple target compression and very good inertial confinement	Accelerator several kilometers long

where h is the Planck constant, ν is the peak radiation frequency, k is the Boltzmann constant, and T is the temperature.

If this blackbody cavity is isentropically compressed, the blackbody temperature will increase according to the following relation:

$$T = (r_0/r)T_0,$$

where r_0 and T_0 are the initial radius and temperature of the cavity, respectively, and r and T are the radius and temperature during the compression, respectively, given at any point in the process.

Physically, the most important aspect of photon compression—and this is the genius of the Winterberg proposal—is the fact that the power density of the blackbody radiation increases as T^4. This is the Stefan-Boltzmann law, which gives

$$\phi = \sigma T^4,$$

where $\sigma = 5.75 \times 10^{-5}$ erg/cm²-sec-°K, ϕ is the energy flux density, and T is the temperature.

As can be readily observed from the two relations, a very small compression of the blackbody cavity results in a large increase in the radiation energy flux.

Figure 1 shows schematically how photon compression can be applied to inertial-confinement fusion. A blackbody cavity containing both blackbody radiation at a relatively low temperature and energy flux level and a conventional inertial-confinement fusion target pellet is ablatively imploded. As the blackbody radiation energy flux increases during the compression, it begins to ablatively implode the inertial-confinement fusion target pellet. Compare this target with the conventional target shown.

A more complex configuration (Figure 2) would consist of a blackbody cavity that has a portion of its wall designed

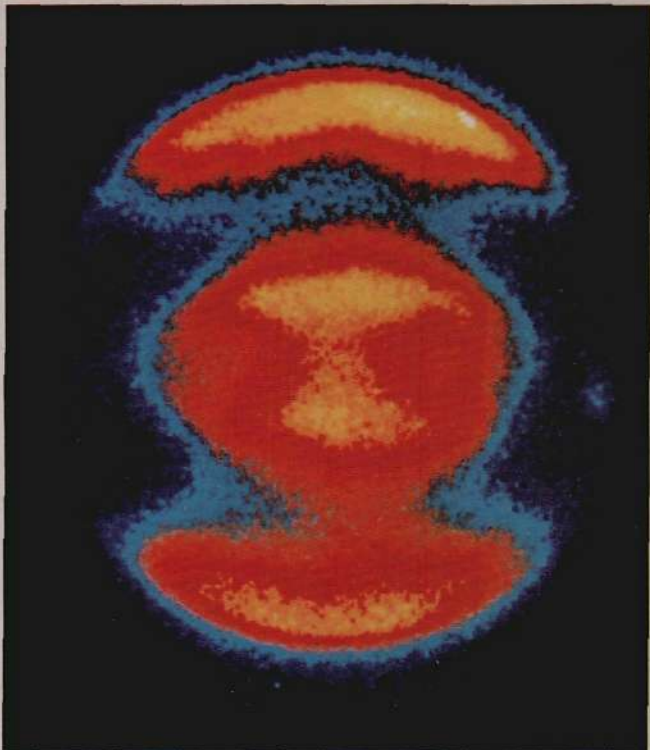
Table 2
INERTIAL-CONFINEMENT DRIVER REQUIREMENTS

	High confidence	Low confidence
Energy (joules)	10^7	10^6
Power (watts)	10^{15}	10^{14}
Power density (W/cm²)	10^{16}	10^{14}

Table 2 summarizes the principal driver requirements for inertial-confinement fusion with high and low confidence levels for success. The required energy ranges from 10^6 to 10^7 J, the power from 10^{14} to 10^{15} W, and the target spot size from 0.1 to 1 cm².

Table 3
ENERGY DENSITY OF INERTIAL-CONFINEMENT DRIVERS

Driver	v/c	ϵ_{max} [erg/cm³]	ϵ_{min} [erg/cm³]
Laser	1	$\simeq 3 \times 10^{12}$	$\simeq 3 \times 10^{10}$
Relativistic electron beam	$\simeq 1$	$\simeq 3 \times 10^{12}$	$\simeq 3 \times 10^{10}$
Light 10-MeV ion beam	$\simeq 1/10$	$\simeq 3 \times 10^{13}$	$\simeq 3 \times 10^{11}$
Heavy 10-GeV ion beam	$\simeq 1/3$	$\simeq 10^{13}$	$\simeq 10^{11}$
Microparticle beam	$\simeq 3 \times 10^{-3}$	$\simeq 10^{15}$	$\simeq 10^{13}$
Superconducting projectile	$\simeq 10^{-3}$	$\simeq 3 \times 10^{15}$	$\simeq 3 \times 10^{13}$



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The fusion process in the small and large. At left: Implosion of a fusion fuel pellet in a Lawrence Livermore experiment. At right: A U.S. hydrogen bomb test in the Pacific.

to burn out when the radiation flux reaches a desired level during the compression. When the window burns out, the compressed blackbody radiation is released into a second chamber containing the inertial-confinement target pellet. In this way, premature implosion of the target at radiation energy fluxes too low to obtain significant amounts of inertial fusion reactions would be avoided.

A second alternative is to design the inertial-confinement fusion target in an onionskin manner, with the outer layers burning off prior to reaching the desired radiation energy-flux levels.

Practical Considerations

Two aspects of the first stage of the photon compression approach must be examined practically. First, how do we obtain the initial blackbody radiation trapped within the cavity that is going to be compressed? Second, how fast must we compress the blackbody cavity if we are to avoid having most of the trapped radiation leak through the cavity wall before the desired energy-flux levels are reached?

With regard to the second question, perfect blackbody materials do not exist. The best approximation is a heavy-element metal like gold, which, because of its large number of electrons and electron energy levels, absorbs radiation over a wide range of electromagnetic frequencies. In any case, in the real world the blackbody radiation photons undergoing compression will tend to diffuse through the cavity wall. Winterberg has carried out approximate calculations for this complex "radiative heat-transfer" problem and found that with implosion velocities in excess of 10^6 cm/sec, a substantial portion of the blackbody radiation remains trapped within the cavity during compression to the desired energy-flux levels.

If this were the only constraint on the system, the needed implosion velocity generated by the primary driver would be decreased by an order of magnitude, compared to conventional inertial-confinement approaches. In those approaches, the driver must directly accelerate the fusion fuel to implosion velocities of 2×10^7 cm/sec (Nuckolls *et al.* 1972). This means that the power flux of the primary driver for the Winterberg configuration can be decreased by as much as two orders of magnitude.

Since the energy-flux level is the primary technological difficulty confronting inertial-confinement fusion systems, this general relaxation of needed power levels through photon compression brings inertial confinement to a point where state-of-the-art conventional methods for achieving these velocities could be utilized together with existing inertial-confinement driver systems.

The first point, how to generate the initial blackbody radiation, is actually the determining step in the first stage of the Winterberg system. It is this step that can directly involve key aspects of magnetic plasma confinement.

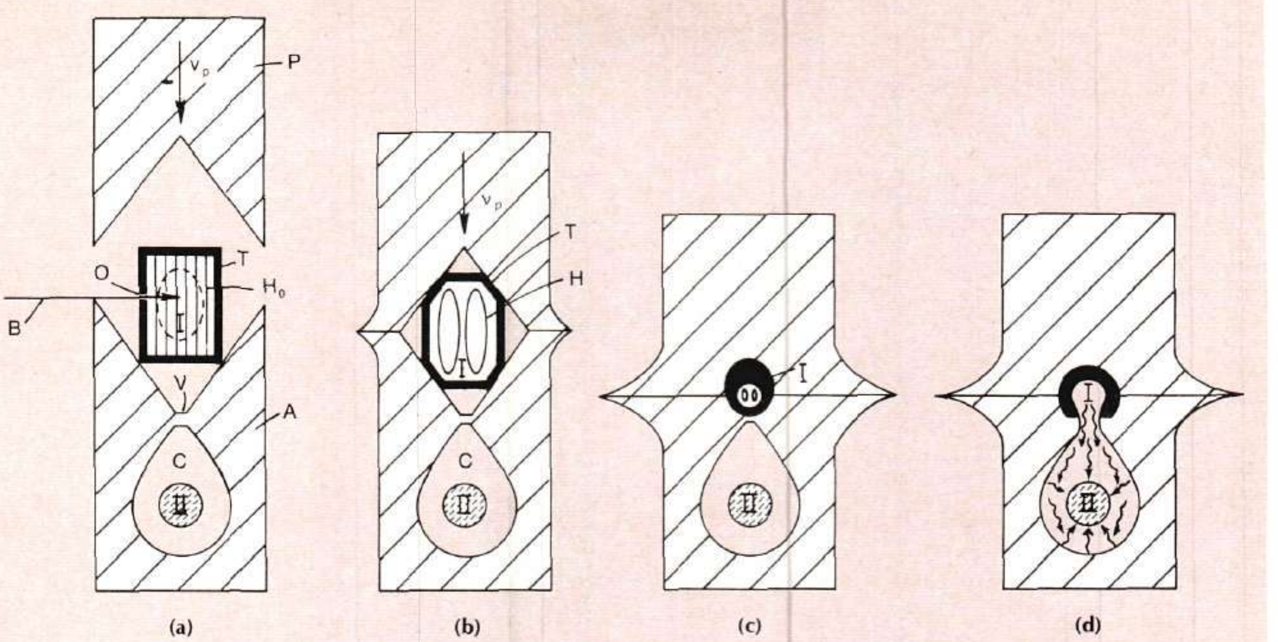

Figure 2
STAGED IMPLOSION USING BLACKBODY RADIATION
In this staged configuration, the magnetized plasma in the first chamber I is imploded by the driver P and burns a hole through the wall into a second chamber C, imploding the conventional target there. The power is greatly increased by the blackbody radiation produced in the magnetized plasma.

In his calculations on photon compression (Winterberg 1980a), Winterberg calls for an initial blackbody temperature of 5×10^6 °K. This is then raised by compression to a temperature of 10^7 °K. This original presentation suggests that the initial blackbody radiation can be generated by an adroit utilization of the initial shock waves produced in the first stages of the cavity implosion.

These initial shock waves will travel faster than the implosion velocity and therefore reach the interior of the cavity before any significant compression has been attained. If we have placed a low-density, heavy-element gas in the container, large amounts of radiation will be generated as the shock wave passes through the gas (Landau and Lifshitz 1959). The blackbody temperature of this released radiation will depend on the shock velocity, which in turn depends on the implosion velocity. Winterberg showed in his papers that in order to obtain radiation at 5×10^6 °K, the implosion velocity must be greater than 5×10^6 cm/sec. This is a fivefold increase over what we found necessary from considerations of blackbody materials alone.

The Magnetic-Liner Approach

An alternative to the shock-generated method of creating the initial blackbody radiation is to place an efficient blackbody radiator within the cavity, which begins to emit radiation when the compression is initiated. Hot, dense plasmas are ideal blackbody radiators. Furthermore, if our hot, dense plasma is trapped within a magnetic field and the walls of the imploding blackbody cavity conduct electricity, the overall configuration that we find is exactly that of the fast magnetic-liner approach (Stevens 1979).

In a fast magnetic liner, the imploding, cylindrical metal liner acts on the magnetic field of the plasma confined within the liner in such a way that its inward motion compresses the magnetic field. The magnetic field, in turn, compresses the trapped plasma. As a result, the density and temperature of the trapped plasma are raised. It has been calculated that in order to generate net fusion energy with fast magnetic liners alone, one would have to make the liner cylinder several meters long (Gerwin and Malone 1979).

A simplified diagram of a fast magnetic-liner configuration is shown in Figure 3. A hot plasma is introduced into the liner in some manner. An electrical current is induced in the metal liner, which generates both a magnetic field within the liner to trap the hot plasma and an external magnetic field to compress the liner.

But when the liner approach is married to Winterberg's photon compression, it is no longer necessary to achieve net energy gains with the fast-liner configuration. For example, one could use the suggested system of Rudakov, the Soviet electron-beam fusion scientist who has recently proposed to use his Angara V electron-beam circuit to drive fast-liner cylindrical foils, with liners as small as 1 cm in diameter and length to produce significant radiation

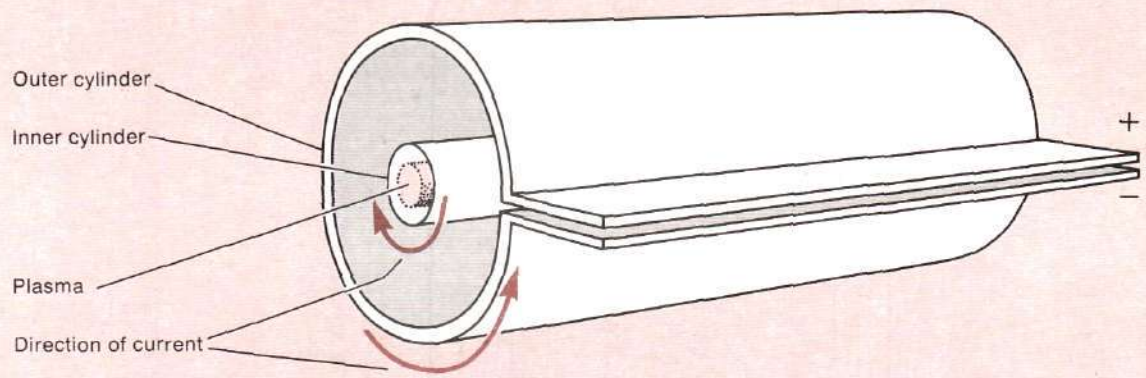

Figure 3
COLLAPSING FAST-LINER SYSTEMS

The current flowing in the outer cylinder in one direction induces a current in the inner cylinder in the opposite direction. This produces a magnetic field that collapses the inner cylinder. The inner cylinder, called the liner, traps the magnetic field within itself as it implodes, compressing it to very high field strengths—millions of gauss. This system provides a conventional method to trap, compress, and heat a plasma to fusion conditions.

outputs, although not total energy gains (Rudakov 1979, Stevens 1979).

The idea is to use the thermonuclear plasma generated by fast-liner compression to generate significant amounts of soft X-rays, and not to produce an overall energy gain at this stage. From the perspective of the second stage of the process, the implosion of the inertial-confinement target with the soft X-rays, the magnetized plasma-radiation step represents a negentropic process even though *no net energy gain is explicitly obtained during this phase.*

Once the blackbody radiation is generated from the compressed fast-liner thermonuclear plasma, this radiation is then permitted to burn a "window" out of the liner wall and into a second chamber containing the inertial-confinement target pellet. From this point, the process is generally "all downhill." Even if the first target implosion (generated by the fast-liner-produced soft X-rays) were not to achieve a significant energy gain, the soft X-ray output of this initial target microexplosion could be used to drive a second, larger inertial-confinement target.

Ironically, the most crucial step in this approach to inertial confinement involves the problem of setting up the initial fast-liner plasma, together with its dynamics, during compression. The type of initial plasma required is a magnetically confined plasma at a temperature of about 10 million °C and at a density of 10^{18} to 10^{19} particles/cm^3. Although an open-ended, magnetic, cylindrical bottle might be sufficient for these purposes, closed magnetic configurations greatly improve the efficiency of the first-stage process, which consists of the fast-liner implosion. That is, a closed magnetic configuration would confine and heat the imploding plasma much more efficiently, leading to a larger fusion burn with a consequent larger radiation output during this first stage.

Fusion magazine and the *International Journal of Fusion Energy* have been at the forefront of reporting research on precisely the type of initial plasma desired (Bostick 1977, Bardwell 1978, Wells and Ziajka 1978, Stevens 1980). The connection to the work of Rudakov—the first to note the desirability of soft X-rays for driving inertial-confinement targets, in 1976—may be most relevant and was first pointed out to me by Winterberg in a private communication.

The Rudakov Mystery

For more than a year, Leonid Rudakov has remarked that his Angara V electron-beam machine could be used to drive magnetic liners as an alternative to conventional electron-beam-driven inertial confinement (Rudakov 1979). This has puzzled many U.S. researchers, because Rudakov's Angara circuit at first glance does not appear well suited for liner implosions. The Angara V puts out an electrical pulse with a high voltage—over 1 million volts. And a high-voltage electrical pulse tends to vaporize the metal liner in the early stages of the implosion.

It has generally been suggested (Gerwin and Malone 1979) that low-voltage, high-amperage currents be used. But as Rudakov points out, it is possible to drive liners with high-voltage currents if "magnetic insulation" (Winterberg 1971), a concept that has been demonstrated on the Sandia proton-beam fusion accelerator, is combined with a system in which the driving current is carried in a plasma sheath along the outer surface of the liner (Alikhanov and Glushkov 1978).

In fact, if one takes what Rudakov has proposed together with the new Winterberg approach, it becomes quite possible that Rudakov is actually carrying out a program along the lines suggested by Winterberg.

This would explain a second outstanding mystery concerning Soviet plasma-physics research. The Soviet Union has maintained a very large, broad-based, high-beta magnetic-confinement fusion program over the past three decades. ("High beta" refers to the fact that the plasma gas pressure is very close to equaling the confining pressure of the magnetic field.) In the United States, research in this area focused on the old Scyllac program, and more recently the reversed-field zeta pinch. In the Soviet Union, however, this program has had no visible mainline focus.

The fact is, in the Winterberg configuration employing fast liners, the critical step is that of setting up an initial plasma properly matched to the characteristics of the imploding liner. What is most essential, then, is precisely the kind of broad-based research effort into the entire field of high-beta, self-organized magnetic-confinement systems that the Soviet Union has been carrying out!

Rudakov does not explicitly locate his proposals in such a context. However, given the high voltages with which he is driving his liner, it would be possible to set up the initial plasma with a breakdown (ionization) of gas within the liner using the high electric field associated with the high voltage. This reminds one of the plasma focus. A number of interesting experiments carried out by Norman Rostoker of the University of California at Irvine appear to be applicable (Shiloh *et al.* 1978).

Conclusion

The scientific and technological problems that must be addressed to fully realize at least one of the large number of possible configurations suggested by the Winterberg concept are by no means simple. By relocating the critical step in inertial-confinement fusion in the realm of highly organized, high-beta magnetized plasmas, we find that fusion research has advanced to a new manifold beyond that first realized when the successful construction of nuclear fission bombs opened up the technology for crude, large inertial-confinement fusion devices (H-bombs).

Although it is next to impossible to give a certain estimate of how quickly the Winterberg system could be demonstrated, since much of the essential raw data and theoretical calculations involved remain buried under top-secret security classification, it is my informed estimate that, given the resources and the right people, no more than five years would be needed to obtain success.

The sad fact, however, is that the environment for accomplishing this does not now exist in the United States. As I have detailed elsewhere (Stevens 1979), the U.S. fast-liner program was sabotaged by former energy secretary James R. Schlesinger, and a Soviet proposal for a joint liner program was squashed for political reasons.

A joint program with the Soviet Union would be enormously beneficial to the United States. As all scientific experts in the field have stated their views, the Soviets are definitely years ahead of the United States in this particular field. Moreover, experts at every major national laboratory reported to me that Schlesinger and Brzezinski never consulted them on the scientific aspects of the matter. Clearly, by engaging in a joint program, U.S. scientists would obtain great insight into the entire Soviet inertial-confinement fusion effort—we would have everything to gain and nothing to lose.

More detailed scoping studies are needed to determine the exact form of practical reactors for electric power production based on this approach. In general, however, demonstration of the Winterberg-liner configuration would make available large quantities of cheap, clean fusion energy. And even in crude, direct applications, the outcome could be a previously unequaled capability for large-scale desalination, canal and tunnel construction, weather modification, *in situ* breeding of fissile fuel, and enhanced production of oil and natural gas.

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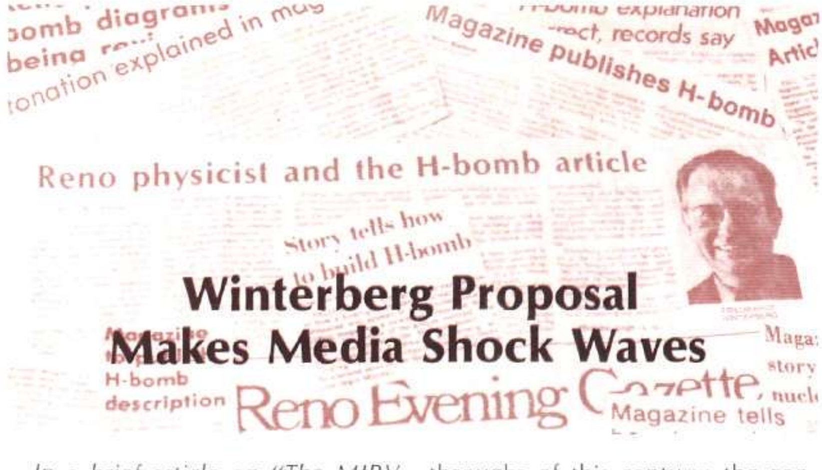


Winterberg Proposal Makes Media Shock Waves

In a brief article on "The MIRV Concept and the Neutron Bomb" in the Oct. 1980 issue of Fusion, *Dr. Winterberg reviewed some of the aspects of the H-bomb that are applicable to inertial-confinement fusion research.*

The national press reaction was overwhelming, focusing on the fact that the article opened up the classification issue that is now strangling research in inertial-confinement fusion for peaceful energy production.

The Peninsula Times Tribune *in Palo Alto, Calif., originally broke the Winterberg story with a Sept. 3 article by Mary Madison titled, "Magazine Publishes H-Bomb Details."*

Among the many papers that picked up the Times Tribune *story was the* Nevada State Journal, *in a Sept. 5 article titled "Reno Physicist's Bomb Diagrams Being Reviewed" by Dick Cooper.*

Dr. Winterberg's reply was published as a letter to the editor in the Nevada State Journal *Sept. 28:*

I wrote the [*Fusion*] article for two reasons. My research work, which you have quoted in your stories, is in reference to initial theoretical work first performed at the Desert Research Institute that has over the past ten years led to a large experimental program. Because of the experimental progress achieved so far there is good reason to believe that we are close to one of the greatest technological breakthroughs of this century: the controlled release of thermonuclear energy, also known as nuclear fusion.

Nuclear fusion will open up a new type of clean nuclear energy source that could last for millions of years. It is the same process by which the sun and stars produce their energy, but it is also the underlying principle of hydrogen bombs. Unlike nuclear energy from fission, it has no large radioactive waste. Unlike solar energy, which is highly uneconomical in most cases, it is cheap. In fact, the entire future of our technical civilization may critically depend on it.

Because of its connection to thermonuclear weapon devices the U.S. Department of Energy (DOE) and its predecessors have persistently tried to retard and restrict scientific progress in this important area of research, in the name of alleged national security.

In suppressing the scientific work of people like me who are not working under direct DOE control, the DOE has excavated a legal dinosaur called the "Atomic Energy Act of 1954." This act in effect tells every citizen that whatever he may invent in the area of nuclear energy is classified in the moment of its inception and can only be made public if and when it has been declassified by the DOE.

Apart from the fact that such a law clearly violates the First Amendment rights of every citizen, it also is completely out of step with the realities of 1980. These realities are that since the inception of the act in 1954 five countries have successfully developed and tested hydrogen bombs. In view of this fact, it is not clear what kind of secret, if any, the government pretends to protect.

The government tries to monopolize peaceful fusion research under the disguise of national security. The arrogant claim by the DOE that it or its large government-funded laboratories are the only places having the right to know about these concepts and are the sole source for such concepts is not only intellectually dishonest but an insult to the intelligence of other scientists.

The reason that not every country is in the possession of thermonuclear weapons has nothing to do with secrecy but is a consequence of the extremely complex and expensive manufacturing process associated with the production of nuclear explosives, which enables only highly industrialized countries to produce these weapons. My article intended to demonstrate that if I can derive how these weapons work then scientists in other countries can probably do the same; it is a delusion that nuclear arms proliferation can be stopped by declaring something secret that has long ago ceased to be a secret. Because of its close connection to peaceful commercial power production the present DOE policy is therefore not only self-defeating but rather against than in the national interest.

Ironically, by imposing secrecy on controlled thermonuclear research for peaceful power production, the government may just precipitate the thermonuclear energy war its secrecy policy seeks to avoid. The Third World wants nuclear energy for its people and views all the attempts by our government to sell them the uneconomical solar energy option as a new form of colonialism. Fusion is also the great hope for them.

—*Dr. Friedwardt Winterberg*

Planck's theory of blackbody radiation 80 years ago posed a problem that has continued to confront 20th-century physicists: Why is energy quantized?

The Original Mystery Of Blackbody Radiation

Its Relevance to Fusion Today

by Dr. Morris Levitt

'[Planck] announced his radiation law before the Berlin Physical Society on October 19, 1900. Then on December 14, 1900 he produced the full theoretical deduction of the law of radiation. This was the birthday of the quantum theory.'

—Memorial to Max Planck
delivered by Max von Laue
Albani Church, Göttingen, October 7, 1947

'Midway through his paper ["On the Theory of the Emission and Absorption of Light," Annalen der Physik, 1906] *Einstein wrote:*

'"We must, therefore, recognize the following position as fundamental to the Planck theory of radiation: The energy of an elementary resonator can take only values which are integral multiples of $(R/N)\beta\nu$ *where R is the gas constant, N Avogadro's number, and* β *a constant. During absorption and emission the energy of a resonator changes discontinuously by an integral multiple of* $(R/N)\beta\nu$*."*

'That passage is the first public statement that Planck's derivation demands a restriction on the classical continuum of resonator states. In a sense, it announces the birth of the quantum theory.'

—Thomas S. Kuhn
Black-Body Theory and the Quantum Discontinuity, 1894-1912

THE IDEA OF USING blackbody radiation as the intermediate "driver" for inertial confinement fusion recalls the history of the blackbody problem, one of many raging controversies that erupted during the 50 years spanning the last quarter of the 19th century and the first quarter of the 20th century. The one individual involved in all of them was the German physicist and Nobel laureate Max Planck. His original solution to the blackbody problem in the year 1900 marked a great turning point in physics. Put simply, the blackbody problem involves the question of why the radiation from a physical object at a definite temperature *T* should always distribute itself in a definite way over the range of radiation frequencies. Planck's revolutionary discovery was that the experimentally measured distribution of blackbody radiation could be accounted for only if the energy associated with radiation processes was always a definite multiple of the frequency. This was known as the *quantization* of energy.

This result was a two-edged sword for Planck. On the one hand, it confirmed his basic belief that the Second Law of Thermodynamics—the maximization of entropy—was an essential guiding principle in physics. On the other hand, it indicated some qualities of physical interaction that would take physics beyond the second law and beyond the paradox that Planck had been unable to resolve: the conflict between 19th-century thermodynamics and the other existing laws of physics. These issues define the questions we will take up in turn to unravel the blackbody story. What is the Second Law of Thermodynamics and under what conditions is it obeyed experimentally and theoretically? How did Planck apply it to the blackbody problem? What was the original form of the quantum hypothesis? How did this lead to Schrödinger's development of the first picture of the quantized radiation process? Finally, what new theoretical issues are involved in the use of blackbody radiation in fusion today?

The simple formula for the temperature dependence of the energy density in a blackbody radiation field, which Friedwardt Winterberg has proposed as the basis for a new approach to inertial confinement fusion,[1] has been known for just over a century. Originally, however, the blackbody problem was a mystery whose solution provided the key to unlocking modern quantum theory, just as research today on the complex problem of the interaction between intense radiation and matter is one of the critical frontiers of science.

Many important details of this story were collected during the 1970s and published in 1978 in the valuable reference work by science historian Thomas S. Kuhn, *Black-Body Theory and the Quantum Discontinuity, 1894-1912.* Reviewing the highlights of that history and extending it to include the broader scientific outlooks of the three men most responsible for transforming the blackbody problem into a quantum theory—Max Planck, Albert Einstein, and Erwin Schrödinger—will give us a better appreciation of the deeper conceptual implications of the Winterberg proposal.

Blackbody radiation is a classic thermodynamic phenomenon; that is, energy is distributed within the *microscopic* domain of the blackbody radiation system in an extremely well-defined way to produce a stable *macroscopic* state. This is, of course, not the usual situation in physical systems; for example, it is not what happens in a plasma undergoing fusion. Usually there is a more complex process in which the very nature of the microscopic states and the interactions among them is evolving along with the global (macroscopic) conditions.

In inertial confinement fusion, the blackbody radiation (or other radiation) acts as a stable form of energy to compress and heat the plasma fusion fuel. Theoretical and experimental studies have shown that this series of plasma states can be quite structured and well ordered, especially if the plasma is magnetized. As I shall show, the general principle underlying this geometrical ordering, the principle of least action, was also at the heart of the development of the quantum theory, which originated in the blackbody problem.

Planck and Thermodynamics

Max Planck's scientific life work was the elucidation and application of the general laws of the science of thermodynamics. As he says in his autobiography, he was filled with awe as a young student in Kiel at the universality and absoluteness of the First Law of Thermodynamics, the principle of conservation of energy. Later, he had no such respect, however, for the views of his contemporaries in the last quarter of the 19th century on the more controversial subject of the Second Law of Thermodynamics, and he appointed himself to explain and establish the second law as a separate counterpart to the first law. In his view, the second law placed further restrictions on the transformation of energy. As he recalls in his *Scientific Autobiography*, his ideas on the subject were set from the time of his first studies of Clausius's classical text as a physics student in Munich, beginning in 1874:

> What I particularly admired was the exact formulation of the two laws of thermodynamics and the pioneering demonstration of the sharp separation between them. Previously, as a consequence of the material theory of heat, the opinion had been current that the transmission of heat from a higher to a lower temperature was like the sinking of a weight from a higher to a lower altitude, and this erroneous view was not easily suppressed.

Planck's commitment to the distinct status of the second law was key, particularly his belief in the independent thermodynamic variable of entropy (as the counterpart to energy) and in the primacy of thermodynamic processes that were irreversible because of the necessary *increase* in entropy. This set him apart at first from many of his colleagues and ultimately permitted him to open the way to solution of the blackbody problem.

The Second Law of Thermodynamics, as I have described elsewhere, holds under restricted rather than universal conditions.[2] To mention some important exceptions to the second law: Riemann's work on shock waves and subsequent investigations by others in many fields of physics have demonstrated the importance of isentropic processes; that is, the linking of qualitatively different states of matter with *no* increase in entropy.[3]

Thermodynamically, entropy is most simply defined as a parameter of a physical system when the state is produced by a reversible exchange of heat Q with some surrounding medium at temperature T. The change in entropy ΔS is simply the amount of heat exchanged by the system divided by the temperature:

$$\Delta S = \Delta Q/T. \tag{1}$$

For more general irreversible processes, this simple equality no longer holds and the second law, according to Clausius and Planck, is stated as a restriction on the entropy change in relation to the heat exchanged in the form of the following inequality:

$$\Delta S \geq \Delta Q/T \tag{2}$$

or $\Delta S \geq 0$ for an isolated system where no heat is exchanged. This is usually known as the law of increase of entropy. Planck's statement of the law is most explicit in terms of the connection between change of entropy and irreversibility: "The process of heat conduction cannot be completely reversed by any means."

The entropy-increase principle as the basis for the second law was the subject of Planck's doctoral dissertation at the University of Munich in 1879. According to Planck, no one at the time understood his work or even tried. Kirchoff, whose radiation law inspired Planck's interest in the blackbody problem, disagreed that entropy could be applied to irreversible processes. Clausius refused to answer his letters or to meet with him at his home in Bonn. Planck later commented that the best way to get new scientific theories accepted was to have their opponents die off!

In pushing his ideas on the second law, Planck was treading on a scientific terrain filled with epistemological and political land mines. He strode through it boldly, however, publishing a major paper in 1885 with a title sure to rile everyone, "The Nature of Energy." The work established him professionally, and he was given an associate professorship in Kiel. Just how controversial the subject was, however, can be seen from the fact that his paper won *second* prize in the 1887 competition of the philosophical faculty at Göttingen, although no one else won a prize.

In addition to the prize, Planck won some friends in Berlin; two years later when Kirchoff died, Planck was appointed to the major chair in physics in Berlin.

Beginning somewhat earlier, Ludwig Boltzmann, almost alone, pioneered the definitions of entropy in terms of atomic dynamics and statistics. If the thermodynamic system is a gas of molecules, and $f(v)$ is the distribution function that specifies what fraction of molecules lie in the range dv about the velocity v, he showed that entropy can be simply expressed in terms of that function.

If, on the other hand, the gas is specified by the number of possible molecular arrangements in the microscopic phase space that is consistent with a given macroscopic (thermodynamic) state, this number of "complexions," W, defines the entropy as a *combinatorial* (statistical) quantity via the relationship

$$S = k \log W, \tag{3}$$

where k is some constant.

This is the form ultimately used by Planck to correctly describe the blackbody problem. Einstein later showed that this probabilistic definition of entropy is proportional

Max Planck: The Man & the Scientist

Burndy Library/Courtesy AIP Niels Bohr Library

Max Karl Ernst Ludwig Planck (1858-1947)

Planck's 1900 quantum hypothesis had two crucial aspects: first, that microscopic amounts of energy and action must take on definite, discrete values; second, that these energy quanta are organized as a totality, distributed in an orderly way over possible frequencies according to a definite "statistical" law.

This provided for the first time an experimentally grounded theory to directly validate Leibniz's principle (expressed in his *Monadology*) that physical action is a self-differentiating process characterized by indivisible units. Planck called this result the "physical structure of phase space," which also implicitly verified Riemann's basic concept of the complex "relativistic" geometry of physical space.

Originally a strict, classical thermodynamicist, Planck was forced by the revolutionary developments of the early 20th century (which included his own work) to recognize that there was a deeper lawfulness underlying the classical theory. His commitment to the principle of causality later brought him into opposition to the irrationalism of Bohr's "Copenhagen School" in the 1920s, just as he had opposed Mach and the mystical energeticists in the 19th century.

Planck's principled life was not without other controversies. As a devout Christian and German patriot, he made no secret of his opposition to the Nazis. Even though Planck was the dean of German physicists, he was granted only one meeting with Hitler, which consisted entirely of a screaming tirade by the dictator against Germany's most respected scientist. And shortly before the end of World War II, Planck's son was murdered by the Gestapo. Never recovering from this blow, Planck died shortly after the war.

His name lives on in West Germany's most prestigious scientific institutions, the Max Planck Institutes.

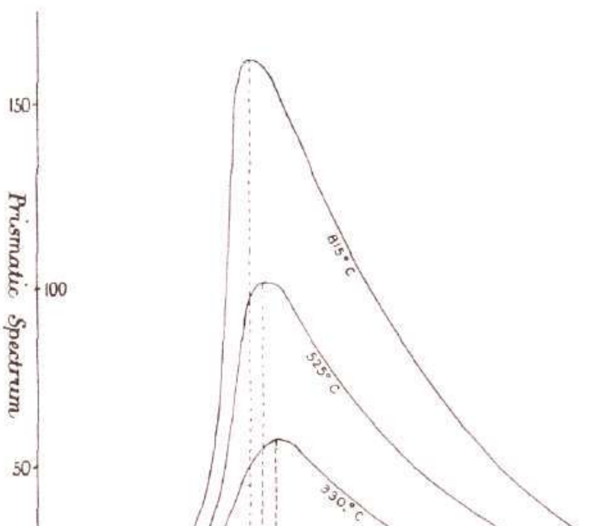


Figure 1
EARLY BLACKBODY DATA

Shown here are some of the earliest experimental data on blackbody radiation (beginning in 1886) taken by the American astronomer S.P. Langley using a blackened copper radiator. Langley's data show the typical shape of blackbody radiation at a given temperature. The crucial result is that as the temperature increases, the overall amount of energy significantly increases and the frequency at which the maximum energy is emitted also increases in a definite way. The vertical axis is proportional to the energy intensity. The horizontal axis is proportional to wavelength, and inversely proportional to frequency.

Planck's theoretical derivation of the blackbody radiation distribution law involves two basic results. The first is that the energy associated with light of frequency ν *can only have the value* $nh\nu$, *where* n *is an integer and* h *is Planck's constant. The second step is the calculation of the possible ways that the total radiation energy can be distributed among these quantized energy states. The peak tends to occur as shown at intermediate frequencies. There is little energy at the ends of the spectrum because at high frequencies there are many possible quantum states, but a very low probability of populating them, while the opposite is true at low frequencies.*

to the volume of phase space associated with a thermodynamic state.

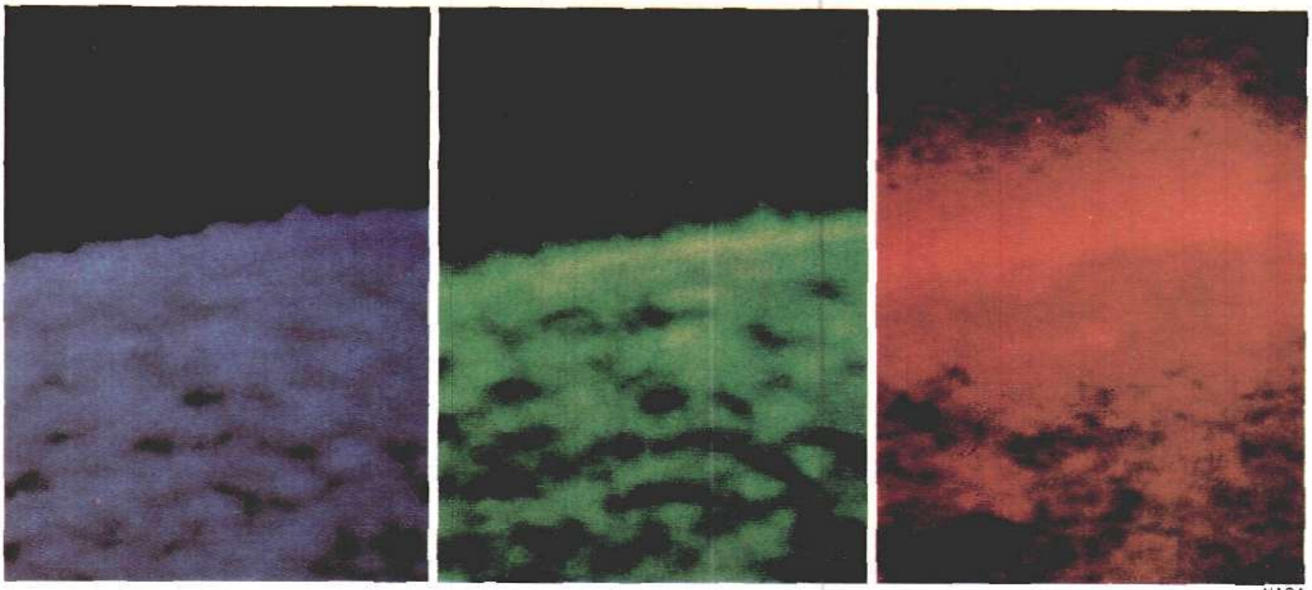
Although this is fine for defining equilibrium states and showing that entropy is maximized at equilibrium, the more difficult problem is how to demonstrate that for an arbitrary initial state, entropy must increase until it is maximized—as the equilibrium state is inexorably reached. Boltzmann was able to demonstrate in his famous H-theorem how this occurs for a gas in which the entropy is defined by the distribution function.

It can be shown that the entropy continually increases until it and the function *f* reach their equilibrium values, respectively, only if the distribution function obeys a simple kinetic equation—the Boltzmann equation—for the way it varies in time and space until a uniform equilibrium state is achieved. This is not the most general dynamical equation even for a gas, however. It holds only for the special situation of a gas that is not too dense (so that molecules that collide cannot escape from the collision region or phase space cell in which the collision occurs) or too dilute (so that there are large deviations of quantities like *f* from their average values within a small cell). Even then, the Boltzmann equation depends on statistically averaging over the microscopic dynamics.

This still leaves the following problem: If a thermodynamic transition indicated by $(A \rightarrow B)$ or the associated trajectory in the multidimensional phase space (phase space is a geometry constructed out of the microscopic dimensions of a system such as position and velocity of the various atoms) is such that the entropy increases, then the opposite trajectory with initial state B and final state A *in which entropy decreases should be physically allowed* as well, because the trajectory in phase space is dynamically reversible. (That is, the equations of motion are termed *time reversible*.) This point, known as the *reversibility paradox*, was pursued forcefully by Zermelo, Loschmidt, and Poincaré. It also was recognized by Planck, who took it to prove the impossibility of an atomistic or statistical basis for the universality of the second law. Instead, he sought such universality in nonlinear interactions within a *continuum* of matter and energy.

The real problem, however, still remained: The elementary reason that the Boltzmann equation leads to the Boltzmann H-theorem result and avoids the reversibility paradox is that the equation itself is not time reversible, because of its built-in averaging. However, while most physical processes involving "many-body" systems do not satisfy the conditions for Boltzmann's H-theorem, they are, nonetheless, as Planck perceived, irreversible. *Thus, the reversibility theorem is no more a general law of nature than is the Boltzmann H-theorem and the Second Law of Thermodynamics. Both are based on oversimplified physics.*

This implies a deeper relationship between collective and microscopic behavior. The interaction either can drive the system toward a stable configuration or can produce irreversible qualitative changes—in either case with or



NASA

The principle of the blackbody relationship between temperature and dominant wavelength is illustrated by these pictures of various layers of the Sun. Each picture is taken at a different ultraviolet wavelength in order to "see" just the solar layer at a corresponding temperature. The layers shown are, from the left, the high chromosphere at 70,000 °K (blue), the chromosphere-corona transition region at 300,000 °K (green), and the even hotter inner corona (red). The colors shown are not the true temperature characteristics, but are added for visual clarity.

without increases in entropy. Later, after his work on blackbody radiation had set the stage for quantum theory, Planck termed this underlying microscopic situation "the physical structure of phase space."

The remainder of this article will describe the partial success in solving this problem for the case of blackbody radiation and the nature of the more general problem involved in irreversible processes.

Planck and the Blackbody Problem

The problem in physics that forced the resolution of the issue of the relationship between thermodynamics and microscopic radiation processes was the blackbody radiation distribution. A blackbody is an object like a cavity at a definite temperature that can absorb and emit radiation at all frequencies and that is in thermodynamic equilibrium with a radiation field with which it is exchanging energy. The key question about the blackbody radiation is how the energy in the field would distribute itself among the various radiation frequencies from zero to infinity. In the 1880s, only fragments of the theoretical and experimental answers were known.

By the 1890s, four important preliminary results had been established by a combination of general thermodynamic arguments and the first crude experimental measurements of the properties of the blackbody radiation field:

(1) *The Kirchoff radiation law* (1859-1860) stated that the intensity of radiation K (the amount of energy passing through unit area in unit time) at a particular wavelength in a blackbody field depended only on the wavelength and the temperature and not on any peculiarities of the cavity or its materials. This intensity, designated as $K_\lambda(T)$, was thus a universal function.

(2) *The Stefan-Boltzmann law* for the total energy density u in the field as a function of temperature indicated that it varied as

$$u = \sigma T^4, \tag{4}$$

where σ is a universal constant. This was based on Stefan's empirical extrapolations of 1879 and Boltzmann's thermodynamic analysis in 1884 of the work done by a radiation field in a variable cavity, which made use of the important relationship between radiation intensity K and radiation energy density u:

$$u = 4\pi K/c. \tag{5}$$

(3) *The Wien displacement law*, developed by Wilhelm Wien of Munich, indicated that the wavelength at which the maximum energy in the blackbody field was concentrated varied inversely with the temperature according to the law

$$\lambda_{max}\, T = \text{constant}. \tag{6}$$

This follows from the more general Wien displacement law (1893) that the energy density was a function of a single variable (λT).

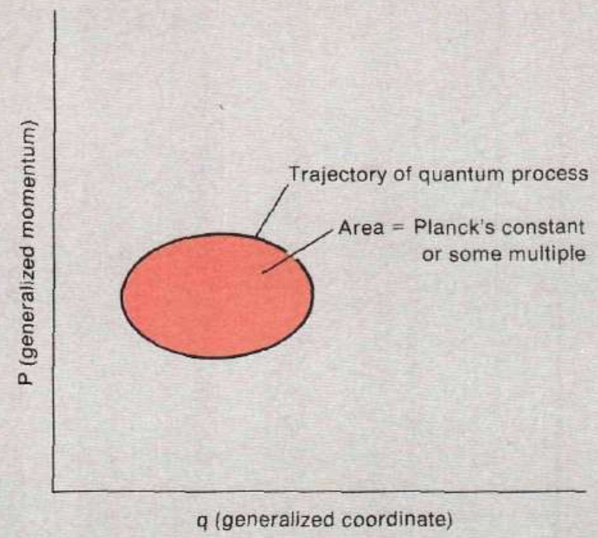


Figure 2
QUANTIZATION OF ACTION IN PHASE SPACE
Planck's result that energy is proportional to a definite constant (Planck's constant) times frequency also has a basic geometric consequence in phase space. Any physical process such as an oscillator or atomic orbit that has a closed path in phase space encloses an area that has dimensions that are the same as the physical quantity called action. In fact, it follows that the enclosed area must be the product of some integer times Planck's constant. Schrödinger showed, however, that the idea of a raylike path in phase space was no longer valid.

Wien was later to be one of the first proponents of the quantum theory that flowed from Planck's later work and a staunch defender of Schrödinger against Bohr's attacks. Wien's law, like Boltzmann's, was based on thermodynamic arguments.

(4) *The Wien distribution law.* During the same period, Wien also put forward a specific distribution law based on his own speculations and contemporary proposals by Paschen:

$$K_\lambda = b\lambda^{-5}\, e^{-a/\lambda T}. \qquad (7)$$

By the 1890s, Planck had achieved some notable successes with the application of the second law to such problems as electrolytic solutions. But the three-way dispute with the energeticists (whose homogenized energy concept accepted neither the second law nor the reality of atoms) and Boltzmann on the second law and its dynamical basis seemed increasingly sterile, promising to produce "nothing new" for science. The blackbody problem, however, stood out as offering a crucial and decisive testing ground for the outstanding theoretical questions. Planck, the successor to Clausius as the leading German theorist of general thermodynamics, was convinced that the correct distribution law could be obtained from proper application of the second law.

The two results that Planck later cited as being most important in directing him to complete dedication to the problem were measurements of the thermal spectrum of bodies by O. Lummer and E. Pringsheim of the German Physico-Technical Institute and Kirchoff's law. Although improvements in the former at the end of the century were to be decisive for forcing Planck's ultimate breakthrough, at first no other motivation was required than Kirchoff's law—namely, in equilibrium the spectrum of radiation produced by bodies in a perfect cavity depends only on the equilibrium temperature. As Planck recalled ". . . this so-called Normal Spectral Energy Distribution represents something absolute, and since I have always regarded the search for the absolute as the loftiest goal of all scientific activity, I eagerly set to work." His research began in earnest in 1894.

Wrapped up in this search for the absolute were also all the issues that were in dispute among the leading physicists of the late 19th century: the relationship between the second law and the microscopic laws of interaction and the basic forms of matter and energy.

The general model that Planck had in mind was that the interaction between an electric dipole oscillator (representing the atoms in the cavity walls as an idealized mechanism for redistributing energy in the field) and the field was an irreversible scattering process that would redistribute the energies at various frequencies and maximize the entropy of the blackbody radiation. Thus, he undertook a scrupulous study of the problem of an oscillator interacting with an electromagnetic field.

Although several years' work was invested, the results were inconclusive, and his five-part series of articles "On Irreversible Radiation Processes" is now of more historical than scientific interest. Planck was able to show that the details of how the interaction between the field and the oscillator was damped out did not affect the result. But he was unable to avoid the devastating conclusions that absorbed and emitted radiation frequencies were the same, and therefore, that special conditions were required to trace any irreversibility in the field spectrum.

In particular, Planck found that no approach to an entropy-maximizing equilibrium was possible unless he averaged over the short time fluctuations in the radiation field. This description, which he judiciously termed "natural radiation," was the equivalent of Boltzmann's assumption of "molecular disorder" within phase-space cells in order to obtain the gas-kinetic H-theorem. Thus, Planck, like Boltzmann, was detoured into a statistically based H-theorem, rather than a rigorous demonstration of the second law from dynamical first principles.

Even so, Planck's incredible tenacity within what finally turned out to be a dead-end approach nonetheless by 1899 produced an equilibrium distribution function of exactly the same form as the Wien distribution.

Planck did not have long to reflect on the failure of his main purpose—to develop an electromagnetic H-theorem—or on the fact that Boltzmann in 1898 demonstrated that such a result was impossible. Speculations on the remarkable analogy between his results and Boltzmann's were soon overshadowed by new experimental results. These showed conclusively that the Wien distribution law, and therefore Planck's derivation as well, were wrong!

Remarkably, even before this occurred, Planck had returned to his original methodological approach in order to be prepared for whatever might come. After his and Boltzmann's demonstrations that there were no fundamental irreversible reactions between electric oscillators and radiation fields, Planck began to recognize "that in the chain of argument an essential link was missing which should lead to the comprehension of the nature of the entire question."

The Thermodynamic Approach

At this point, Planck recounted, "I had no other alternative than to tackle the problem once again—this time from the opposite side, namely, from the side of thermodynamics, my own home territory where I felt myself to be on safer ground." The new starting point was "the idea of correlating not the temperature but the entropy of the oscillator with its energy."

Thus, at the critical juncture, thermodynamics offered Planck what he perceived as the key link in the blackbody problem: the relationship between energy and microscopic interaction as communicated to the macroscopic level by the entropy term. Specifically, he postulated that thermodynamics most directly connects to the blackbody distribution function through the second derivative of entropy with respect to energy, "for it is this differential coefficient that has a direct physical significance for the irreversibility of the exchange of energy between the resonator and the radiation." (The first derivative is the rate of change of the entropy for a given change in energy, and the second derivative is the rate of the rate of change of the first derivative.)

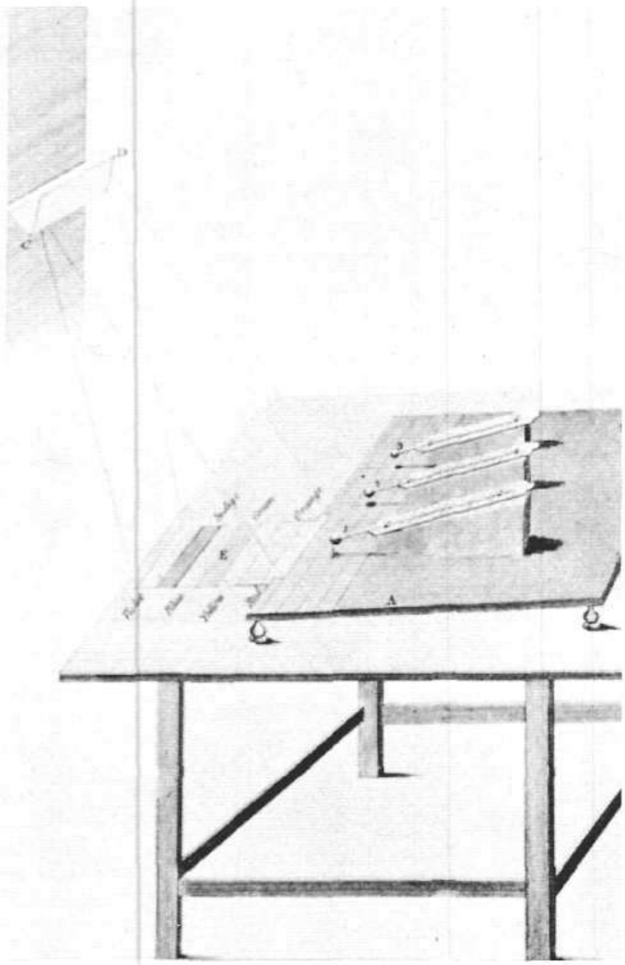
With this approach, Planck was readily able to use thermodynamics to obtain the Wien distribution function. Soon, however, Wien's law was found to break down at large values of energy and at long waves (the two "ends" of the distribution). Lumer and Pringsheim found this first, followed by H. Rubens and F. Kurlbaum, who performed the decisive experiments on infrared radiation from fluorspar and rock salt.

Planck was ready. In his thermodynamic derivation of Wien's law, he had demonstrated that the old data implied that the inverse of the second derivative of entropy with respect to energy was just proportional to the energy. The new results—which deviated from the Wien law by a resounding 50 percent—required the reciprocal of the same derivative to be proportional to the *square* of the energy.

By integration of the expression obtained by summing these two results (actually integrating an interpolated sum of each term multiplied by an unknown constant), Planck obtained an expression for the derivative of energy with respect to entropy. Then, using the basic thermodynamic expression that this derivative also equals the temperature, Planck was at long last able to write the correct distribution function:

$$K_\lambda = C\lambda^{-5}/(e^{C/\lambda T} - 1). \qquad (8)$$

The result was presented to the Berlin Physical Society on October 19, 1900. The experimentalists verified that it gave the best fit to the new data. However, Planck was still not satisfied. "So long as it [the new distribution law] had merely the standing of a law disclosed by a lucky intuition," he wrote, "it could not be expected to possess more than a formal significance."



The original apparatus with which the English astronomer William Herschel in 1800 measured the energy intensity of sunlight at various colors. Light is passed through a prism and falls on strips that are connected to different thermometers.

Immediately, Planck set out to find the "true physical meaning." It was an effort that he subsequently described as "some weeks of the most intense work of my life." Planck reported the results in a second extraordinary presentation to the Berlin Physical Society on December 24, 1900. As Max von Laue later stated, it was "the birthday of the quantum theory."

Although historians have often quoted Planck's statement on the strenuousness of these last days of the year 1900, his full remarks are much more exciting: "After some weeks of the most intense work of my life clearness began to dawn upon me, and an unexpected view revealed itself in the distance." It was a view that, fittingly, depended critically on all the years of work and debate on the oscillator-radiation problem and Boltzmann's combinatorial approach to the second law. But above all, it depended on a new insight.

The critical new element Planck introduced in order to obtain the proper high-frequency behavior was the additional assumption that in calculating the entropy from a combinatorial standpoint, the oscillator phase space must be divided into a distinct grid, corresponding to a series of oscillator energy levels given by

$$\epsilon_\nu = nh\nu . \qquad (9)$$

This provided the correct distribution function—as spelled out in Equation 8, but with the exponential term now further refined in the form $e^{h\nu/kT}$.

Planck was perhaps even more excited that the constant h—which now immortalizes its discoverer as Planck's constant—had the dimensions of a universal constant of *action*. The other constant in his theory k, now ironically known as Boltzmann's constant—provided the other dimensions required to construct for the first time a full set of consistent physical laws and units of measurement for those laws and their associated constants.

Planck's result established that energy and temperature were connected by Boltzmann's constant. The absolute values of energy were determined by Einstein's relativity theory. Nernst's theorem of 1906 also made it possible to specify absolute values of entropy, since it was demonstrated that the value of the entropy of any physical system at the absolute zero of temperature was itself zero.

Planck's constant h determined the "elementary region" of phase space, and thereby the quantization of action, the dynamical quantity whose central role in macrophysics and microphysics will be discussed shortly. As Planck pointed out, the advent of relativity theory revealed that "the amount of action contained in a space-time element can be expressed by a perfectly definite number and thus is deprived of its former relative character." Planck had good reason to see a new, more unified picture of physics emerging. The problem that still remained, however, as Planck wrote, was that "either the quantum of action was only a fictitious magnitude—or a true physical concept. If the latter . . . [it would] transform completely our physical concepts which since the introduction of the infinitesimal calculus by Leibniz and Newton have been founded upon the assumption of the continuity of all causal chains of events." In other words, if energy cannot be infinitely subdivided, how are physical events causally connected across the "gap"?

The reality of the quantum was soon established in different types of experiments ranging from the Franck-Hertz result of 1914, which directly measured the quantum of action by electron bombardment of atoms to produce photons from excited states, to Millikan's measurements confirming Einstein's interpretation of the photoelectric effect as indicating quantization of electromagnetic energy, and a broad range of results on the specific heats of solids as a function of temperature. Perhaps the most striking phenomenon was the discrete series of lines in atomic radiation.

Atomicity was established even before these results, when Rutherford and Geiger had measured Boltzmann's constant in experiments on alpha particles in 1908, upsetting the great atomist Boltzmann's conviction that the mass of an atom could not be accurately measured.

The new scientific battleground of the 20th century quickly became the epistemological interpretation of the quantum raised by Planck's remark on continuity. One side in the dispute consisted of scientists who at first did everything possible to obscure Planck's result. In the early part of the century, the famed British scientists Lord Rayleigh and Sir James Jeans, both leading spiritualists and ether-theory mystics, took up the blackbody problem. They assumed a mechanical model of the excitations of the electromagnetic field to obtain the density of modes as a function of frequency. Then they assigned the normal thermodynamic energy of equipartition, kT, to each mode. This led directly to what has since been known as the Rayleigh-Jeans distribution law

$$u_\nu = (8\pi\nu^2/c^3)(kT). \qquad (10)$$

Although this law matched the Planck function in the low frequency range, it predicted a blowup of energy in the high frequency range. This embarrassing theoretical circumstance was dubbed "the ultraviolet catastrophe."

It was Einstein who provided the powerful and elegant formulation of statistical mechanics required to show the relationship between the simplistic Rayleigh-Jeans law and the more general Planck distribution. Einstein showed that if a large number of resonators were present, the way in which a fixed amount of energy would be distributed among them depended on whether the energy levels of the oscillators took on continuous values or were definite multiples of the oscillator frequency. The former case gave the Rayleigh-Jeans law and the latter the Planck distribution.

The actual form of the Planck-Einstein photon quantum statistics underlying the blackbody radiation distribution is also most important for the application proposed by

Winterberg. No matter how the photon energy may be redistributed after the blackbody field is initially formed, it obeys a general redistribution law called the Liouville theorem. The practical result is that the energy density propagating in any direction remains equal to the blackbody density; no matter what focusing may be used to concentrate the radiation, the effective radiation temperature cannot exceed the blackbody temperature.[4]

Thus, the energy-densification associated with the T^4 dependence of the blackbody radiation field is not only produced but also maintained by the underlying quantum processes and statistics.

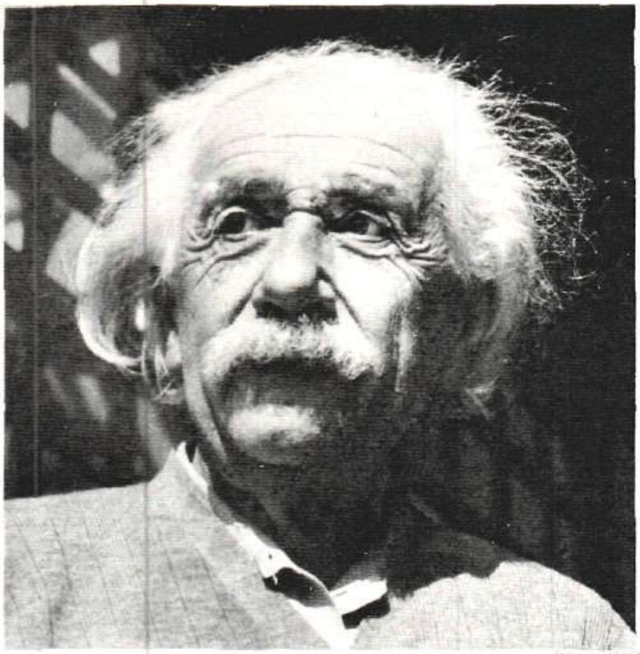
For his part, Planck gradually became more explicit in his support for the general quantum hypothesis, always concerned to prevent any exploitation of his theory that might be used to introduce elements of arbitrariness into physics. By 1910, the quantum hypothesis was almost universally accepted, but with two quite different schools of thought shaping up.

Planck, Einstein, Wien, and their colleagues focused on the quantum result as evidence of a more thoroughgoing absolute causality and a more complex structure of matter and energy that was yet to be comprehended. The opposite faction was exemplified by Sir James Jeans, who until that point had clung to mechanical ether models and the principle of equipartition (equal distribution) of energy among the assumed vibrational modes. By 1910, when this position clearly became untenable, he unceremoniously became a convert to the quantum hypothesis. For the next decade, he coordinated all British scientific intelligence on the quantum aspects of radiation. This led directly to the reduction of quantum theory to a new set of inexplicable "rules" through the program initiated by Niels Bohr in the second decade of the 20th century.

In his Nobel Prize address in 1920, Planck explicitly criticized Bohr's quantum theory, which was essentially based on nothing more than extending Planck's elementary quantization of action to the values of action for atomic orbitals, without any physical theory for why that should be so. Planck pointed out that Bohr's theory could not account for why the electrons in their quantized orbits did not radiate, or why the frequency of light emitted from atoms was different from the frequencies of the electronic orbitals. He sternly cautioned that "the mere introduction of the quantum of action does not yet mean that a true quantum theory has been established."

Schrödinger and Wave Mechanics

The first steps in the theoretical approach demanded by Planck were provided by the Austrian physicist Erwin Schrödinger in a series of landmark papers in 1926-1927. By that time Einstein's postulated quantization of light had apparently been demonstrated by Compton's 1922 experiments on light scattering from atoms, while Davisson and Germer had shown in 1926 that de Broglie's 1915 theory of matter waves was confirmed by crystalline diffraction of electron beams.



Wide World

Albert Einstein (1879-1955)

Despite major contributions to blackbody theory in 1905 (photoelectric effect) and 1916 (light absorption and emission), several years before his death Einstein commented, "If anybody tells you that he understands what $E = h\nu$ means, tell him he is a liar."

Before meeting Planck's challenge for a real quantum theory, Schrödinger had demonstrated how the Planck-Einstein statistics for the energy distribution of oscillators (now known as the Bose-Einstein statistics for photons) could arise from multiple wave excitation.[5] The wave approach, in fact, was already firmly embedded in the most advanced formulation of classical dynamics—the Hamilton-Jacobi theory—developed by Riemann's teacher, Jacobi.

Schrödinger noted most emphatically at the outset of his historic series of papers founding quantum wave mechanics that his work represented a continuation of the 19th-century school of geometrical and wave mechanics:

> The *inner* connection between Hamilton's theory and the process of wave propagation is anything but a new idea. It was not only well known to Hamilton, but it also served him as the starting point for his theory of mechanics, which grew out of his "optics of nonhomogeneous media." Hamilton's variation principle can be shown to correspond to Fermat's *Principle* for a wave propagation in configuration space (q-space), and the Hamilton-Jacobi equation expresses Huyghens's *Principle* for this wave propagation. Unfortunately this powerful and momentous conception of Hamilton is deprived, in most modern

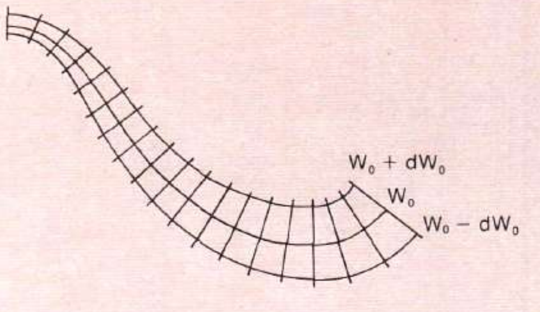


Figure 3
SCHRÖDINGER'S DRAWING OF LINES OF CONSTANT ACTION IN PHASE SPACE

This drawing, taken from Schrödinger's collected papers on wave mechanics, shows for a hypothetical physical system a series of curves each of which corresponds to a definite value of the action term. By reconsidering the relationship between these action curves and the related trajectory in phase space of a physical system, Schrödinger found a way to incorporate Planck's result described in Figure 2 into a new microscopic description that assumed that the action contours shown here moved not only in the way shown but also oscillated in time (as light does as it propagates). From this standpoint the energy levels of a simple atom were found to be related to an atomic configuration of standing waves and the Planck relations for the radiation process emerged as a natural related feature.

reproductions, of its beautiful raiment as a superfluous accessory, in favor of a more colorless representation of the analytical correspondence.

Schrödinger then explained how this past correspondence between a well-defined path or ray in phase space mechanics and geometrical optics must be extended to a correspondence between the more general case of physical optics rather than purely geometrical optics and microscopic, or quantum, mechanics:

> The Hamiltonian analogy of mechanics to optics is an analogy to geometrical optics, since to the path of the representative point in configuration space there corresponds on the optical side the light ray, which is only rigorously defined in terms of geometrical optics. The undulatory elaboration of the optical picture leads to the surrender of the idea of the path of the system, as soon as the dimensions of the path are not great in comparison with the wavelength. Only when they are so does the idea of the path remain, and with it classical mechanics as an approximation; whereas for "micromechanical" motions the fundamental equations of mechanics are just as useless as geometrical optics is for the treatment of diffraction problems. In analogy with the latter case, a wave equation in configuration space must replace the fundamental equations of mechanics.

Schrödinger further emphasized that the development of quantum theory had been held back by the erosion of this outlook: "Felix Klein has since 1891 repeatedly developed the theory of Jacobi from quasi-optical considerations in non-Euclidian higher space in his lectures on mechanics," but in 1901, Klein had remarked that his lectures 10 years earlier at Halle, in which he had emphasized the great importance of Hamilton's optical works, had not been adequately appreciated.[6]

In the Hamilton-Jacobi formulation, it is the action term (see Figure 3) that determines the changing curvature of phase space and thus the "least action" path actually followed in the phase space of a mechanical system. (The action term is most simply defined as the product of net mechanical work performed in a given time interval multiplied by the time.) This is closely linked to the fact that all the explicit time-dependence is also contained in the action term. Schrödinger posed the possibility that the time might enter more directly, if the action term were also a factor in the phase of any wave excitation.

Thus, if simple waves like sinusoidal waves were excited on a phase space manifold and are of the form

$$\psi = \sin(\omega t - W/h), \qquad (11)$$

and if the action has the simplest form for its time dependence, $W = Et$, then it follows from the harmonic properties of phase space that $E = h\nu$, the condition originally postulated by Planck and Einstein for the black-body problem.

We now bring the story full circle. With this approach, Schrödinger was able to develop a generalization of the Hamilton-Jacobi equation, now known as the famous Schrödinger equation, which describes the quantization of microscopic processes as a natural by-product of oscillations in phase space. Planck's constant also enters in a natural way because the wave theory is still essentially based on the universal *principle of least action*, although in new form. In his first paper, Schrödinger summarized the picture of quantized atomic structure and of the process of radiation that emerges:

> The notion of whole numbers . . . is not introduced [arbitrarily]. Rather when integralness does appear, it arises in the same natural way as it does in the case of the node-numbers of a vibrating string.

Because the atom itself (the "oscillator" of the Planck problem) is some sort of stationary distribution of materialized electromagnetic energy (like a plasma), or of coupled interaction between stationary states:

> The emission frequencies appear therefore as deep "difference tones" of the proper vibrations themselves. . . . One only needs to imagine that the light wave is causally related to the beats, which necessarily arise at each point of space during the transition; and that the frequency of the light is defined by the number of times per second the intensity maximum of the beat process repeats itself. . . .
>
> It is hardly necessary to emphasize how much more congenial it would be to imagine that at a quantum transition the energy changes over from one form of vibration to another, than to think of a jumping electron. The changing of the vibration form can take *place continuously in space and time.*

Schrödinger finally took note of the fact that after a transition the light energy is irreversibly carried away. His theory, like all earlier dynamics, could not account for that result, which he wisely left to future developments. Nevertheless, he had provided the first physical model of the processes involved in radiation and hence in creating the blackbody field.

A New Set of Problems

As Schrödinger pointed out, there were far more general forms possible for the wave equation, beginning with the addition of nonlinear terms. Despite many theoretical advances since then, it still remains an open question of what more powerful generalization of the principle of least action to high-order manifolds is required to account for particles, fields, and their interactive modes. The problem has two levels.

First, the existence of elementary particles and basic constants is far from explained. Second, in fluids and plasmas, the problem of discontinuities in phase space may be even more complex.

In each case what is needed is a positive conception of the physical structures (whether individual particles or collective states such as solitons) that appear as mathematical singularities or discontinuities in the present theories. This requires further fundamental advances in mathematical physics.

The use of blackbody radiation in fusion raises a new set of problems to be solved concerning the relationship between thermodynamics and microscopic physics in such complex situations. What Planck foresaw even before the emergence of the present incomplete theories, as he stated in the conclusion to his 1920 Nobel address, remains equally true today:

> There can be no doubt that science will someday master the dilemma, and what may now appear to us *unsatisfactory will appear from a higher standpoint as* endowed with a particular harmony and simplicity.

Morris Levitt, an atomic physicist, is the executive director of the Fusion Energy Foundation.

AIP Niels Bohr Library

Erwin Schrödinger (1887-1961)

Uniquely combining the Austrian tradition of Boltzmann's atomism and the Göttingen school of geometrical mechanics, Schrödinger developed the first detailed theory of microscopic dynamics and atomic structure. Like de Broglie, he recognized that his result accounted only for "first-order" effects and that a more general nonlinear "equation of motion" is required. The more fundamental insight into this problem is the Riemannian conception that quanta, as well as their statistics and dynamics, are the physical existences characteristic of action in higher-order manifolds.

Notes

1. The Winterberg proposal is the subject of the preceding article by Charles B. Stevens in this issue.
2. See the author's article on entropy and linearity, "Ludwig Boltzmann and the Second Law of Thermodynamics," in the *FEF Newsletter*, Sept. 1976, p. 3.
3. For Riemann's approach to this problem, see U. Parpart, "Riemann Declassified," *Fusion*, March-April 1978, p. 24. Applications of isentropic radiation-driven shock waves in laboratory and astrophysical fusion processes are discussed in the articles by Dr. John Schoonover and Charles B. Stevens in *Fusion*, Dec. 1980, pp. 40, 48, 54. Also the relationship between the common quantum statistics of radiation thermodynamics and of isentropic processes in highly organized states of matter is discussed in the author's "The Physical Significance of Superfluidity," *Fusion*, March 1978, p. 23.
4. See L.D. Landau and E.M. Lifschitz, *Statistical Physics* (Reading, Mass.: Addison-Wesley, 1958).
5. For a discussion of Schrödinger's development of particle statistics from multiple wave excitation see U. Parpart, "The Present Theoretical Impasse in Inertial Fusion," *Fusion*, Nov. 1979, p. 30. The modern form of the derivation of blackbody photon statistics is due to Bose in 1924.
6. For a fuller discussion of the geometrical forms that arise from Klein's applications of Riemannian manifolds to mechanics, see S. Bardwell, "The Three Body Problem," *Fusion*, June 1978, p. 21. The application of Hamiltonian theory to describe the development of plasma structures is discussed in D. Wells and P. Ziajka, "Production of Fusion Energy by Vortex Structure Compression," *International Journal of Fusion Energy*, Vol. 1, Nos. 3-4, 1978, p. 3.

FEF research director Uwe Parpart tells how Mexico has some hard policy decisions to make if it is to achieve its development goals.

Reestablishing Mexico's Polytechnical Tradition

Fusion Energy Foundation research director Uwe Parpart traveled to Mexico in September to give a seminar on the LaRouche-Riemann econometric model and its application to Mexican development (see Conference section). Parpart is a developer of the model and directed the recent work of the Mexican Association for Fusion Energy (AMEF) on developing a capital-intensive program for Mexican agriculture. In the week before the seminar, Parpart was taken on an official tour of the modern petrochemical facilities of the state-run Petroleos Mexicanos (Pemex) in the southeast of the country and held discussions with the governor and other officials in the northwestern state of Sonora.

On his return to the United States, Parpart spoke with Fusion *energy news editor Lydia Schulman about the AMEF-FEF program and assessed the progress of Mexico's development efforts to date.*

* * *

'Technological and scientific independence are really the very essence of national sovereignty. Without such independence, all talk of political independence and sovereignty is really idle chatter.'

Question: There has been considerable debate among Mexican planners over the priority for the Mexican economy at present—investment in agriculture or in basic industrialization. What in your view is the best pathway for Mexican development?

Posing the question that way—in terms of the priority of agricultural or industrial development—presents false alternatives, because you cannot develop agriculture without developing industry. In developing agriculture you dislocate a large part of the peasantry, which must be absorbed in industry or you face social problems and impediments to further economic progress.

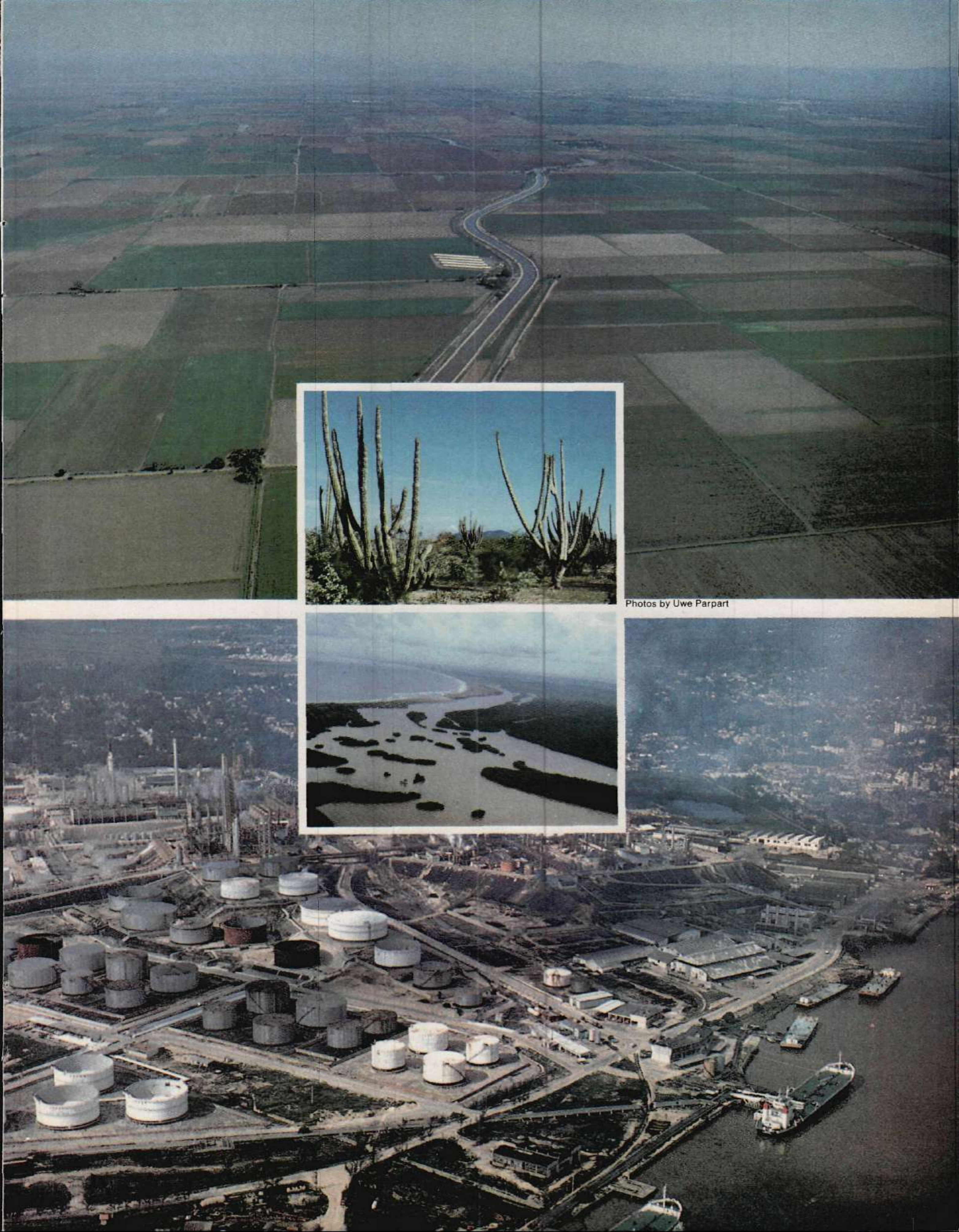
The way one has to approach the question of Mexico's development is to look at the entire Mexican economy today, establish its strong points and weak points, and determine how one best resolves the problems with the available means. The obvious Achilles' heel of the Mexican economy is the backwardness of large sections of Mexican agriculture, which is often subsistence agriculture. There are some stretches in Sonora, Sinaloa, and other parts of the country that compare in productivity and development with American standards, but in most cases this is not so. As a result, Mexico has had to import substantial quantities of food. It has had to spend a good deal of its oil revenues for these imports, and this has had a bad effect on the overall performance of the economy.

Thus the key question is: What is the strategy for eliminating this largest of all bottlenecks for Mexican development? The answer is relatively straightforward. An ambitious network of water projects must be implemented, which we have outlined in the AMEF plan, combined with mechanization and fertilizer utilization to bring Mexican agriculture up to a modern level.

The system of water projects that we are proposing involves transferring water from the country's south coastal areas to the potentially fertile soil of the northern coast, and linking this system up with a North American water system that will deliver the abundant water from Alaska and Canada southward through a network of canals and natural river systems. We are also proposing to increase by fourfold the amount of installed machine horsepower per unit of harvested area in Mexico over the next 10 years.

Now, within the type of approach I have been discussing, some very

High-technology agriculture and industry: You can't have one without the other. Above: An advanced irrigation system in Sonora's Yaqui River Basin. Inset: Unirrigated land in Sonora. Below: Pemex's La Cangrejera petrochemical complex in Veracruz. Inset: The Laguna del Ostion (Lobster Lagoon) next to La Cangrejera, the planned site of an even larger petrochemical complex.


Photos by Uwe Parpart

The education system must be a transmission belt turning peasants into skilled workers.

Left: A family farm house on a Sonora ejido, *a collective farm where farmers jointly cultivate the land using modern agricultural techniques. Below: Members of the committee formed to support Phlino, part of the network of water projects proposed by the AMEF, discussing the successful adoption of the plan in Sonora.*

significant achievements have occurred, largely through the activities of Pemex in the oil and petrochemical sector. There has also been a certain amount of development of heavy industry, although this is still in its initial phase. One of the largest problems in the further development of industry will be the problem of transportation—the very backward state of the Mexican railroad system in particular.

Question: How would you evaluate the government's present development strategy?

In Mexico, as in India and elsewhere where you have a great deal of government participation in economic development, one thing that tends to go wrong is that the attempt is made to plan every single detail of industrial development. I don't think this is possible or feasible. I think that what can and must be planned are certain large projects, which will be completed in a predictable amount of time and which upon completion can be expected to have a definite impact on global productivity and therefore on overall economic performance and growth rates. There is no need to plan every single detail. In fact, the attempts to do that and then to impose those details on the rest of industry tend to have a very stifling effect.

The other problem the government has been caught up in is that it has tended to get trapped in the debate over the priority of agricultural or industrial development. As I said earlier, you cannot develop one without the other. In developing agriculture, you dislocate the peasantry, and unless you are industrially prepared to absorb these individuals, then you get an aggravation of already existing social problems. In Mexico City, for example, there are now 2 to 3 million people living on the outskirts of the city in conditions of horrible poverty, comparable to the worst conditions one would expect to find in any part of the world. Some of the circumstances I saw in Mexico are worse than anything I encountered on my recent trip to India.

The basic problem that has to be solved in carrying forward Mexican development is the absorption of the peasantry as it becomes dislocated from the land into large industrial projects or light industry that do not initially require very high skills. One of the most important questions is whether an educational system exists that is capable of acting as a "transmission belt" for these developments.

Question: The program for Mexican development proposed by the AMEF clearly depends on the rapid growth of skilled labor and scientific manpower. What is the condition of Mexico's skilled labor force at present, and how do you think the educational system can be upgraded to act like this "transmission belt"?

Let me emphasize at the onset that the task ahead is not just that of eliminating illiteracy in the population. In fact, to some extent Mexico has made significant progress in that direction.

What is really striking is the lack of scientific and engineering manpower of a high quality. Unless the problem of educating scientists and engineers is solved, and solved through the creation of new indigenous institutions, then the difficulties that exist will not be solved.

Then there is the problem of the University of Mexico at Mexico City, which is really a city within a city of some 500,000 to 600,000 people. This university educates a very large number of students, but it educates them by and large to professions and in a manner which, if anything, are a hindrance to the development of the country rather than an asset. The emphasis there has been increasingly on the so-called social sciences. In opposition to this kind of situation, Cardenas [president of Mexico from 1934 to 1940] founded a polytechnical institute, which still exists, that trains people at a significant level, but that has nowhere near the support or facilities that it needs.

Mexico must institute from the top down an ambitious polytechnical education system, which should be based on the same fundamental ideas that led to the founding of the Ecole Polytechnique in France in the 18th century and to the establishment of comparable institutions in Germany in the early 19th century, which were the basis for industrial development in those countries. The monstrosity at UNAM [the Universidad Nacional Autónoma de México] probably has to be completely reorganized, with the overall emphasis for the organization of education in Mexico placed on science and engineering. Otherwise, the manpower bottlenecks will not be resolved.

It should also be quite clear that technological and scientific independence are really the very essence of national sovereignty. Without such independence, all talk of political independence and sovereignty is really idle chatter.

It is interesting to contrast India in this regard. India is overall a much poorer country, but unlike Mexico it has a tremendous pool of scientific and engineering manpower, which is its greatest asset and which defines the possibility for the pursuit of an independent policy. Mexico is not capable of carrying out such a policy at this point. It is still the case that close to 80 percent of all Mexican technology is imported.

Question: What were your first-hand impressions of Pemex's petrochemical facilities?

One of the facilities I toured, which is known as La Cangrejera, is going to be the largest petrochemical complex in the world when it is completed by the end of 1981. There are other facilities completed or planned. These are brand-new facilities that are being carved out of the jungle in the southeast of the country.

Pemex is building not only refining and petrochemical complexes, but it is also building docking and unloading facilities for supertankers. It is in looking at these facilities that one gets a sense of what Mexico's future could be, not in the long term but in the relatively short term.

National sovereignty is meaningless without technological and scientific independence.

Left: A butane gas tank at Pemex's La Cangrejera complex. Below: Mexico's Independence Day parade, Sept. 16, 1980. The diplomatic corps and military guests are shown in the foreground. President López Portillo is in the background.

Photo by L. Carrasco

Above: A view of the Pyramid of the Moon at the ruins of Teotihuacan near Mexico City. Right: FEF research director Uwe Parpart standing next to the head of Quetzalcoatl, the chief god of pre-Hispanic Mexico, at Teotihuacan.

Question: What kind of role can advanced sector countries play in Mexico's development?

The complex under construction that I toured is an excellent example of the type of collaboration between developing and advanced sector countries that can succeed if it is undertaken under the right type of circumstances. In this project there has been large-scale U.S., West German, and a significant amount of Japanese participation.

A lot of the civil engineering for the complex is being carried out by Mexican engineering and construction firms. The expectation is that as Mexican development proceeds, Mexico will increasingly be able to build facilities like these on the basis of indigenous capabilities.

Question: What was the focus of your discussions with government officials in Sonora?

In Sonora one of the great problems is water. The network of water projects that we [FEF and AMEF] are proposing for the whole of Mexico will transfer water from the south to Sonora for agricultural irrigation. The major scientific-technological problem to be resolved in Sonora is desalination, so we proposed that the Mexican government participate with the government of Sonora in sponsoring a very concentrated research effort on desalination, possibly with the establishment of a research institution in Sonora. The AMEF is also proposing that a nuplex facility be constructed in Sonora, where fertilizer plants utilizing local deposits of phosphate rock would be situated around a central nuclear facility.

With everyone we talked to we stressed the need for Mexico to get an ambitious nuclear program going, so that the country will have an energy source other than its oil and gas reserves, which could then be saved for petrochemical production. Our program calls for 50 gigawatts of nuclear-generated electricity by the year 2000.

Question: In covering your press conference the Mexican press highlighted your criticisms of Milton Friedman and the theory that Mexico's development has been too rapid. What was the context?

The basic question was that of inflation. Why is Mexico now faced with a 20-30 percent inflation rate? There are all sorts of political theories about this, the most pervasive and silly saying that any country developing too rapidly will experience high rates of inflation and Iranian-style social dislocations. Therefore, development in Mexico should be slowed down. This theory, associated with Friedmanite economics, is the notion that I attacked at the press conference.

In reality the problem of inflation in Mexico has two principal causes. The first is that importing capital goods and food on a large scale ties Mexico into the world market and a significant amount of imported inflation. A related problem is that in the past 15 or 20 years Mexico has built up a significant external indebtedness, which is being repaid out of oil revenues. This diversion of Mexico's oil revenues from the creation of productive capacity is also responsible for the inflationary developments.

The other problem is that productive development in agriculture and in industry is occurring too slowly. Inflation is the result of this more than anything else. The elimination of the bottlenecks in agriculture and in transportation would go a long way toward dealing with inflation. Otherwise, I don't think that one should worry overly about inflationary pressures—as long as one is putting together the large projects that will have a predictable, positive impact on productive capacity, and which will therefore have a counterinflationary tendency in the long run.

"To understand what has gone on in Iran, one must read what Robert Dreyfuss wrote in the Executive Intelligence Review."

—**Empress Farah Diba Pahlevi,**
widow of the Shah of Iran, to the West German magazine *Bunte*

The EIR's Mideast Editor Robert Dreyfuss, predicted in a series of articles that the fall of the Shah was the first phase in a plan to disrupt Mideast oil flows. The plan, as Mr. Dreyfuss documented, was to blackmail Europe with an oil cut-off and to put a full stop to Iran's attempt to modernize. It was this plan which the Shah only belatedly came to understand—as Empress Farah has reported.

While the Shah was too late, the readers of Executive Intelligence Review were not caught off guard in Iran. Week after week, Editor Dreyfuss and his team of Middle East experts informed those with stakes in the area on the regional and international implications of the "Islamic Revolution."

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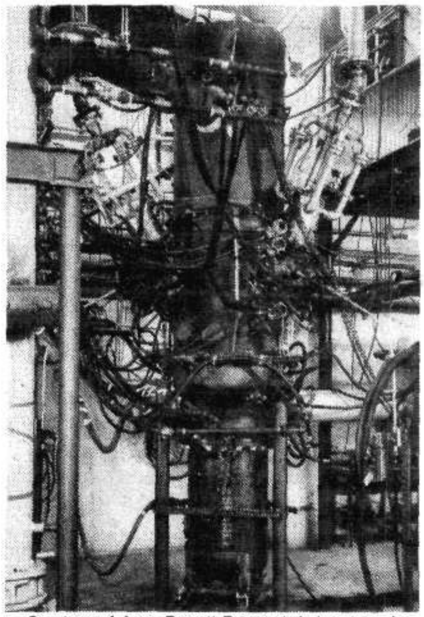
U.S. Coal Policy

Economic Warfare Instead of Energy



Courtesy of Avco Everett Research Laboratory, Inc.

A preliminary study conducted by the Fusion Energy Foundation on U.S. electricity requirements for the year 2000 determined that, in addition to a 1,000-GW (gigawatts or 1 billion watts) on-line nuclear capacity, it will be necessary to increase U.S. coal capacity from the present 200 GW to 600 GW. Without this increase, it will be impossible to return to and maintain the growth rates of energy and electricity consumption that have historically corresponded to economic growth.

Although nuclear energy has been under severe attack in the United States since 1977, it is also the case that coal production has been hamstrung—despite the Carter administration's incessant talk about forging "energy independence" based on the nation's vast coal resources and the publication last May of the influential World Coal Study, which promotes coal over every other energy source.

U.S. coal production has bounced up and down since President Carter first announced his coal-based energy program in 1977; the current boomlet in coal production is the result of exporting coal to make up lost Australian and Polish production and the shutdown of U.S. nuclear capacity.

The reason that there has been no sustained takeoff in coal production is actually straightforward: None of the coal plans that have been floated has represented a coherent program to get energy and coal production going.

What, then, is the meaning of Deputy Energy Secretary John Sawhill's talk about making the United States the "Saudi Arabia" of coal exports? The ongoing study by the U.S. Interagency Task Force on Coal Exports, headed by Sawhill, and the World Coal Study, which was directed by Carroll L. Wilson of the Massachusetts Institute of Technology, are economic-warfare policies, not energy policies.

Both studies propose substituting increased reliance on coal for nuclear power and oil within an overall framework of sharply reduced economic and energy growth rates. And interviews with participants of both studies make it clear that the only thing certain in these proposals is the reduced growth rates—the ambitious projections on coal use are subject to substantial revision.

The unstated assumption of this approach to coal use is escalating tensions in the Middle East leading to the destruction of oil fields and refining capacity—something that is already happening as a result of the prolonged Iran-Iraq war. In this scenario, Western Europe and Japan become increasingly dependent on coal and U.S. coal exports. Thus, this coal program is in reality a program for controlling energy resources for political purposes.

The World Coal Study

The World Coal Study projects that world coal use will double by 1990 and triple by the year 2000. U.S. exports of steam and metallurgical coal, it says, will rise incrementally to 80 million tons in 1985, 120 million tons in 1990, and 200 million tons by the turn of the century.

These export projections compare with 66 million tons exported in 1979 and are significantly higher than previous projections by the Department of Energy (100 million tons by 1990) and Data Resources (only 60 million tons by 2000).

The methodology by which these projections were generated reveals the actual policy thrust of the World Coal Study. A group of experts from 16 countries started with government projections of energy growth rates for the OECD (Organization for Economic Cooperation and Development) countries. Then, according to technical director Dr. J. Michael Gallagher, the group discounted the rates significantly on the grounds that the projections both for on-line nuclear capacity and oil consumption were "overly optimistic." Each member thereby revised the growth projections for his country.

The group thus arrived at reduced overall growth rates for the OECD nations of 1.8 percent per annum for total energy and 4 percent per annum for electricity consumption over the next two decades. These rates are only slightly more than one-half the average growth rates achieved during 1963-1970, the last period of relative extended economic growth, in the OECD area.

The group then estimated how many oil and nuclear power-based electrical plants could, as they put it, "realistically" be expected to come

DOE

U.S. coal policy: promises instead of advanced technology. Left: a high-temperature coal combustor for a low-pollution electric power plant based on MHD. Right: miners prepare for work.

on line over the next two decades. They then filled in the gap with coal.

The other assumption built into the World Coal Study projections on total energy and coal consumption was a "decoupling" of economic growth from energy growth—a reduction in energy input per unit of GNP (which would likely entail a continuing shift from energy- and capital-intensivity to labor-intensivity in the advanced-sector economies). The target used was a .6 ratio of energy to economic growth, the ratio subsequently adopted by the Venice Summit.

"We were surprised to find that coal wasn't the focal point for any of the national plans before," the World Coal Study's Gallagher said in an interview. "In the United States there was a total blindness to the possibility of large exports of coal and the industrial uses of coal. The oil figures were too high; the nuclear numbers are revised downward every three months; but coal is already available."

As for the implementation of the World Coal Study's recommendations, Gallagher noted that the study had created a network of 80 people from all levels of government and industry who are now back in their 16 nations working to influence policy. "The Department of Energy was heavily connected to the study," Gallagher said. "John Sawhill got sensitized to the program while we were doing the study, and he understands the export potential for the United States."

Coal Exports

Coming off the World Coal Study, the U.S. government Interagency Taskforce on Coal Exports was pulled together last summer under Deputy Energy Secretary Sawhill's direction to formulate a detailed policy statement on U.S. coal exports. The starting point of the study is the World Coal Study. However, Bernhardt Wruble, executive director of the taskforce, reported that the group is taking a much harder look at the recent escalation of demand and the state of U.S. port and other facilities requisite to launch a major expansion of coal exports.

"The World Coal Study took an academic look at the potential for increased coal exports. Our study is addressed to the people who are going to spend the money," Wruble commented.

Wruble added that a number of things have changed since the World Coal Study was done. The study's projections for U.S. coal exports in 1985 will probably be met in 1980. U.S. coal exports to Western Europe, Japan, and Canada are up about 20 percent this year and are expected to hit the 80 million ton target, principally because of a coal strike in Australia and political instability in Poland. "Countries that have been relying on Australian and Polish coal are going to think twice about relying on those sources," Wruble said.

He added that the war in the Middle East would have a longer-term impact on the growth of U.S. coal exports. "The war is a forceful reminder of the need to break the oil habit," he commented.

Problems in other coal-producing nations and war in the Middle East do not necessarily translate into a sustained "boom" for U.S. coal exporters, however. In this regard, it is interesting to note that for all the ballyhoo about increased coal use, the projections for U.S. coal production in the World Coal Study are actually *lower* than previous U.S. government projections, because of the assumptions on reduced economic growth and the decoupling of economic from energy growth. In 1977, when President Carter first presented his National Energy Plan, the goal was to double U.S. coal production to 1.2 billion tons per annum by 1985. The current Department of Energy projections, which were used in the World Coal Study, are for 950 million tons of production by 1985—870 million tons for domestic consumption and the rest for export.

However, last summer the Department of Energy revised its projections downward once again. The DOE is now assuming, unofficially, that because of the deepening world recession, electricity growth rates in the United States to 1990 will probably be closer to 3.4 percent per annum than the 3.9 to 4 percent assumed in the World Coal Study.

Coal Use and the Economy

Demand for U.S. coal has bounced up and down since the 1973 Arab oil embargo, following the graph of the economy. In 1977, President Carter promised the industry that his program would double coal production by 1985. Yet, coal production fell by 27 million tons that year. It rose in 1979 to compensate for the first drop in nuclear-generated electric power since 1959 (a result of the government response to Three Mile Island). However, coal consumption did not keep up with production, and coal stockpiles increased by more than 35 million tons in 1979.

Coal stockpiles are now 176 million tons, the highest level in history. The utilities are doing some stockpiling in anticipation of higher prices as a result of inflation and railroad deregulation and a possible coal strike next spring. However, the other principal factor is the continuing recession.

The expected 50-million-ton increase in U.S. coal production this year will go mostly for export. The promise of a growing export "boom" is being thrown out to the industry because it is otherwise in severe straits. Environmental Protection Agency regulations continue to make it almost impossible to add new electric generating plants—and the coal export taskforce has no intention of recommending that these regulations be lifted or even reviewed. The steel industry, one of the coal industry's biggest industrial markets, has no plans to reopen capacity shut down last summer.

None of the "coal programs" that have been floated since 1977 has done anything to stabilize the market for coal or convince the industry that there will be a growing market for coal in the future. But there clearly is a need for intensified coal production for domestic electricity generation.

The Fusion Energy Foundation conference in Pittsburgh Nov. 5 will present a positive program for U.S. coal production that will be reported on in *Fusion*. In brief, if the country is serious about carrying through on the policy of reindustrialization, it will have to return to the energy growth rates of the 1963 to 1970 period—3 percent per annum for overall energy consumption and 7 percent for electricity. The most cost-effective means of attaining these targets will be to have approximately 1,000 GW of nuclear capacity and 600 GW of coal capacity on line by the year 2000. The United States now has approximately 70 GW of nuclear and 220 GW of coal capacity.

The target for coal-generated electricity establishes the basic parameter for developing a program for the intensified mining of coal and construction of coal-fired power plants. Such a program would have to entail a suspension of EPA standards covering existing coal-burning plants, because it is economically counterproductive to retrofit old coal plants with scrubbers. These systems waste energy, reduce the productivity of the power plants and steel plants (where they have been installed), and they have put an undue financial burden on utilities, which has stifled investment in new capacity.

Second, a determined government effort is needed to make coal-burning magnetohydrodynamic systems available for widespread commercial use by the early 1990s. MHD is a process that burns coal at very high temperatures and generates electricity by pushing the ionized coal through a magnetic field. To help make the coal gas electrically conductive, a potassium seed is added, which chemically combines with the sulfur in the coal and captures it before the polluting gas can escape. No scrubbers or other "antipollution" equipment is needed. And the MHD process almost doubles the amount of electric power produced per ton of coal, increasing the productivity of the entire system.

As for the outlook for U.S. coal exports, the important points are as follows: Unlike the U.S. Department of Energy, the governments of Japan and Western Europe are trying to stabilize the Mideast political situation and future oil supplies and are committed to energy growth policies that include both nuclear and coal. Second, any projections of future U.S. coal exports must start from the requirements of future economic development and not the political manipulation of world energy supplies.

This article was researched by Marsha Freeman and Lydia Schulman and was written by Lydia Schulman.

YEAR-END STOCKS OF BITUMINOUS COAL AND LIGNITE

A stockpile of promises: The United States needs an energy program that will get coal moving. Since the end of 1979, coal stockpiles have been at their highest levels in history.

Source: Energy Information Administration, DOE

Interview with Tim Beecher, McDonnell Douglas Corp.

McDonnell Douglas Wins Contract to Build EBT

On Sept. 11 the U.S. Department of Energy Office of Fusion Energy awarded a contract for the construction of the Elmo Bumpy Torus proof-of-principle (EBT-P) fusion experiment to a consortium of firms headed by McDonnell Douglas Corporation in Missouri. Although General Atomic in California has maintained a large fusion effort, this is the first time that a private U.S. firm has become the prime contractor for a major government fusion experiment. Fusion *interviewed Timothy J. Beecher, an External Relations representative for McDonnell Douglas, concerning the role of private industry in the U.S. fusion effort.*

* * *

Question: Could you describe the EBT-P experiment and tell us what its advantages are?

The Elmo Bumpy Torus was developed at Oak Ridge National Laboratory in Tennessee. It is the chief alternative approach to magnetic fusion being researched and is therefore the main backup to the tokamak and tandem-mirror systems. The EBT is actually a series of toroidally connected magnetic mirrors.

What we are building is the EBT-P, the "proof-of-principle" experiment, a device for which the initial experiments have been carried out at Oak Ridge. The EBT is one of the nation's leading alternative fusion energy reactors.

Its chief advantages are that it can run steady state, as opposed to the pulsed modes of operation seen in the main-line tokamak, for example, and that it is amenable to easy maintenance. The EBT-P will test out the physics needed for developing a fusion reactor based on the Elmo Bumpy Torus approach.

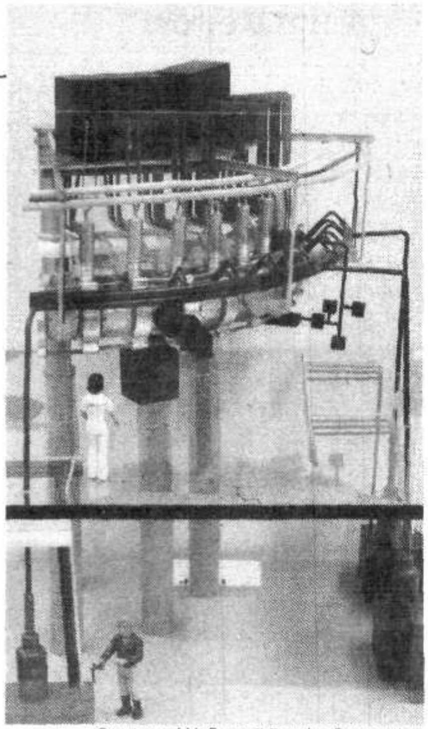
Question: When will the EBT-P come on line?

Well, perhaps I should give you a little background on this. The contract that we just received is actually phase II of a DOE program for EBT. In phase I several industry teams researched the EBT and put forward proposals for the EBT-P, the next step. Phase II commenced with the awarding of the contract to McDonnell Douglas. This phase of the program involves the design, construction, and testing of an EBT-P at Oak Ridge. The device is to be completed within four and one-half years. Then the actual operation of the EBT-P will be phase III of the program, in which we hope to have an active part.

Question: Could you describe the contract in a little more detail?

The contract was awarded on Sept. 11, 1980. The total dollar amount should be somewhere between $70 and $100 million, but we are currently negotiating the exact figure.

The major subcontractors to McDonnell Douglas will be General Dynamics, which will be responsible for the superconducting magnets used on the EBT-P. Gilbert Commonwealth is the architectural engineer; Continental Electronics is responsible for the power supply; Jaycor in California and Rensselaer Polytechnic Institute in Troy, N.Y. are responsible for the theoretical physics problems that arise; and Helix Technology will handle the cryogenics technology.



Courtesy of McDonnell Douglas Corporation

This quarter-section model of the Elmo Bumpy Torus proof-of-principle experiment illustrates the scale and some of the 36 rings that are joined together to form the torus.

Question: I understand that this is the first time that private industry has been given this much responsibility for a major fusion experiment from scratch.

That's absolutely true. And what we are seeing here is the first time that industry has been given this level of responsibility in the fusion program. Of course, we will work very closely with and under the supervision of Oak Ridge National Laboratory. But what is happening here is that we are becoming a prime contractor for the project, with our making arrangements with a subcontractor. That is more common in aerospace programs, past and present. This kind of responsibility has never been given to private industry in the fusion program before.

Question: The McCormack fusion bill was recently signed by President Carter and calls for a commercial demonstration fusion reactor by the year 2000. Do you think that private indus-

try has a major role to play at this stage of fusion development and in realizing the goals of the McCormack bill?

Absolutely. What I think we are seeing here is a transfer of knowledge beginning in the fusion program. The national laboratories have done an outstanding job on the physics and engineering research to this point. But for fusion energy to emerge as a commercial reality, now is a good time for industry to take a more prominent role.

Question: Are there any industries that you think will be particularly important for developing fusion?

Well, I can say for our part that we have been involved in fusion research and technology since 1974. And we feel that the high-technology expertise currently available at McDonnell Douglas received a pretty solid foundation from the aerospace program—the Apollo, Gemini, and Mercury programs, the Space Shuttle, Sky Lab. These kinds of programs lend themselves quite readily to fusion energy research because of the high-technology problems encountered. We have the types of facilities and personnel that fit very well into the effort to develop a commercially feasible fusion reactor.

Question: As you noted, fusion involves a lot of advanced technologies. Do you see any possibility for major technological spinoffs prior to the achievement of the main goal of the fusion program?

Certainly. In fact, there you find a particularly good correlation to the space program, where high-technology companies like McDonnell Douglas were involved and where there were a great many spin-offs to the technology. I think we can do the same thing in the fusion program, while keeping our eye on the ball—the goal of a commercial fusion reactor. So far it appears that what happened in the space program will happen in the fusion program. The potential is there.

Bethe Calls for Fusion-Fission Hybrid Device

Dr. Hans Bethe, a world-renowned physicist and pioneer in nuclear fusion and fission research, called for the "near-term" development of fusion-fission hybrid fuel factories, in a September colloquium at Sandia National Laboratories in Albuquerque, N.M. These factories would use fusion-generated neutrons to produce fissile fuel for existing light-water nuclear power plants. Bethe stated that practical fusion-fission hybrid fuel factories could be developed within this decade.

As Bethe outlined in his talk, there are basically two approaches to fusion-fission hybrid systems. The first method is to use fusion-generated neutrons to induce fission in a blanket surrounding the fusion reaction chamber. Because of their high energies, fusion neutrons induce fission reactions in materials that do not ordinarily undergo substantial fission in nuclear fission reactors.

As a result, the initial fusion energy output is greatly enhanced, and the total energy would then be used to generate electricity. Some critics have pointed out, however, that this type of fusion-fission hybrid combines the technological difficulties of fusion with the safety problems of fission.

The second approach to a fusion-fission hybrid avoids these problems. In this system, fission reactions are suppressed in the hybrid blanket—by moderating the high-energy fusion neutrons to lower energies, for example. Instead, the fusion neutrons are absorbed by the material in the blanket surrounding the fusion chamber and the material is converted to fission reactor fuel.

Thorium is one of the best materials

DOE

Bethe's hybrid: Electricity at 2¢ per kilowatt hour.

to use in such a hybrid fusion-fission blanket, as Bethe pointed out. Absorption of a neutron converts thorium-232 into uranium-233, a fission reactor fuel.

The Fuel Factory Idea

Bethe's "new" idea is to use such a hybrid to produce fission reactor fuel solely—the heat generated by the fusion reactions could simply be discarded. Such a machine is greatly appealing because, since fusion reactions liberate vast quantities of neutrons, economical fuel-factory hybrids could be built with much lower fusion energy-generating efficiencies than are required for pure fusion reactors.

According to new studies that Bethe cited, fission reactions can be almost completely suppressed while large quantities of fission fuel are generated. These studies are based on the concept of using a "blanket" in the form of a liquid, molten-salt mixture of thorium fluoride and lithium fluoride. The mixture would be circulated through a region next to the fusion reaction chamber and then pumped through a chemical plant, which would continuously remove the uranium-233. At the same time, lithium would be converted to tritium, the fusion reactor fuel.

As Bethe pointed out, there would not be a need for very many of these fusion-fission hybrid fuel factories. As many as seventy 1,000-MW fission reactors could be fueled annually by one hybrid fuel factory. This support ratio, of course, depends on the sophistication of the fission reactor.

Although, Bethe said, much research must be completed before the fusion system needed for this hybrid fuel factory can be developed, the engineering of the fuel factory will be relatively simple once it has been demonstrated. In terms of the economics, Bethe stated that if the factories are coupled with the most advanced fission reactor technology, electricity could be produced for as little as 2 cents per kilowatt-hour, with a virtually unlimited fuel supply. He noted that it now costs about 6 cents to generate 1 kilowatt-hour in an oil-based power plant.

DOE Declassifies Fusion Concepts

Without warning or explanation, the U.S. Department of Energy has quietly taken the secrecy lid off two concepts in the field of inertial confinement fusion.

The action came last month in a notice to classification officers at the Lawrence Livermore Laboratory and other government research centers, reported Ray Kidder, a physicist at Livermore.

The order to declassify the concepts came from Duane Sewell, assistant secretary for defense in the DOE, said Kidder.

Neither Sewell nor Robert Duff, head of classification for the DOE, was available for comment.

James Cannon, public information officer for the DOE, said he was unaware of the specific concepts being declassified. He noted that DOE never makes public announcements about declassifying information.

Rep. Paul McCloskey (R-Calif.) said that he found it "curious and somewhat disturbing that no public acknowledgement was made."

Kidder is an international authority on inertial confinement fusion, who has long advocated that the United States end secrecy in the entire field.

Now, the DOE has officially declassified these two general statements:

- "In thermonuclear weapons, radiation from a fission explosive can be contained and used to transfer energy to compress and ignite a physically separate component containing thermonuclear fuel."
- "In some ICF targets, radiation from the conversion of focused energy (for example, laser or particle beam) can be contained and used to transfer energy to compress and ignite a physically separate component containing thermonuclear fuel."

Inertial confinement fusion creates a thermonuclear reaction in order to obtain energy. Compressing fissionable material in various ways sets off the reaction. ICF is not directly involved in making weapons.

Kidder said the newly declassified concepts could not be considered dangerous for the public to know. He termed their declassification "a small, but significant first step toward eliminating undesirable and unnecessary classification restrictions."

"I know that the DOE is busily working on a new classification guide," he said.

"I'm encouraged by the fact that the DOE is proceeding in the direction of declassification."

Kidder asserted, "I believe they have a long way to go because I believe the whole thing should be declassified. They are moving in a more gradual manner, but it's better than nothing."

Kidder said that declassifying the material was a result of *The Progressive* magazine case and the publication of a hydrogen bomb description by Charles Hansen of Mountain View.

After the DOE and Justice Department settled *The Progressive* case in court, certain concepts in nuclear weaponry were declassified because they had been published or found to be in the public domain.

Kidder was one of a number of scientists who signed affadavits on behalf of *The Progressive* last year in its legal fight with the government.

This article by Mary Madison appeared in the Peninsula Times Tribune *Oct. 11 and is reprinted here with permission. The California daily recently reported on the* Fusion *article by Friedwardt Winterberg (Oct. 1980, p. 95) on the MIRV concept and the neutron bomb.*

Advanced Nuclear Weapons Research Curtailed

"The continuing trend of emphasis on weaponization (i.e., the adaptation of existing nuclear technology to specific weapons systems) at the expense of advanced development (the 'new ideas' part of the weapons program) is borrowing against the future. If the deficit becomes too large, it may be extremely difficult to make up." Dr. Roger Batzel, director of Lawrence Livermore National Laboratory in Livermore, California, made these remarks in his annual State of the Laboratory review, presented to an audience June 12, 1980 and printed in the August 1980 issue of *Energy and Technology Review*.

Lawrence Livermore is one of the main nuclear weapons laboratories in the nation, and Dr. Batzel's warning should be taken seriously. Although Washington sources indicate that this situation will be reversed as a by-product of the current DOE revitalization program for weapons-production infrastructure, researchers indicate that this devolution of U.S. advanced-weapons development will continue for fiscal 1981, at least.

This state of affairs directly reflects

the shortsighted "production-in-width" policy of the Carter administration, which is the basis for a near-term military buildup.

This policy is just the opposite of the "in-depth" science and technology policy followed by the United States in the 1950s. For example, Lawrence Livermore's advanced-weapons research permitted the timely development of the small W47 thermonuclear warhead, which provided the technical basis for the Polaris submarine-launched missile in August 1957. Some experts believe that the W47 marked the transition from bulky shock-wave-ignited thermonuclear devices to those based on focused soft-X-ray ignition.

Peaceful Nuclear Explosions: **Is the Soviet Union Developing Pacer?**

Recent information indicates that the Soviet Union is making wide use of peaceful nuclear explosions, and there is speculation that the Soviets may be developing a Pacer project.

In the Nov. 1980 *Fusion*, Dr. Walter Seifritz of the Swiss Federal Institute for Reactor Research reviewed the tremendous energy and economic potentials of using hydrogen bombs to generate hydrogen and fissile fuel in a Pacer-type project ("HACER: A Grand Design for Fusion Power in This Century," *Fusion*, Nov. 1980, p. 22).

Pacer is the concept developed by U.S. researchers for using H-bomb explosions contained within salt-dome cavities to produce energy and breed fissile fuel—the concept upon which Seifritz based his Hacer proposal.

In the United States, the Carter administration curtailed even the studies of this technology, along with all remnants of the U.S. Plowshare program—peaceful applications of nuclear explosions, or PNE's.

The Plowshare program, begun in 1957, took its title from the Biblical phrase, "They shall beat their swords into plowshares; neither shall they learn war any more." After a series of successful experiments, Plowshare began to investigate the use of nuclear explosives for excavating canals; building tunnels, harbors, and dams; and recovering such natural resources as oil, gas, and minerals.

Even at the time of Plowshare's initiation, it was noted that peaceful nuclear explosions were particularly attractive for the Soviet Union, with its huge deposits of minerals and petrochemicals and its vast development projects. Now that the United States has aborted Plowshare and the Pacer research, the question remains: To what extent is the Soviet Union carrying out work along these lines, and what are the strategic implications?

The fact is, the Soviet Union has maintained the largest PNE program in the world. For example, U.S. intelligence estimates that at least seven PNE test shots were performed in the Soviet Union in 1979. These same sources calculate that the Soviet Union has devoted as much as 8 percent of its nuclear tests to peaceful applications over the last few decades. Given the siting and explosive power of recent Soviet underground detonations, it is likely that the Soviets have an active program to develop Pacer.

Since the United States shut down Plowshare in 1976, all exchange of information with the Soviet Union on PNE's has ceased, and the United States has not even maintained a working intelligence group to monitor the Soviet PNE program. It should also be noted that the former director of Air Force Intelligence, General George Keegan, included in his discussions of Soviet antimissile beam weapons the necessary development of a Pacer-type system for the pulsed electric power supply to drive them.

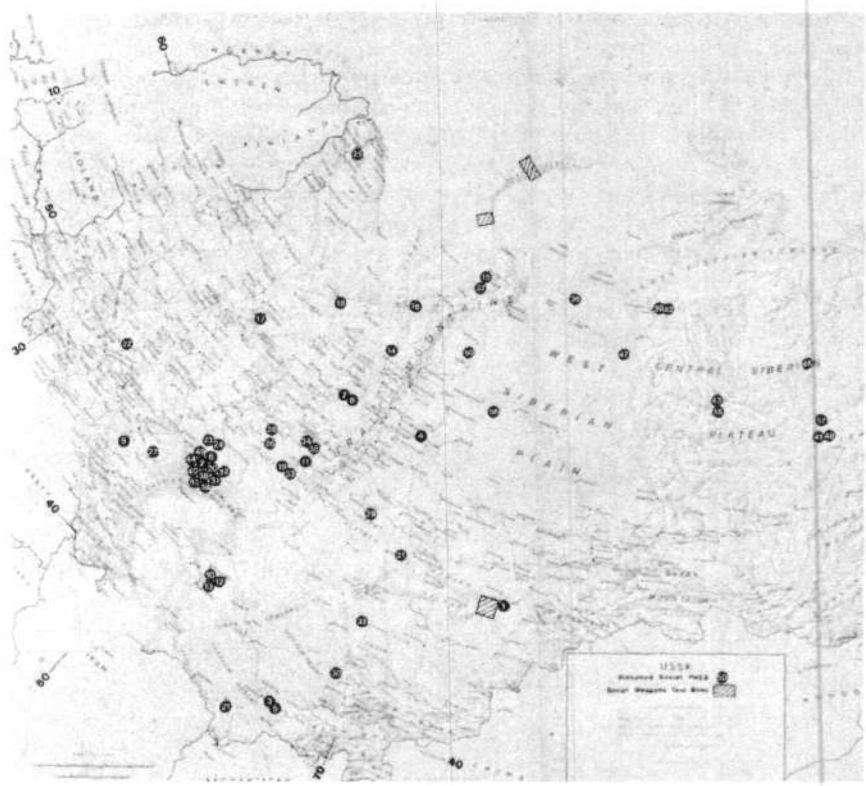
The key idea in the Pacer concept was first developed by H. W. Hubbard of R&D Associates. Experience from numerous underground nuclear tests indicated that, given the proper geological formation, several hundred H-bombs could be detonated successively without destroying the cavity within which they were exploded. The particular geological formation needed is that of a salt dome, in which the mechanical stresses caused by the explosion-induced seismic shock can be dissipated in a controlled manner.

The Pacer concept consists of setting off a 20-kiloton TNT-equivalent, deuterium-based H-bomb every few hours within such a cavity. Steam containing suspended particulates of uranium or thorium is continuously passed through the 575-foot-diameter cavity located about 1 mile below the surface. In this way, the heat energy from the bomb blast can be extracted. Simultaneously, fusion-generated neutrons are absorbed by the uranium or thorium suspended in the steam. When this occurs, the uranium or thorium is converted into fissile fuel (plutonium or uranium-233), which can then be extracted from the steam and fabricated into fuel rods for nuclear-fission electric power reactors.

Pacer is a most prolific breeder of fissile fuel. Enough fissile fuel can be bred from fusion-generated neutrons so that 12 to 20 times more energy is created in the form of fission reactor fuel than the immediate energy released by the H-bomb detonation.

Strategic Implications

It is commonly thought that there are more than enough nuclear weapons in today's arsenals (currently estimated at a total of 100,000 strategic and tactical warheads) to destroy the world several times over. In reality, however, when one considers alternative applications of nuclear devices such as antimissile "flak," military excavation and construction with clean H-bombs, and explosive power supplies for beam weapons, the possession of greatly enhanced nuclear-weapons stockpiles could be of immense strategic significance. The chief cost and production constraint



This government map shows 50 presumed sites where the Soviets have conducted peaceful nuclear explosions from 1965 to 1979. Note the concentration of sites near the Caspian Sea, an area of known salt domes.

on nuclear weapons production is that of procuring the fissile fuel needed in all types of warheads.

With conventional technology, such as uranium diffusion plants and nuclear breeding reactors, major increases in production of weapons materials would take at least several years to develop and could not be done in complete secrecy. A Pacer system for solely breeding fissile materials would not suffer from these drawbacks and could only be definitely observed—through seismic measurements of the continuous thud of Pacer underground explosions—once production had actually begun.

Larger Devices

The key factor determining just how efficient and economic Pacer could be as a fissile-material breeder is the question of how large an H-bomb could be detonated within a 575-foot-diameter cavity without destroying it. The original U.S. projection of 20 kilotons was an extremely conservative estimate based on a limited number of underground explosions and theoretical calculations. Some experts believed that explosions as large as 200 kilotons could be achieved. These larger devices would incur no increased economic or fissile-fuel investment and would effect a tenfold increase in the amount of fissile fuel generated.

In order to determine whether use of these more efficient, larger detonations is feasible, actual tests would have to be carried out. And in fact, the Soviet Union has carried out a number of underground explosions near this 200-kiloton level (which is slightly above the maximum levels allowed by the Nuclear Test Ban Treaty, 150 kilotons) in Azgir, a region of the Soviet Union that contains natural salt-dome formations.

Fusion Extra

Continued from page 28

Staten Island Advance, Staten Island, N.Y., Oct. 7, article by Robert C. Cowen

This [passage of the bill] is a moral, as well as strategic, victory for Rep. Mike McCormack, D-Wash., chairman of the House Subcommittee on Energy Research and Production and principal sponsor of the House bill. . . .

It has become increasingly obvious over the past year that fusion research is at a major turning point. Last December, in a study organized by the International Atomic Energy Agency, 400 fusion scientists from Europe, Japan, the Soviet Union, and the United States concluded that "it is scientifically and technologically feasible" to move quickly to build a fusion engineering test facility (ETF) and have it running by the early 1990s.

* * *

Nuclear News, Sept. 1980, article by E. Michael Blake

Assuming that fusion arrives in time to offset the loss of fossil fuels in energy production, its destiny is not at all clear. In an ideal situation, it would seem that fusion could provide so much cheap, abundant energy that conservation could become as outmoded as the fox trot. Fusion has been proclaimed by some as the key to Third World development, since the underdeveloped nations may catch up with the developed only if there is enough energy around to permit sharp increase in worldwide consumption. The signs are good that fusion can be technically feasible and environmentally acceptable. But this does not mean that fusion can be looked upon as salvation, or that the hoped-for world powered by fusion, solar, and hydrogen as a chemical fuel will come to pass.

In the end, the problem may be people. Bluntly put, are there now or will there be enough technically competent people to build, operate,

Continued on page 73

Secret EPA Memo Plans End to U.S. Steel Industry

A secret memorandum circulated in-house by the Environmental Protection Agency calling for a phaseout of the U.S. steel industry was uncovered by Senator Richard Schweiker and inserted in the *Congressional Record* in September. The memo stated that "a rational policy would allow the industry to gradually decrease in size."

As the Pennsylvania Republican noted, the memo came to light just as President Carter was announcing his election program to "revitalize" the steel industry.

The steel industry and other basic industries like auto have been designated "sunset" industries by policy-making circles behind the Carter administration, whose objective has been to deindustrialize the United States, preserving only advanced computer, communications, and electronics industries in what is termed a postindustrial or information economy. The Environmental Protection Agency has long been a primary weapon of these forces, using the pretext of clean air or water standards to force cutbacks in capital formation in basic industries.

The EPA memo uncovered by the senator does not even go through the motions of purporting concern for the environment, but employs strictly "sunset industry" economic arguments. As Schweiker reported Sept. 26 on the floor of the Senate: "At the same time that Carter is moving to set up a new steel policy for the nation, we see that top administration officials are ringing a death knell for this industry."

The memo was drafted July 10 by Franz Kok of the EPA's planning division and is signed by EPA assistant administrator for planning and management William Drayton, Jr. It states that "our analysis indicates that there is no need to maintain any more capacity than is required for defense purposes and to replace outmoded plants would be foolhardy—based on production cost the United States cannot compete in the raw steel market in the future."

"We therefore find ourselves at odds not only with the conventional wisdom of the time and the politically attractive point of view," the memo continues. "Nevertheless, we feel that it is vitally important that someone begin to make this argument. To offer subsidies to an industry in which the United States no longer has a competitive advantage would be the worst possible economic policy. It would put us firmly on the road to lemon socialism. A rational policy would allow the industry to gradually decrease in size, to inaugurate programs to provide transitional relief to workers and depressed communities and to provide incentives for diverting out resources to more promising industries."

"As I am sure you realize," the memo concludes, "espousing these policies will not make you the most popular figures around town. . . . I think that we have a great deal of groundwork to lay before we can spring these ideas full-grown onto the public."

The memo, of course, does not call attention to the fact that the high cost of meeting EPA clean air and water standards has been largely responsible for preventing the steel industry from modernizing and becoming competitive in the world market. It also does not mention the vast need for steel if the nation were to build the necessary number of nuclear plants to meet U.S. and international energy requirements.

Courtesy of Inland Steel Co.

The solution to the steel industry's low profitability is modern technology, not plant shutdowns. Here the control pulpit of the new, fully computerized No. 7 blast furnace at Inland Steel's Indiana Harbor Works, the most advanced application of process control techniques to iron-making in the world.

Congress Passes McCormack Nuclear Safety Bill

A bill to improve the safety of nuclear power plants, written and introduced by Congressman Mike McCormack (D-Wash.), has passed both the House and the Senate in different forms. According to House Science and Technology Committee staff, an amended revision of the nuclear safety bill will be sent to the Senate after the election, when Congress reconvenes in "lame duck" session. Prospects depend on the postelection political climate.

The House bill, HR 7865, the Nuclear Safety Research and Development Act of 1980, was introduced by McCormack with support from the Science and Technology Committee. It gives legislative direction to increased R&D funding that Congress added to the Energy Department's budget after the Three Mile Island incident.

McCormack is best known as the initiator and chief sponsor of the 20-year fusion development bill signed by the president Oct. 7.

The bill includes a cost-sharing arrangement for new programs and testing for nuclear plant safety between the utilities industry and the federal government. It specifies areas to upgrade in the Department of Energy's safety program, including operator training programs, control room design modification, and improvements in reactor design for safety upgrading.

The authorization bill increases to $26.4 million the government funding for nuclear safety—about $1 million more than the Carter administration requested for its program.

Assessing Comparative Risk

McCormack's bill also includes the authorization of a study to be carried out by the Department of Energy to evaluate comparative risk from all energy production technologies. When assessing comparative risks, for example, the government might find that coal technologies carry a higher risk than nuclear power.

The Senate version of the bill, S2884, was introduced by Senators Church (D-Idaho) and Jackson (D-Wash.) and was amended to remove the comparative risk assessment study.

Other changes were also made, including a provision to have the DOE do a study on nuclear operators corps to inspect and supervise the utility operators of nuclear power plants. According to Capitol Hill sources, House sponsors believe that this is unnecessary, and that the way to improve safety is to improve reactor operator training—not to burden the industry with federal inspectors and the taxpayer with a new bureaucratic structure.

A second important piece of nuclear-related legislation, the Nuclear Waste Policy Act of 1980, HR 6390, is tied up in two House committees. It has been passed out of the Science and Technology Committee with the support of committee chairman Don Fuqua (D-Fla.) but is stalled in the House Commerce and Interior committees.

The waste policy bill would initiate a research, development, and demonstration program for nuclear waste technology. The nuclear waste disposal issue has been used to try to stop commercial nuclear development in a half-dozen state referenda this year.

Inside DOE

Fusion Office: Room at the Top

Dr. Franklin Coffman, director of the Development and Technology Division of the DOE's Office of Fusion Energy since March 1978, has transferred to the fission program, where he will direct the Office of Advanced Nuclear Systems and Projects. The office's projects include advanced isotope separation processes, space and terrestrial systems, nuclear energy centers, and the High Temperature Gas Cooled Reactor program.

Coffman was one of the five division directors responsible for a major aspect of the fusion program's work, an area that will become increasingly important as fusion moves into an engineering stage.

Coffman is not the first OFE scientist to leave the fusion program. In 1977 when the DOE replaced the Energy Research and Development Administration, the fusion office had more than 70 staff members. Today it has fewer than 40. Under ERDA, the office also had an additional senior position, then held by Dr. Stephen O. Dean, overseeing all magnetic fusion experiments. Since the freeze on government hiring by the Carter administration, positions left vacant from transfers, resignations, and retirements have not been filled. Instead scientists in the Fusion Office have been put in the position of doing two or three people's jobs.

At the same time, the Fusion Office is now gearing up to supervise the design, engineering, and construction of a $1 billion machine—the largest fusion project ever undertaken. Furthermore, a new laboratory, the Fusion Engineering Center, will be built from the ground up.

Overall, the fusion program over the next two decades will need thousands of new scientists and engineers, who will be trained under Fusion-Office-led programs. No one is in favor of increasing government employment just to feed a growing bureaucracy. But if scientists are driven out of the government, the broadened fusion effort of the coming years may suffer most from inadequately staffed leadership at the very top.

Wide World

IMF managing director de Larosiere (l.) and World Bank president McNamara

IMF Policy

Depression and Debt Payment

The annual meeting of the International Monetary Fund and World Bank, held in Washington, D.C. at the end of September, advocated prolonging the current world economic downturn into a five-year depression as a matter of official policy.

IMF Managing Director Jacques de Larosiere and outgoing World Bank president Robert McNamara both proposed that the advanced sector should deindustrialize instead of using advanced-sector industrial resources to develop the resources of the Third World nations. Resources, they said, should be diverted in the form of financial flows for the exclusive purpose of rolling-over Third World debts.

De Larosiere stated that "three problems dominate the state of the world economy: inflation, energy, and the plight of the non-oil-developing countries" and then proposed to deal with these problems by keeping industrial economies depressed. In this way, he said, banking systems will not be called on to lend heavily for economic growth at home, but can divert resources to papering over Third World deficits and lending under "conditionalities" that have already produced starvation in Africa, near civil war and a drug-economy in Jamaica, and military coups in a number of countries, most recently Turkey.

De Larosiere also proposed that all available international resources be concentrated in the most costly and inefficient forms of energy production. These could be made "competitive," he said, by raising oil prices to $80 per barrel by 1990.

McNamara on Biomass

Predicting that the developing countries will be running a $280 billion oil import bill by 1990, retiring World Bank president Robert S. McNamara stated that the developing countries will have to make sweeping structural changes in their economies "that can enable them to pay from their own resources for increasingly more expensive, but necessary, oil." McNamara was Lyndon Johnson's Secretary of Defense.

McNamara called for:

- A significant rise in net financial flows to deficit Third World countries from $9 billion in 1980 to $33 billion in 1990 to help finance the deficits.
- A sharp increase in the savings rate of the low-income oil-importing countries. (Elsewhere in his speech McNamara noted that per capita income is already less than $220 per annum in these countries.)
- The substitution of domestic energy production for oil imports.

McNamara elaborated: "At current and prospective oil prices, many oil-importing developing countries can now turn what were previously regarded as marginal energy reserves of oil, gas, hydroelectric, and forest reserves into commercial propositions. If they maximize energy production between now and the end of the decade and pursue a vigorous program of energy conservation, we estimate that these countries could by then cut their annual oil-import bill by more than $50 billion."

The basis for McNamara's predictions about the Third World's oil import bill was his dictum that "the price of oil . . . is likely to continue to rise in real terms by perhaps 3 percent per year"—the inflation rate plus 3 percent. It is this assumption that also makes the Third World's marginal resources "economical."

McNamara specifically excluded nuclear power plants from his list of possible energy sources.

DNA Researchers Win Nobel Prize

Dr. Paul Berg received the 1980 Nobel Prize in chemistry "for his fundamental studies of the biochemistry of nucleic acids with particular regard to recombinant DNA" Nov. 14. Berg, a professor at Stanford University in California, shared the prize with two others, Drs. Walter Gilbert of Harvard University and Frederick Sanger of Cambridge University, whose work is also in the area of genetics.

The importance of their overall work is that they have provided critical tools for the current discoveries in the field of molecular biology—discoveries that provide insights into the fundamental aspects of the chemistry of life and provide the research base for the process known as genetic engineering.

Berg is sometimes referred to as the father of genetic engineering. "His pioneering experiment has resulted in the development of a new technology, often called genetic engineering or gene manipulation," said the Royal Swedish Academy of Sciences, the group that awards the Nobel Prizes.

Berg was the first to successfully demonstrate that DNA (the genetic material of life) from one species could be inserted into a second species where it would undergo many of the normal physiological functions that the normally present host DNA does. He was able to do this by joining or "splicing" the genes of the foreign organism to those of the host organism.

The Obvious Benefits

There are several immediately obvious benefits from this technique. The first is that one could take a small, difficult-to-obtain piece of DNA and, because of the reproductive characteristics of the plasmid DNA in bacteria, produce large and easily purified quantities of the genetic material. This has allowed researchers to examine and further manipulate this DNA, which is necessary for the study and experimentation of the structure and functional aspects of the material.

The importance of this research cannot be overstated. Although there is a level of understanding of how DNA functions in normal physiological processes, this understanding is based on a simplistic dogma that is inadequate for the interventions required if scientists are to cure cancers or develop plant and animal strains that will qualitatively advance the global ecology.

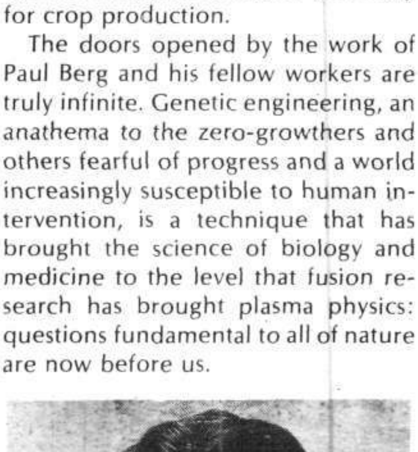
Another development to result from this technological breakthrough is the ability to transform bacteria into industrial plants, genetically engineered to produce substances of value to medicine, the chemical industry, and so on. There has already been a successful demonstration of this capability; human insulin has been produced by bacteria, and initial efforts on interferon production are highly encouraging.

The ability to cheaply produce rare and valuable biochemical products by this methodology is proven; therefore, the potential is imminent for increasingly promising modes of medical treatment based on these products.

Still another potential biomedical and ecological intervention realizable because of the recombinant-DNA technology is that of true genetic engineering; that is, the insertion, or *in situ* alteration, of particular genes in order to bring about a "new" organism.

For instance, it is potentially possible to remove pancreatic cells from a diabetic individual, genetically engineer these cells so that they will contain functional genes for insulin, and then reinsert them into a now-cured individual. Work is ongoing to genetically engineer plants so that they will be able to fix nitrogen (as legumes now do), thereby decreasing the amount of applied fertilizer necessary for crop production.

The doors opened by the work of Paul Berg and his fellow workers are truly infinite. Genetic engineering, an anathema to the zero-growthers and others fearful of progress and a world increasingly susceptible to human intervention, is a technique that has brought the science of biology and medicine to the level that fusion research has brought plasma physics: questions fundamental to all of nature are now before us.


Wide World

Dr. Paul Berg: father of genetic engineering.

Fusion Extra

Continued from page 69

maintain, and inspect the numerous fusion reactors that would be needed just for a few hundred GWe? Would a person with the education of a plasma physicist be content to perform intellectually rigorous, but menial tasks as part of power plant employment? . . .

In the next century, will fusion's promise be dimmed by just such a limitation?

* * *

Chicago Tribune, Sept. 12, editorial

. . . *If fusion can deliver on only half* of its promise it should be an enormous boon in a world that is rapidly running out of traditional sources of energy. . . .

We urge the Senate to go along with the House version [of the McCormack bill]. Alongside the $90 billion annually being spent on imported oil, $20 billion in 20 years is not great.

* * *

Reporter-Herald, Loveland, Colo., Sept. 2, editorial

There is plenty of energy around if we could just figure out how to use it. The nice thing about that energy supply is that it is not all fossil fuels.

The greatest potential source of energy may be nuclear fusion, the source of the sun's power. Fusion is a nuclear process that generates its own fuel. This, the energy supply, once fully harnessed, is almost endless since the basic ingredient is never used up. . . .

In a modern world, fossil fuels are nearly as crude a form of energy as wood. The universe has many more sophisticated forms of energy than fossil fuels.

It is incumbent on research to isolate and develop the usage of these energy forms if we are to survive as a society. The search for a way to harness fusion is a step in the right direction.

AMEF/FEF Seminar, Mexico City, Sept. 18

LaRouche-Riemann Model Opens New Vistas for Mexico's Growth

A seminar sponsored jointly by the Mexican Association for Fusion Energy (AMEF) and the Fusion Energy Foundation in Mexico City Sept. 18 sparked widespread interest in the LaRouche-Riemann econometric model and its application to Mexican economic development among leading layers of the Mexican government and private industry.

The seminar, "The Industrialization of Mexico for the Year 2000," drew scientists, economic planners, government officials, and executives from private industry to a discussion of the sophisticated economic-planning techniques made possible by the new model.

Salvadore Lozano

An FEF-AMEF press conference after the seminar received prominent coverage in eight Mexican daily newspapers. Here FEF research director Uwe Parpart (l.) and AMEF executive director Cecilia Soto de Estevez meet informally with reporters.

A panel featuring two U.S. and Mexican economic and scientific experts presented the conceptual foundations of the model, as well as the specific program for Mexican capital-intensive agriculture developed by the AMEF and FEF using the LaRouche-Riemann approach.

The opening presentation was given by FEF research director Uwe Parpart, who was in Mexico to tour the petrochemical facilities of Petroleos Mexicanos. Parpart presented a conceptual overview of the model, which treats the economy as a thermodynamic system and, unlike conventional econometric models, examines the causal relations among economic inputs. He emphasized that the model is uniquely capable of gauging the effect of a given technology mix on global productivity in any economic system and hence on economic growth rates.

"Of all the factors that affect productivity," Parpart said, "energy is the most important." Criticizing current theories of "decoupling" economic growth from energy growth as detrimental to economic development efforts, Parpart said that the critical parameter of productivity and economic growth is the energy flux density—the overall energy throughput per time per area—of energy production modes. Nuclear energy and fusion are the superior energy sources, he said, because they have the highest energy flux densities.

Energy Recovery Time

Parpart also described energy production modes in terms of the related concept of "energy recovery time"—the length of time a given energy production device must be run in order to recover the amount of energy that was required to build it. Parpart commented that the recovery time for a light-water fission plant is estimated to be about 4 to 5 months. For conventional fossil-fuel power plants the energy recovery time is half that, but for currently available solar cells, it is about 48 years—considerably longer than the lifetime of such solar devices, Parpart said.

"In the case of energy production, if you use energy-dense devices, you actually increase productivity. Similarly, if you use greater energy flux densities in agricultural production, you increase agricultural productivity, at the same time lowering the unit price of agricultural production in energy terms. If you put a lot of energy into the cultivation of land, then the amount of energy per ton of wheat will go down," Parpart stated.

The Thermodynamic Analogy

During the discussion period, Parpart was asked whether the thermodynamic representation of the economy is just an analogy to thermodynamic systems in physics or a true description of economic processes. Parpart answered that it is both. "Some of our most interesting insights into the economy have been arrived at using the analogy to thermodynamics, rather than speaking in actual energy-economic terms," he said.

Parpart explained that the analogy with thermodynamics had led to very useful results in considering the decrease in energy-intensity in the U.S. economy. "We looked at the economy through the analogy between an economy that becomes more labor intensive and a thermodynamic system which, as a closed system, develops a higher rate of entropy. Like the *entropic thermodynamic system,* the economy characterized by deteriorating energy intensity heads into an irreversible decline—unless countermeasures are taken."

"On the other hand," Parpart continued, "it is not simply a matter of analogy, because it turns out that energy flux density is indeed the key parameter for our form of economic analysis. . . . In the latest development of our model, we have been able to begin to take into account such parameters as energy flux density. This involves a system of partial differential equations that is actually capable of taking these parameters into account. The basic question that we have to ask ourselves there is how is the economy affected by the introduction of certain types of technologies that operate at a given energy flux density."

An Optimal Investment Strategy

Parpart was followed by Dr. Steven Bardwell, the FEF director of plasma physics, who explained the usefulness of the LaRouche-Riemann model for arriving at an optimal investment strategy for an industrializing country like Mexico.

In Mexico the highest rate of investment should go into the oil and petrochemical sector, Bardwell said, because this sector of the economy will increase global productivity the fastest; it is the sector capable of generating a financial surplus that will enable Mexico to import the capital goods it needs to industrialize. "Mexico is in a very advantageous situation," Bardwell said. "Its enormous potential as an oil producer allows it to finance capital from the outside, without overly straining its own industry."

Bardwell explained that continued high rates of investment in the oil sector are also necessary to build up a high-technology nucleus that can catalyze development throughout the economy and labor force.

Bardwell's comments directly intersected an ongoing debate within Mexican planning circles over whether Mexico should continue to invest its surplus in oil development or whether it should concentrate investment in subsistence-type agriculture.

A comparison of the March 1979 National Industrial Development Plan with the April 1980 National Global Plan shows that there has already been a shift in favor of agriculture. The latter plan allocates agriculture nearly double its share of oil revenues at the expense of the industrial sector, which will receive only half its original share. The current Mexican Food System advocates incremental investment in one of the least productive modes of agriculture in Mexico—subsistence farming on rainfed areas. The rationale behind this shift in investment patterns is the recent plummeting of agricultural output, caused in large part by severe drought, which forced Mexico to import 150 percent more grain in 1980 than in 1978.

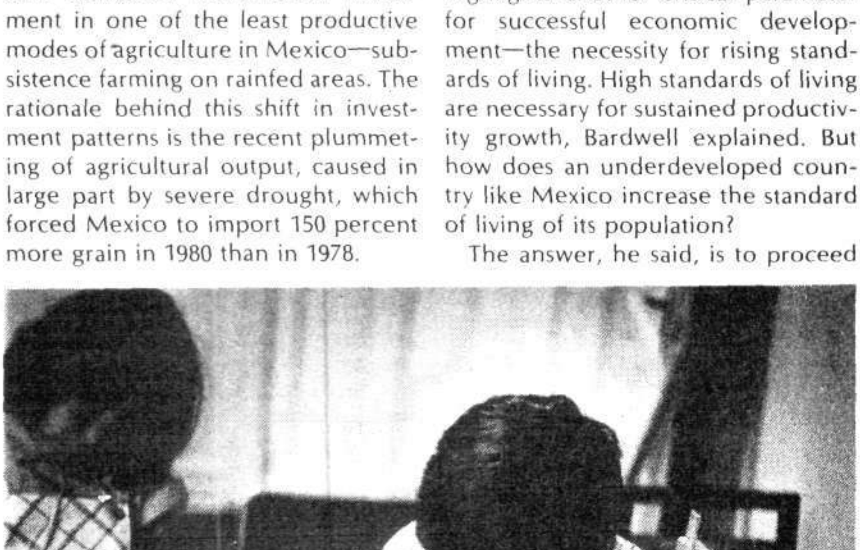
In discussing the relationship among capital investment, productivity, and economic growth, Bardwell emphasized that increased investment in subsistence agriculture, a sector with lower than average productivity, would actually aggravate the bottlenecks in Mexico's economy. Such investment would make merely incremental improvements instead of *transforming agriculture.*

"Subsistence agriculture not only does not increase productivity, it diminishes it, and it is therefore a sector that must be eliminated as rapidly as possible," Bardwell said. The solution to Mexico's agricultural crisis is for Mexico to invest in oil today to generate the capital for mechanizing Mexican agriculture.

Parameters of Development

The mechanization of agriculture and freeing of peasants from the land highlights another critical parameter for successful economic development—the necessity for rising standards of living. High standards of living are necessary for sustained productivity growth, Bardwell explained. But how does an underdeveloped country like Mexico increase the standard of living of its population?

The answer, he said, is to proceed



Salvadore Lozano

The AMEF education activities include physics classes for children. Here youngsters are using a soap solution to measure superficial tension.

in a "stepwise" manner, concentrating investment in the sector that has the highest standard of living and generating a general rate of economic growth in that way. Bardwell cited the examples of India and South Korea, which have used a "concentric-circles" approach to training technicians and introducing higher standards of living.

The other critical paramater of economic development is the rate of technological development, Bardwell continued. The level of technology defines a resource base—technology created oil, for example, he said. "In a few years Mexico could triple its proven oil reserves, making Saudi Arabia's look like a drop in the bucket," Bardwell said, "if it is given advanced technologies for oil development."

Bardwell stressed that Mexico must now consume its oil resources at a sufficient rate to guarantee that a new level of technology will be ready by the time that Mexico's oil and natural resources are depleted.

In the discussion period, Bardwell was asked to elaborate on the concept of productivity that he was using and specifically whether the measure of productivity takes into account productivity in one country only or productivity internationally.

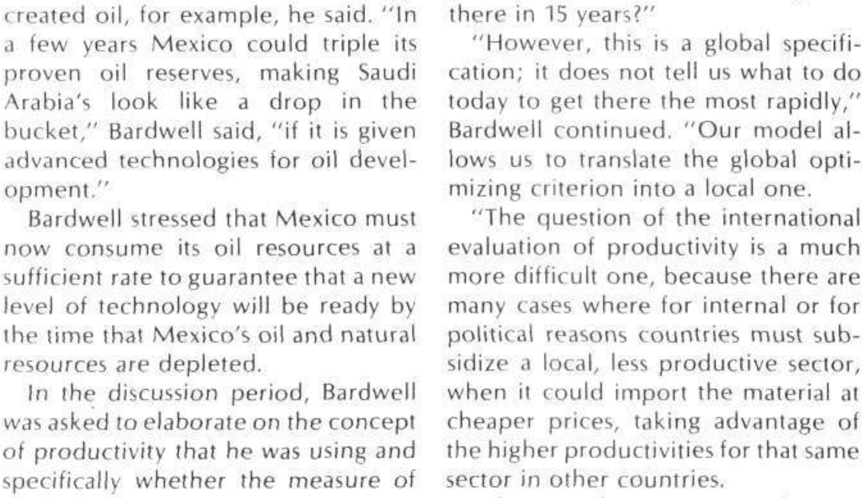
"We have defined a measure of productivity that is considerably different from the usual concept," he answered. "It is an indication of the efficiency of a given deployment of labor for the production of gross profit in an economy."

This criterion, Bardwell said, is an extremely useful tool for evaluating the effectiveness of investment strategy: "The simplest optimizing criterion for the process of economic development is a shortest-time criterion: we know where we would like to be in 20 years; what investment strategy will get us there in that time period? Is there one that will get us there in 15 years?"

"However, this is a global specification; it does not tell us what to do today to get there the most rapidly," Bardwell continued. "Our model allows us to translate the global optimizing criterion into a local one.

"The question of the international evaluation of productivity is a much more difficult one, because there are many cases where for internal or for political reasons countries must subsidize a local, less productive sector, when it could import the material at cheaper prices, taking advantage of the higher productivities for that same sector in other countries.

"The case of Mexico's capital goods industry is an example of this," Bardwell said. "There are very difficult decisions that have to be made about balancing tariff restrictions that will allow Mexican industry to develop against the economic advantages of imported capital goods. It is a tradeoff which is outside the sphere of strictly economic considerations."



Salvadore Lozano

AMEF director Patricio Estevez speaking to farm leaders at a recent meeting in Sonora.

After a luncheon break, Cecilia Soto de Estévez and Patricio Estévez, executive directors of the AMEF, presented the specific program for the Mexican economy that has been developed through the model.

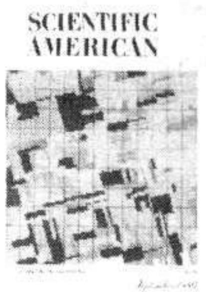
Cecilia Soto de Estévez emphasized the need to complement Mexico's ambitious oil-development program with a nuclear-development policy, and she outlined the educational program needed to develop an indigenous scientific and technical cadre.

Patricio Estévez outlined the AMEF/FEF program for eliminating subsistence farming. The first phase of the agricultural program calls for intensive application of energy- and capital-intensive methods—irrigation, mechanization, and the use of fertilizers and high-yielding crops—on existing fertile crop land to achieve a rapid increase in agricultural yields, which will become the model for the rest of the agricultural sector, he said. Subsequent phases of the program call for applying technology-intensive methods on all farms and expanding the amount of irrigated land under cultivation through establishing a network of water projects.

Represented at the conference were, among others, Mexico's ministry of planning and budget and ministry of industrial development; Nafinsa, the government finance agency; the Mexican Institute of Petroleum; the National Institute of Nuclear Research; and the private banking group Bancomer. Also in attendance were advisors to the state governments of Sonora and Puebla.

A press conference held by Uwe Parpart after his presentation received prominent coverage in eight of the country's major dailies. *El Sol de Mexico's* article described the LaRouche-Riemann model as "the most advanced method of economic analysis in the world."

—*Lydia Schulman*



Scientific American Goes Maoist: Part 2

Editor's note: Last month this column critically reviewed the September special issue of Scientific American *on economic development, noting its emphasis overall on "redistribution of wealth" instead of industrial development and publisher Gerald Piel's stated admiration for the labor-intensive Chinese model. Because the issue is vital for the developing nations as well as our own economy, here we review in more detail the* Scientific American *articles on India and Mexico.*

* * *

INDIA FROM THE 'LAP OF THE GODS'

India's current and potential economic development is grossly misunderstood in the West. The usual image of India is one of massive poverty and underdevelopment, punctuated by pockets of modernization that have had little impact on the masses of the world's second most populous nation.

Raj Krishna's contribution to the September *Scientific American*—"The Economic Development of India"—has the virtue at least of not perpetuating such myths. Krishna fairly accurately portrays the extensive industrialization that has taken place and criticizes those who contend there has been "excessive investment in capital goods" sectors of the economy. Krishna also takes note of the relatively unnoticed success of Indian agriculture, which has taken the nation within this decade from large-scale food importing to self-sufficiency (at admittedly low caloric consumption levels) and surplus production.

"For India," he states, "the gloomy prediction of a growing gap between food demand and food supply, a prediction that some international agencies publicize regularly, seems in fact to have no basis."

Unfortunately, Krishna's contributions to a better understanding of India's economic status and future come to an end at this point.

World Bank Influence

Krishna's credentials give some insight into the problems that are evident in the future paths and solutions for India that he offers. He is typical of a layer of development economists in India who are attached to the formulas of the World Bank, on whose staff he served. More important, Krishna was a member of the Planning Commission of the recently replaced government of Moraji Desai, a government whose draft Five-Year Plan (which he worked on) is now being rewritten by the new government of Prime Minister Indira Gandhi.

The reason for scrapping the plan is evident in the prescriptions for India that Krishna favors. Although he dares not directly criticize Indian industrialization—"small is beautiful" does not have a great constituency among Indian economic experts, except those on the dole of various international foundations—he essentially favors the labor-intensive, supposedly employment-generating schemes in both agriculture and industry that the Desai government had emphasized. These schemes are not antiindustrial on the surface, but they are in effect because they view the problem of the Indian economy as essentially rural-oriented distributionism and not net wealth creation.

Krishna's major concluding emphasis is a classic World Bank attack on Indian industrialization. The bottlenecks in further growth, he says, are the product of "bureaucratic overcontrol," mismanagement, public sector waste, and labor unrest. Although it is certainly true that managerial problems plague the Indian economy and that bureaucracy is often a hindrance to rapid mobilization of resources, the key to solving the problem involves political and planning leadership from the top.

Here Krishna reveals his partisan—that is, anti-Gandhi—prejudices. He concludes: "The Indian political system has simply not produced a leadership that is knowledgable and sincere enough to break the syndrome of slow growth and growing poverty. . . . Which scenario (of slow or rapid growth) in fact materializes will depend on the shifts in leadership that may occur. These are in the lap of the gods."

The gods aside, India's present government, despite some shortcomings in leadership, has reversed the antiindustrial policies of the Desai government and is moving to revive industrial growth, which had slipped backwards during the time of Krishna's service on the Planning Commission.

High Technology Omissions

Perhaps the most telling aspects of Krishna's article are what the author fails to say. First, he never mentions the single most important factor in Indian development—its unique (to the Third World) reservoir of skilled scientific, engineering, and technical manpower, one of the largest in the world as a whole. India's scientists and engineers, who rank with the best in the world, give the nation the capacity to absorb the highest levels of new technology and reproduce it rapidly. With an input of the real shortage—capital and capital goods—this manpower resource would rapidly expand Indian industrialization.

Second, Krishna hardly mentions what has been the biggest bottleneck in industrial growth—the energy shortage. The low levels of capacity utilization, for example, which the author blames almost solely on "poor management," are mainly a product of severe power shortages affecting everything from coal production to transport and machinery utilization. The number one problem to solve for both industry and agriculture is the effect of oil price hikes combined with a far too slow growth of power-generation capacity.

Here India's scientific capabilities are crucial. Nuclear energy is recognized in India as the long-term solution to the energy problem, along with short-term measures now underway to increase coal and hydro generation of electricity. With the largest nuclear program in the developing sector, an extremely competent and well developed nuclear research and development infrastructure, India is poised to increase the nuclear component of the power grid—if the nation is not held back by international antinuclear (what is euphemistically called nonproliferation) policies. Krishna did not even mention nuclear energy and India's skills in this field.

Finally, despite his praise for Indian agricultural progress, Krishna misses the boat entirely on the one large-scale effort that will enable India to become a massive grain *exporter* in the not too distant future: the harnessing of India's incredible water resources, those of the Ganges-Brahmaputra riparian system whose seasonal flow remains largely untapped and uncontrolled. National water management systems involving large-scale canal and reservoir systems, plans for which are on the boards, can provide the year-round irrigation and flood control (plus hydro power) that will make India boom and fundamentally solve the agrarian problems, including those of underemployment.

I invite the author (and *Fusion* readers) to take a look at the excellent and well-received 40-year program for Indian development, "Making India an Industrial Superpower," prepared by the Fusion Energy Foundation in collaboration with specialists in India. This program, featured in the May 1980 issue of *Fusion*, takes up where Krishna leaves off with a real vision of India's economic development future.

—Paul Zykofsky
New Delhi correspondent

FROM OLIGOPOLY TO OLIGOBBLEDYGOOK

There is probably no place in the world where development prospects are more extraordinary than newly oil-rich Mexico. A rapidly growing youthful population, an extensive "start-up" industrial base, capable industrial and political leadership, surging revenues from the oil—these make up a situation that comes once in the lifetime of a nation.

The Mexicans know this. They are feverishly debating the correct course for investing their petropesos. How much for basic industry? How much for the backward agricultural sector? Should there be a mix of labor-intensive and capital-intensive technology? How much oil is necessary to pay for the imports required? How much is too much and will fuel inflation?

Such government plans as the National Industrial Development Plan (PNDI) and the Global Development Plan (PGD) are tackling the challenge of making the right choices. And a longer-range taskforce assembled by the Mexican Fusion Energy Association (AMEF) with the collaboration of the Fusion Energy Foundation in New York will be unveiling its full development program shortly (see Conferences section, this issue).

Given this context, *Scientific American*'s article on "The Economic Development of Mexico" in the September issue at first seems like a bad joke.

In the first place, the editors selected a Mexican political scientist to write the article, Pablo Gonzalez Casanova—someone without any background or competence in economics. The result? There is not one word on the debate about how to invest the petropesos, nor is there any mention even of the fundamental underlying issue of how to "vertically integrate" the economy by building up basic and heavy industry and capital goods.

The author is further distinguished by his close association with neo-Malthusian leftist circles in Mexico dedicated to reversing the Lopez Portillo government's policies of full-scale industrial development, including nuclear energy. For example, one of Gonzalez Casanova's closest friends, Enrique Gonzalez Pedrero, is an official in the Education Ministry who has authored a widely publicized Maoist tract, "The Wealth of Poverty."

Thus, in addition to the constantly intruding incompetence of the translation of the article, there is also a steady stream of abstract leftist gobbledygook: "[It] is not a case of a general dependence of one country on another but rather of the dependence of a country and its government on foreign- and domestic-owned corporations," or "with all its political and economic stability, which is greater than that in many developed countries, the Mexican state still only fulfills the functions assigned to it on the outskirts of the capitalist world by capitalism." And there are repeated references to "oligopoly" as an all-purpose enemy.

But there is an insidious side to this bad joke. Gonzalez Casanova keeps up a veneer of defending Mexico's rapid population growth from the attacks of the international population control lobby, and he carefully steers clear from a direct attack on the government's industrialization policy.

However, with the sheep's clothing of a progrowth advocate, he focuses his argument on one central policy point: that redistribution of Mexico's admittedly uneven income spread must be the single priority of government effort, eclipsing any focus on the growth of the productive capacities themselves.

Gonzalez Casanova's neglect of the issue of correct investment of the oil money in heavy industry and high-technology growth pathways—which fundamentally addresses the redistributionist issue—is a prescription for exactly the "deep crisis in the social order" that he warns against. Not accidentally, he rose to prominence in the late 1960s as the rector of the National Autonomous University precisely on the basis of his supporting role for the massive 1968 student destabilization in Mexico.

—Tim Rush

JOURNAL OF COMMERCE: 'NO CHOICE' BUT NUCLEAR

The *Journal of Commerce* made a low-key but firm statement in favor of developing nuclear power in its Oct. 14 editorial. After reviewing the results of the Maine referendum in which antinuclear activists were roundly defeated, as well as other post-Three Mile Island shenanigans, the editorial concluded:

"The situation is confused, the possibility of action in the lame duck session of Congress beginning Nov. 14 doubtful. The nuclear industry's new-found optimism could well be premature. The point, though, is clear: the nation has no choice but to continue nuclear development if it is to free itself from dependence on foreign oil. Like the voters in Maine, Americans generally must weigh the luxury of a nuclear-free future against the very real costs."

* * *

LIMITED NUCLEAR WAR OR HOLOCAUST?

In the aftermath of President Carter's announcement of the controversial limited nuclear war doctrine (Presidential Directive 59), more realistic strategic thinkers have begun to counterpose the hard facts of nuclear war to the fantasies emanating from the White House.

In the October issue of *Technology Review*, the magazine published by the Massachusetts Institute of Technology, physicist and leading participant in the Manhattan Project, Professor Victor Weisskopf, describes the grisly effects of a thermonuclear explosion over Boston. Weisskopf then explains simply and straightforwardly why tactical nuclear war is impossible:

"It is extremely unlikely that a war fought with tactical nuclear weapons will stay limited to tactical nuclear weapons. Larger and larger weapons will be used by those temporarily losing, until, in the last instance, strategic weapons are employed. . . . Tactical weapons, in other words, do not really fulfill the purpose for which they were created; on the contrary, they will lead in the end, not with certainty but with great probability, to nuclear holocaust."

* * *


GUERIR LE MAL AU DOS

LE MATIN

SCHMIDT : RISQUES DE GUERRE POUR L'ENERGIE

POLOGNE

WHO'S TRYING TO KILL IRAQ'S NUCLEAR PROGRAM?

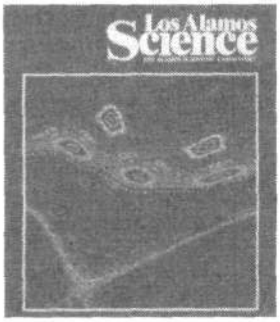
"The French government no longer has any doubts that the bombing of the Iraqi nuclear plant built by the French in Tammuz was an operation carried out by the Israeli armed forces." So wrote the Paris daily newspaper *Matin* Oct. 15. Most press reports have credited the Iranian air force for the raid.

Israeli involvement in the raid should come as no surprise to those who have followed the events over the last 18 months. In April 1979, a terrorist team bombed a reactor ordered by Iraq while it was still under construction in France. At the time, informed observers pointed a finger at Israeli intelligence, the Mossad, as the most probable perpetrator.

Then, during the summer, a leading Iraqi nuclear expert was murdered in Paris, apparently by Arab terrorists, although again there was evidence pointing to Israeli involvement. *Science* magazine Aug. 29, for example, speculated on this, noting the strong Israeli interest in hampering Iraqi nuclear developments for fear that Iraq might build bombs.

There is no evidence, however, that Iraq, a signatory to the nonproliferation treaty, is attempting to develop a nuclear arsenal. Iraq has made it clear that it considers nuclear power to be an essential ingredient in Mideast industrialization, a policy favored by the moderate peace factions on both sides of the Arab-Israel conflict.

* * *



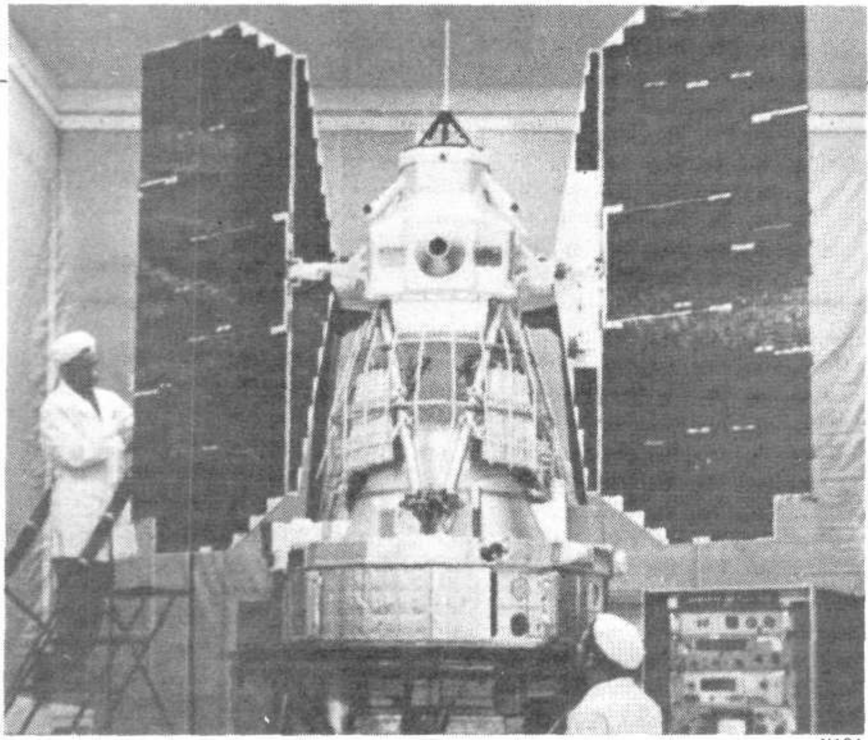
LOS ALAMOS ISSUES NEW SCIENCE JOURNAL

We welcome the new limited-circulation journal *Los Alamos Science* issued by the Los Alamos Scientific Laboratory in New Mexico. The journal aims to provide laboratory staff and contractors with an easily accessible review of the lab's scientific and engineering work.

A highlight of the premier issue, summer 1980, is an article by Dr. Mitchell J. Feigenbaum, a leading mathematician on the LASL staff, who reviews the recent theoretical development of universal behavior in nonlinear systems. This new theory is of great importance and provides a new route to understanding the nature of turbulence, a phenomenon that inhibits progress in many technological programs.

The universality theory for the first time allows a quantitative understanding of how causal systems develop apparently chaotic behavior, which is actually a transition to a new level of ordering.

NASA's Landsat Is Vital for Agroscience



NASA

Landsat-3 (above), launched in 1978, will be replaced by the more advanced Landsat-4 in 1981. Its overlapping orbits cover the entire globe every 18 days.

Landsat, the satellite system for continuous worldwide data gathering launched by NASA in 1972, has the potential to revolutionize agricultural planning. For the first time, agricultural planners can organize production with an accurate, detailed, scientific data base. And in comparison to the earlier alternatives of ground survey and aerial reconnaissance, Landsat costs are minimal.

Landsat-3, the current satellite that will be replaced by the more advanced Landsat-4 in 1981, covers the entire globe in overlapping orbits every 18 days, transmitting a steady flow of information to ground receiving stations. In addition to agricultural information, Landsat supplies data about potential ground water resources, possible earthquake zones, and new sources of oil and gas.

Before Landsat, agricultural planners were forced to rely on ground surveys and photographs taken from airplanes, which could cover only small areas of the earth and which missed wide-area features such as faults in the earth's surface.

In a pilot study of forest land in East Texas, the Texas Natural Resources Information System found that the total cost for mapping an 11-million-acre commercial timber zone would be $294,000 for aerial photography and only $10,289 for Landsat. In addition, the 10.7 man-years for the aerial mapping would be reduced to 4 man-months for Landsat mapping. Other studies show that the overall cost per square mile for land cover inventories is $59.46 for ground surveys, $20.18 for aerial photography, and $4.20 for Landsat.

A spinoff from the high-technology U.S. space program, Landsat uses the most advanced equipment. There are two sensor systems on the Landsat-3 satellite, a return-beam vidicon system, which is a television sensor, and a multispectral scanner (MSS), which detects the emission or reflection of light from the earth's surface. Recording information in visible wavelengths, infrared, and in wavelengths invisible to the eye or a camera, the MSS takes four readings for each 1.1 acre: one for the intensity of reflected green light, one for the intensity of red light reflected, and two for the intensity of infrared. (See "NASA's Boost to the Economy," page 31, for Landsat photographs.)

The digital data produced are computer-processed on earth to create images that show each crop in a different color. Local universities or state governments can receive the data from the Earth Resources Observation System Data Center as photographs or tapes of data that can interface with various computer systems.

NASA has now begun a six-year research program called AgRISTARS (Agriculture and Resources Inventories Through Aerospace Remote Sensing) to make a worldwide agricultural inventory. AgRISTARS is to develop an early warning system that will detect conditions such as drought, excessive rainfall, snowmelt rates, or infestations affecting crop production. The experiment is also aimed at the development of techniques for more accurate commodity production forecasts, a vital factor for international trade.

In the AgRISTARS program, eight crops in seven countries will be continually scanned by Landsat (wheat, barley, rice, corn, soybeans, sorghum, sunflowers, and cotton, grown in Argentina, Australia, Brazil, Canada, India, the Soviet Union, and the United States). The data will be combined with weather information from meteorological satellites of the National Oceanic and Atmospheric Administration, observations from ground-based weather stations, and comparison data from previous years. The combined data will be analyzed by computer to provide a basis for predicting crop yields.

One important agricultural application of Landsat surveys is erosion control. Recently, the state of Iowa teamed up with NASA's Earth Resources Laboratory to demonstrate how Landsat can help determine land erosion potential. The project examined the increased soil erosion that resulted from conversion of pasture land to row crops in unsuitable locations—for example, on high slope terrain with unstable soils.

Landsat classification maps showing changes in land cover from 1973 to 1978 were combined with digitized soil maps and terrain data to calculate expected soil erosion and identify potential problem areas. The study then produced a series of color maps showing the degree of potential erosion for the area.

Freeze Predictions

The National Oceanic and Atmospheric Administration's GOES (Geostationary Orbiting Environmental Satellite) is also providing agricultural information. GOES sends infrared pictures to earth every 30 minutes showing statewide temperature data for Florida farmers. These data provide an accurate means of observing freeze conditions and of predicting exactly when and where freezing will occur and how long it will last.

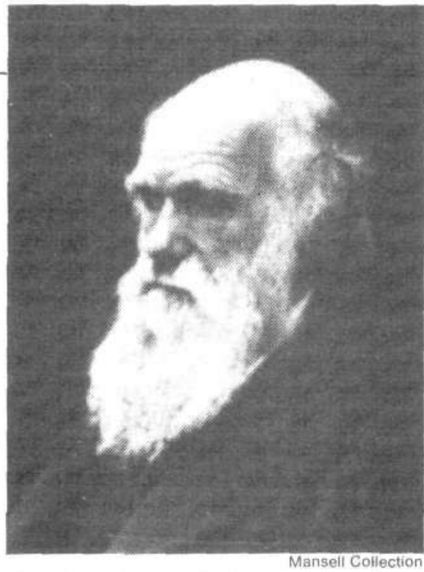
This temperature-forecasting information is vital to agricultural interests, particularly citrus growers, whose entire crop can be ruined by a sustained freeze. When freezing is predicted, growers use grove heaters and wind machines to prevent crop damage. Precise information is crucial because a single night's operation can cost $6 million for the Florida citrus industry and early ignition of the heaters may cause them to run out of fuel if the duration of the freeze is not predicted accurately.

Landsat's agricultural applications include crop inventories, estimating yields, monitoring crop disease (a notable example was its successful use during the early-1970s corn blight in the Midwest), mapping irrigated fields, assessing drought impact, and supplying data for rangeland management. In Third World nations, where aerial photography is often impossible for financial and technical reasons and where ground surveys are limited by manpower and logistical problems, Landsat provides information vital to maintain and expand agricultural production.

Although Landsat surveys have supplemented or entirely replaced aerial photography for agricultural data in many parts of the United States and many state governments now have programs to utilize Landsat data for agricultural planning, widespread use of this technology by American farmers is still limited. The proved capability and growing potential of space-based agricultural monitoring, however, will determine the direction of U.S. farming in the future.

—Susan Schoonover

Darwin: A Victim of His Unfit Theory


Mansell Collection

Darwin: "My mind seems to have become a kind of machine."

To Be an Invalid: The Illness of Charles Darwin
Ralph Colp, Jr., M.D.
Univ. Chicago Press, Chicago, 1977

Many scientists have puzzled over Charles Darwin's strange psychosomatic invalidism, which kept him in relative seclusion throughout his life so that Thomas H. Huxley was left to present Darwin's ideas to the public and thus became the chief spokesman for Darwinian evolution.

Dr. Ralph Colp's book, *To Be an Invalid: The Illness of Charles Darwin*, gives a convincing and well-documented argument for the psychological conditions causing Darwin's illness. As Colp says:

"When he came ill, after realizing the consequences of his evolutionary thoughts, this illness indicated that he was emotionally and physically sensitive to the difficulties of his theory and to being hated and rejected. . . . For most of his life he seems to have been severely anxious—what he described as 'a perpetually half knocked-up condition.' . . .

"When, after meeting a new individual, he suffered 'violent shivering and vomiting,' this may (as has been suggested) have been a displacement onto the individual of his anxieties about his evolutionary theory."

Darwin's autobiography also indicates the psychosomatic origins of his illnesses. His mental deterioration arose from the fact that his theory of evolution had *no supporting* paleontological evidence and no support among his scientific colleagues. As Colp explains:

"Darwin suffered because he had 'so few friends'; he also suffered because old friends (like Owen and Fitzroy) opposed his theory, and because the few friends he did have (Lyell and Hooker) had reservations about his theory. . . .

"He also suffered illness when some evidence—such as the facts Hooker brought him about the geographical distribution of plants—did not uphold his theory. The more he collected evidence and explored the multitudinous ramifications of natural selection, the more he encountered—among problems solved—new problems which could not be solved. The unsolved new and old problems caused him to be tortured with obsessional thoughts, and to become (in his words) 'tired' in his thoughts and physical actions."

Darwin became psychologically and therefore physically ill because he was totally obsessed with proving a general law that skirted both scientific evidence and the more interesting questions posed by the natural science developing during his period. As Louis Agassiz, a leading naturalist of the time, noted of Darwin's theory: "This is truly monstrous . . . the result of laziness, . . . a false theory [that avoids] investigating the difficult points of science."

In an age when such renowned scientists as Louis Pasteur, Jean Baptiste Lamarck, and Louis Agassiz were opening up new branches of biological science with the strictest rigorous search for causes, Darwin presented a theory that was cribbed from others, acausal in essence, and completely lacking in scientific evidence. No wonder, then, that his scientific friends completely rejected this unscientific rationale for Malthusian philosophy.

The Malthus Connection

The question that must be answered is why is a man known to be incompetent in his own time held up as the great biological theorist for the 20th century? The answer lies in the Malthusian basis of Darwinian evolution.

Thomas H. Huxley was the main public proponent of Darwin's theory. Huxley, a political agent of the British Admiralty and its corporate entity the British East India Company, financed the "research" of Thomas Malthus and funded Darwin's journey on the Admiralty's HMS Beagle as well as publication of the first edition of *The Origin of Species*.

After Malthus supposedly demonstrated that population growth will outstrip the means of production, it was necessary to have a more scientific excuse for imposing population control and eugenics. Darwin admits in his autobiography that he got his idea of "survival of the fittest" while reading Malthus.

A secondary purpose was to abort the flourishing of biological science in the work of Pasteur and Lamarck. At the same time that Darwin was spouting unsubstantiated nonsense, Lamarck had already posed rigorously the *causal* problem faced in evolution of the biosphere: What process in nature has produced "all the species of animals in succession, beginning with the most imperfect or simplest, and ending her work with the most perfect, so as to create a gradually increasing complexity in their organization?"

In describing biological evolution by its hydrodynamic, self-differentiating, and self-perfecting qualities, Lamarck located evolution in a way coherent with the evolution of the solar system, the stars, the galaxies—in fact, in terms compatible with the self-organizing evolution of all plasmas. Darwin's scheme, in contrast, reduces evolution to the banal attributes of animal reproduction.

The Platonic scientific tradition of Lamarck, of continually rethinking and retesting each hypothesis, "is probably the grandest example of the unscientific use of the imagination extant," according to Huxley. So Huxley turned Darwin into "a kind of machine for grinding out general laws out of a large collection of facts," as Darwin himself notes.

Using public debates with carefully selected foils, Huxley made Darwin's untested idea a "hypothesis" beyond any need for proof. Huxley bragged that "I shall have my workmen thinking they are monkeys." At the same time, Huxley supported Darwin's relative Sir Francis Galton, who created the so-called science of eugenics. Since civilization violates Darwin's law of survival of the fittest, eugenics must be pushed to prevent the free propagation of the unfit. "I cannot doubt that our democracy will ultimately refuse consent to that liberty of propagating children which is now allowed to the undesirable classes," Galton wrote.

An Unfit Theory

Darwin's theory imputed mere randomness and acausality to a process that is actually vectored toward increased complexity of organisms, increased differentiation of species, increased efficiency of metabolisms, increased population potentials, and increased overall negentropy.

His premise that random mutations induce "fit" and "unfit" variations that are sorted out by struggles to survive and procreate is subject to verification by the fossil record. That is, there should exist fossil evidence of a gradual, linear change in life forms. But instead, the record indicates long periods of stability interrupted by abrupt transitions of rapid speciation, often effecting total transformations in flora and fauna characteristics.

Darwinians speak of "missing links" to save this lack of evidence of randomness. But no missing links have ever been found to date, 100 years after Darwinian evolution became the law of the land.

In fact, the paleontological evidence against Darwin is becoming overwhelming. The rapid diversification of flowering plants (angiosperms) in just 10 million years is much too fast for natural selection. Similarly, 20 orders of mammals came into being within 12 million years, and 20 families of ammonites in only 8 million years. The tenets of natural selection and survival of the fittest can account for none of these major shifts.

Modern science is only beginning now to unravel the processes involved in higher evolution, of which random mutations are a secondary, not primary, aspect of speciation.

Huxley succeeded in freezing evolutionary theory around Darwin's dogma. But this mechanistic scheme stripped higher causality from evolution with such vengeance that Darwin himself was reduced to a barely ambulatory psychotic. He could no longer face music, poetry, or anything associated with higher mental processes. In his autobiography, he complained:

"But now for many years I cannot endure to read a line of poetry; I have tried lately to read Shakespeare, and found it so intolerably dull that it nauseated me. I have also almost lost my taste for pictures or music. . . . My mind seems to have become a kind of machine for grinding out general laws out of large collections of facts, but why this should have caused the atrophy of that part of the brain alone, on which the higher tastes depend, I cannot conceive. . . .

"The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character."

Darwin's theory of evolution not only denied the more advanced science of his time, it denied mankind's humanity. And, as documented by Ralph Colp, it destroyed Darwin himself.

—*Carol Cleary*

Books Received

The Complete Handbook of Robotics. Edward L. Safford, Jr. Pennsylvania: TAB Books, 1978. 354 pp., $7.95.

Federal Energy Information Sources and Data Bases. Carolyn C. Bloch. New Jersey: Noyes Data Corporation, 1979. 115 pp., $24.

Coal Liquefaction Processes. Perry Nowacki. New Jersey: Noyes Data Corporation, 1979. 339 pp., $48.

Industrial Energy Conservation. Melvin H. Chiogioji. New York: Marcel Dekker, 1979. 579 pp., $45.

Space Shuttle: America's Wings to the Future. Marshall H. Kaplan. California: Aero Publishers, 1978. 207 pp.

Mapping From Aerial Photographs. C.D. Burnside. New York: Wiley, 1979. 300 pp., $45.

Malthus. William Petersen. Cambridge, Mass: Harvard University Press, 1979. 302 pp., $17.50.

Black-Body Theory and the Quantum Discontinuity, 1894-1912. Thomas S. Kuhn. New York: Oxford University Press, 1978. 356 pp.

Nuclear Physics in Retrospect: Proceedings of a *Symposium on the* 1930s. Edited by Roger H. Stuewer. Minneapolis: University of Minnesota Press, 1979. 340 pp., $25.

Peoples' Capitalism. James S. Albus. College Park, Md.: New World Books, 1976. 157 pp.

Exotic Atoms '79: Fundamental Interactions and Structure of Matter. Edited by Kenneth Crowe, Jean Duclos, Giovanni Fiorentini, and Gabriele Torelli. New York: Plenum, 1980. 403 pp., $45.

Hunger Disease. Edited by Myron Winick. New York: John Wiley, 1979. 254 pp., $15.

Who Owns the Earth? James Ridgeway. New York: Macmillan, 1980. 149 pp., $14.95.

Radioactivity in America. Lawrence Badash. Baltimore: Johns Hopkins University Press, 1979. 274 pp., $17.95.

Letters

Continued from page 13

exposed sisters at menopause. And, for those of us who can have children, what does all of this mean for the next generation? While I wait for the answers to these questions, I do the best I can to minimize the risks. In other words, I undergo special examinations regularly to monitor the effects of my DES exposure. They aren't painful or terribly time-consuming; neither are they free.

My mother carries a burden of guilt for having exposed me to DES. I bear no grudge against her or her doctor. Both did the best thing they knew at the time to protect me. I don't think it's fair to blame medical science for what had not yet been discovered 30 years ago.

But we know better than that now. Or at least, we should. It may be proven some day that feeding beef cattle with DES is not in any way harmful to humans. At the present time, however, we have every reason to fear harmful effects from DES-fed beef. I live every day of my life with the consequences of DES exposure. It is by no means a paralyzing fear, but it is a constant insecurity I wouldn't wish on anyone else.

Granted, beef prices are high, and I don't want to see them increase. I submit, however, that given the tremendous publicity the DES "scare" has received for the past several years and the increasingly concrete evidence that the threat is very real, the livestock producers have had ample time to look for a safe alternative to DES to increase feed efficiency. If Americans are going to pay more for beef, then they at least ought to know where the blame rightly belongs.

Sarah L. Bogue
Rochester, N.Y.

The Author Replies

Your letter is confirmation that we employed the term "scare" correctly in describing the events that led to the outlawing of DES use in livestock raising. Fear has a way of assaulting reason in individuals, undermining it, distorting a person's ordinary judgmental processes. Creating a seemingly valid "scare" among a group of people is the most efficient way to ensure that they will go along with any number of incredible propositions nominally related to the subject of fear.

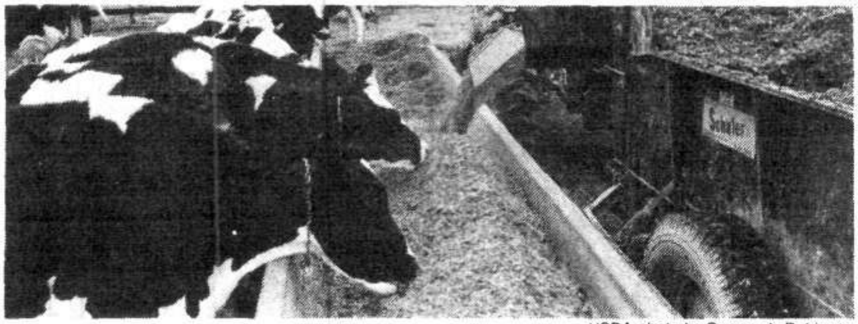
We do not dispute the findings on actual or potential effects on daughters of mothers who took DES to prevent miscarriages. But it is an incredible proposition that these findings have any bearing on livestock raising. Direct consumption of DES in pregnancy-related matters and the use of DES in livestock raising are two qualitatively different phenomena. To ignore the distinction is like ignoring the distinction between eating food grown in a field that has been fertilized and eating fertilizer.

From 1941 to 1971, approximately 3 to 4 million women were given DES by their physicians in doses up to 300 milligrams per day in an effort to prevent miscarriages. In the early 1970s, a Harvard research team stated that the daughters of women who had taken DES during pregnancy ran a slightly increased risk of developing a rare form of vaginal cancer.

More recent studies indicate that the risk is very low—out of 3 to 4 million mothers, only 450 cases of cancer in the daughters have come to light. The latest study, completed this summer by Beth Israel Hospital researchers in Boston, found that cervical abnormalities in DES daughters decrease over time, and may eventually disappear. Of 175 women examined, cervical ectopy—the presence of glandular material instead of normal smooth lining in the cervical area—was present in 121; during a follow-up period, this condition had decreased in 91 of the subjects and altogether disappeared in 38.

To our knowledge, that is the status of the research. It does not, by any means, alleviate the worry of DES daughters, nor does it suggest that there is no need for caution and continued monitoring of exposed individuals.

However, it also does not signify that use of DES by pregnant mothers should be discontinued! That decision is properly made in the broader context of evaluating its effect in preventing miscarriages—life-threatening to both mother and child—and evaluating the availability of other therapeutic measures, and so forth. For example, penicillin will lead to tumor-formation in experimental animals, yet to ban penicillin would lead to death and disease far surpassing any damage done by use of this medication.



USDA photo by George A. Robinson

"Direct consumption of DES in pregnancy-related matters and the use of DES in livestock raising are two qualitatively different phenomena. To ignore the distinction is like ignoring the distinction between eating food grown in a field that has been fertilized and eating fertilizer."

Now let us turn to the qualitatively distinct matter of raising livestock. In livestock raising, the facts leave no doubt that DES use is not dangerous to human life in any way.

Since 1954, about 90 percent of the feedlot cattle in the United States have received either a one-time treatment with 24 to 36 milligrams of DES, often in the form of an "implant" of a slowly absorbed formulation in one ear, or they have been fed 10 milligrams of DES per day orally for several days. The amount of DES absorbed daily into the body system is small; essentially no DES is stored in the body of cattle.

Under Food and Drug Administration regulations in effect through July 1979, cattle producers and feeders were required to remove the "implants" or DES rations within a specified time period before the animal is slaughtered, such that the body system is rid of any and all DES residue. Under those conditions, no DES is found in either the muscle or liver tissue of the carcass. If DES is not withdrawn within the statutory time before slaughter, traces of the drug are occasionally detected in the liver.

In 1976, an analysis by the FDA and the U.S. Department of Agriculture of 1,815 beef livers uncovered nine violations of DES residue standards. These livers had from 0.5 to 2.0 parts of DES per billion parts of liver. At 2 parts of DES per billion, one pound of liver would contain 0.001 milligram of DES. *This is 1/300,000-th of the highest daily dosage of DES taken by pregnant mothers.*

Let us assume for argument's sake that all beef liver contained DES at a concentration of 2 parts per billion. To consume 240 milligrams of DES, a person would have to eat 266,666 pounds of liver. At average annual per capita rates of beef consumption in the United States, that would take 17,000 years!

In other words, the DES "scare," applied to cattle raisers, is just that, a "scare."

Numerous scientific studies have been done. Dr. T.H. Juke's "Antibiotics in Meat Production" (*Journal of the American Medical Association*, No. 232, 1975) states that the risk from DES in cattle is less than 1 U.S. cancer case per 133 years.

O.D. Butler *et al.*'s "Hormonally Active Substances in Foods: A Safety Evaluation" (Report No. 66, the Council for Agricultural Science and Technology) concludes that the risk is "essentially zero."

The DES "scare"—however well grounded in connection with direct consumption by pregnant mothers—has led you and many others to stop thinking rationally at any mention of "DES" or "hormone."

Susan B. Cohen

Viewpoint

Continued from page 11

product. It had a number and read, "Passed." In a relatively short time Japan took over the optical market in microscopes, binoculars, and cameras. Probably 90 percent of you here have optical products imported from Japan. They then went into electronics. Again with the same philosophy—quality products. Sony is just one example of quality coupled with innovative design. Their transistor systems are superb. The Japanese then went into transportation.

Today the overall quality of their automobiles, trucks, and motorcycles exceeds that of any other country. They are doing the same in the heavy electrical industry—transformers, motor generators, turbines. I submit that one of the most innovative concepts of the 20th century was concocted by Japan in deciding to produce and especially export only quality products.

In spite of the bureaucracy and the schools of management, technical innovation is proceeding at a satisfactory rate. It always will in spite of the bureaucracy, because innovation, like humor, is something you can't turn over to the central planning authority. It's looking at things in a different way, letting the imagination rearrange the pieces, and often being surprised at what you find. It's sometime irreverent, it's usually fun, and it feeds on freedom. That's what the best in science and technology really is—doing innovation.

What we need today, however—and this is serious—is to look at our social, political, and legal institutions in a different way—humor and irreverence will help—and consider rearranging some of the pieces so that our society as a whole can be encouraged once again to innovate. That's what has made America great and made most of our great accomplishments for ourselves and the betterment of mankind really happen.

Harold Agnew is the president of the General Atomic Company in San Diego. This Viewpoint is adapted from his presentation at the June 1980 Sperry Corporation Symposium.

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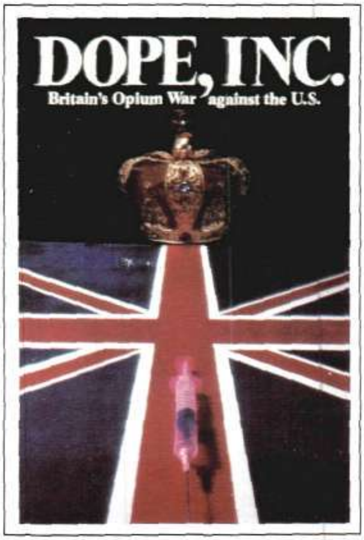

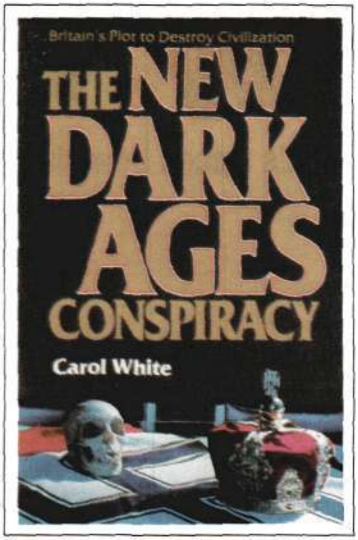

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In This Issue


LASL

A multiple-shell target for a carbon dioxide laser at Los Alamos Scientific Laboratory; the smallest of the three concentric shells is a 100-micrometer-diameter glass microballoon filled with fusion fuel.

BLACKBODY RADIATION AND FUSION

Charles B. Stevens discusses a radical approach to inertial confinement fusion developed by fusion pioneer Dr. Friedwardt Winterberg. Winterberg proposes amplifying the power necessary to heat and compress a pellet of fusion fuel by introducing another step in the process—a magnetized plasma that generates large amounts of blackbody radiation. In an accompanying article Dr. Morris Levitt relates the history of the blackbody radiation problem, centering on the groundbreaking theoretical role of Max Planck.

A '2nd INDUSTRIAL REVOLUTION'

The first of six FEF regional conferences on reindustrialization drew an enthusiastic response in Los Angeles Oct. 15. FEF research director Uwe Parpart characterized the plans presented as "a second industrial revolution founded on the vast resource base and superhigh temperatures of fusion energy." Speakers included Dr. F. Winterberg and Dr. N.W. Snyder of Parsons Engineering Co.


Wide World

Uwe Parpart (foreground) chats informally with conference participants; Friedwardt Winterberg is at center.


Uwe Parpart

MEXICAN DEVELOPMENT: AN FEF ASSESSMENT

Agriculture and industry are usually viewed as competing sectors for Third World development. In a provocative interview, Uwe Parpart tells why this view is false and presents a comprehensive planning approach for capital-intensive development, at the heart of which is a rigorous polytechnical education system. The interview is illustrated with aerial photographs from Parpart's recent tour of Mexico.

An irrigation system in Sonora that has helped to make the desert area the most productive in Mexico.

Cover: Front cover photograph of the space shuttle being readied for test flight, Christopher Springmann/Black Star. Cover design by Christopher Sloan.