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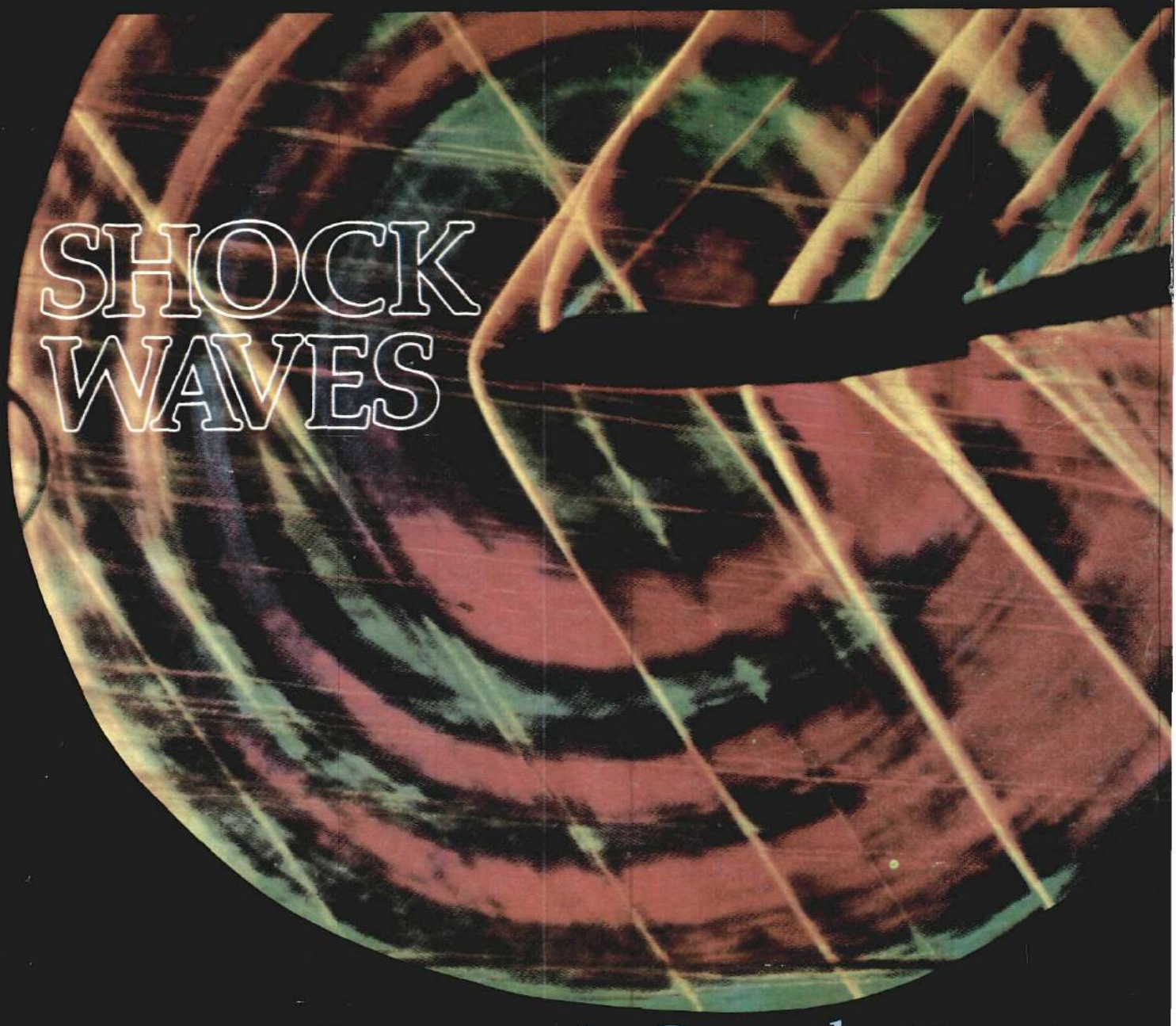

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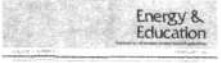

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Courtesy of Adolf Busemann

Shock waves: Understanding them was essential for developing planes that could break the sound barrier without destroying the aircraft. In an exclusive interview, aerodynamicist pioneer Adolf Busemann discusses this and many of his other groundbreaking ideas. Above, Busemann (left) poses at the important 1935 European aerodynamics meeting in Italy with two of his colleagues, Wieselsberger (center) and Ackeret.

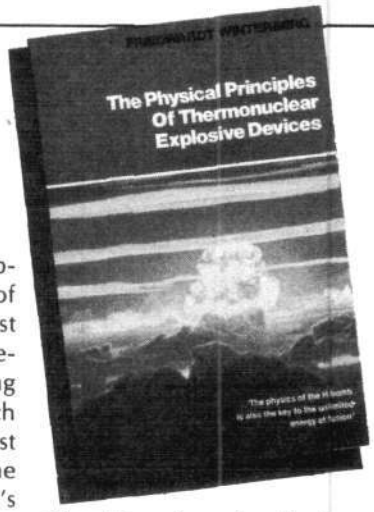
Yes to Lorraine and yes to nuclear power!—the rallying slogans on a poster of the broad-based pronuclear group formed to save the 5,200 MW Cattenom nuclear complex in Lorraine from the axe of French President Mitterrand.

Features

News

Departments

From the Editor's Desk



The Winterberg book: Must reading for those interested in fusion energy.

This issue offers readers a unique opportunity to look at the contribution of the 19th-century mathematical physicist Bernhard Riemann: first, to see how Riemann's work is essential today to solving the impasse in inertial fusion research (page 22); second, to see how a scientist trained in the Göttingen tradition in the 1920s, Adolf Busemann, used Riemann's method to make fundamental advances in aerodynamics (page 33); and third, to understand how Riemann's 1859 paper was the real secret in the *Progressive* case (page 42).

We are especially pleased to announce in this issue our publication of an important book by Dr. Friedwardt Winterberg, *The Physical Principles of Thermonuclear Explosive Devices,* which is must reading for readers who want to fully understand what the government is trying to classify and why such classification would inhibit basic scientific research (page 44). And, don't miss the wide-ranging interview with author Winterberg (page 54).

We also give you some homework! Readers are urged to send telegrams and letters of support to the group formed in France to defend the nuclear industry from the antinuclear President Mitterrand (page 49). The address is Comité Pour Cattenom, 18 Place du Forum, Metz 57000, France. FEF supporters are also encouraged to join our campaign to restore scientific rigor to U.S. education (page 15). And, for those of you in the New York area, the FEF is sponsoring a special dinner to honor Adolf Busemann and his work, Thursday, Nov. 5, in New York City. Call or write the FEF for details.

Finally, an apology: we regret any confusion we may have caused readers in the September issue's cover story, "The World Needs 10 Billion People." Pages 26 and 27 should have been numbered 28 and 29, and vice versa.

Marjorie Mazel Hecht

Marjorie Mazel Hecht
Managing Editor

FUSION

AT THE FRONTIERS OF SCIENCE AND ENERGY

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

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Editorial

The Current Strategic Debate

The debate over U.S. military posture has become more intense in the past two months than at any point in the last 20 years. Although this debate appears to be about contending weapons systems, the actual point of disagreement is whether or not the United States will foster advanced technological development. Directly connected to this is the question of the direction of development of the whole economy.

The generally downward trend of U.S. military capabilities relative to the Soviet Union has now reached the point of qualitative and rapidly accelerating Soviet superiority, a fact recognized by even the most liberal pacifist side of the military debate.

The point of Soviet superiority was reached just at the time that it became abundantly clear, even to the professional skeptics, that a fundamental revolution in military technology was about to take place. While many, including scientists at the Fusion Energy Foundation, have been saying for the past three years that the introduction of directed energy beam weapons (lasers, particle beams, microwave beams, and plasma beams are the currently known varieties) would redefine the central tactical aspects of military conflict, neither the significance nor the practicality of beam weapons came into general political circulation until this spring's announcement by Lawrence Livermore National Laboratory of a spectacularly successful test of the X-ray laser.

As this technological feat made clear, the Soviet capability to deploy such beam weapons over the next five years and the massive improvements in conventional ABM technology have destroyed the invulnerability of our strategic weapons (nuclear-armed ICBMs). For the first time since World War II, one Pentagon commentator noted, the defensive position becomes stronger than the offensive one.

Wunderwaffen Versus Development

A unique and provocative contribution to the strategic debate has appeared from Lyndon H. LaRouche, Jr. (a founder and board member of the FEF), in a series of recent papers published in the *Executive Intelligence Review*. LaRouche's general contention is that leading circles in NATO are attempting a parody of the Nazi military policy of 1933-1945, to the point that the two *wunderwaffen* of the Germans have become the miracle weapons of the 1980s—the Cruise missile and the Pershing II. LaRouche points out the political similarity between the "postindustrial" society proposals, which are used today to justify the investment policies of Federal Reserve head Paul Volcker, and

the programs of Hjalmar Schacht, the finance minister under both Brüning and Hitler. Both restrict military policy to dependence upon *wunderwaffen*. As LaRouche summarized it: "NATO policy makers have insisted that military policy must be subordinated to the effects of such a neo-Schachtian policy for the USA, et al., obliging themselves to adopt a parody of Hermann Goering's 'Guns Instead of Butter' doctrine of arms and operations."

These NATO planners argue that because the Nazis developed frontier quality military technologies under the terms of the Schacht-Speer austerity policies, we can replicate this achievement; because we have much greater geopolitical assets than the Nazis, they say, we can succeed where the Nazis failed.

LaRouche describes the twofold fallacy of this argument:

> First, the Nazi economy used up a previously established scientific and industrial potential which no Nazi or kindred political economic order could produce. The correlated point is that we lack the technological resources comparable to those the Nazi regime appropriated in subjugating the German nation to its rule. In terms of the present state of our educational system, the potentialities for producing, assimilating, and applying technology in our industrial establishment and in the qualification of and the extent of our scientific community, we are relatively far below the resources of the nation which fell into Hitler's and Schacht's hands. The Nazi weapon development center at Peenemünde expresses the role of non-Nazi created scientific and industrial resources in developing an advanced military capability *despite* the contrary implications of Nazi economic, social, and cultural and political characteristics.

A Question of Method

The question of method for the creation and assimilation of new technology is the crux of the matter for both the military and civilian success of a nation. The Nazis perfected a war-losing strategy (all NATO's fantasies aside, the Nazis did lose the war)—a strategy that destroyed the industrial base, manpower potential, and cognitive capabilities of the German nation; they looted the qualities of mind that they inherited from the older generation, scientists like Adolf Busemann, who is interviewed in this issue.

What the United States must master today if it is to survive the present crisis in military and civilian terms—and these, after all, are essentially the same—is the traditionalist military doctrine. As LaRouche summarized this: "The technology of warfare should be defined in respect to a reference-policy of 'Manhattan Project'-scale broad spectrum development and deployment of relativistic plasma-beam antimissile weaponry, combined with the strengthening of the civilian-economic agroindustrial basis from in-depth logistical, mobility, and personnel features of military capabilities. [We must apply] the continuing relevance of the great traditionalist republican military science of Alexander the Great, George Gemistos Plethon, Leonardo da Vinci, Niccolo Machiavelli, Gottfried Leibniz, Lazare Carnot, and the Prussian state reforms of 1809-1810."

It is impossible to develop an in-depth, war-winning capability within the confines of an austerity program dictated either by Volcker, or as has been recently mooted, by the International Monetary Fund. Strategists who have forgotten this should be forcefully reminded of the significance of the Nazi weapons research programs. They should be reminded that the Nazis' V-1 and V-2 weapons are exactly the same as the Cruise missile and the Pershing; only the names are new.

The role of advanced scientific education and research projects at the frontiers of high energy density physics—like laser fusion—is indispensable. And, ironically, the scientific method required for the solution of these problems is identical to the political method required for their translation into social reality.

The Lightning Rod

My dear friends,

No sooner had the various heads of government concluded their deliberations at Ottawa, than I noted with sorrow once again that our sensibilities were being assaulted and our good sense abused by eminent persons wrongfully insistent that the lowering of our own population is the major objective of the human species.

I too say, with *Fusion*, "The World Needs More People!" And by way of presenting credentials in this new movement you are building, I offer a few remarks from a brief essay penned by a young Pennsylvania printer in 1751, which is entitled, "Observations concerning the Increase of Mankind and the Peopling of Countries." Extreme modesty almost forbids me to point out that the author's reasoning on one or two points is entirely adequate to the refutation of the most "modern" arguments devised at Harvard and such, as to the supposed "necessity" of artificially restricting the growth of population.

To wit: It is frequently alleged that improvements in agriculture and industry are to be discouraged as they lead to "overpopulation" of the land, but that more primitive, "labor-intensive" techniques relieve this problem. Yet as the author of the "Observations" pointed out in our nation's infancy:

"America is chiefly occupied by Indians, who subsist mostly by hunting. But as the hunter, of all men, requires the greatest quantity of land from whence to draw his subsistence, (the husbandmen subsisting on much less, the gardener on still less, and the manufacturer requiring least of all,)

Continued on page 6

Lightning Rod

Continued from page 5

the Europeans found America as fully settled as it well could be by hunters. . . ."

It is also much argued that the improvement and increase of the population of other nations engaged in manufactures is a threat to our own, as suggested by Mr. Brzezinski's famous remark on Mexico, that he would not allow "another Japan" on our border. Here is how the worthy printer replied to such views when they were advanced on behalf of Britain against her American colonies *more than 200 years ago*:

"In proportion to the increase of the colonies, a vast demand is growing for British manufactures, a glorious market wholly in the power of Britain, in which foreigners cannot interfere, which will increase in a short time even beyond her power of supplying, though her whole trade should be to her colonies; therefore Britain should not too much restrain manufactures in her colonies. A wise and good mother will not do it. To distress is to weaken, and weakening the children weakens the whole family."

So sure was this author that the increase of population was an indispensable means to the building of nations that he put forward the following theorem:

"The prince that acquires new territory or finds it vacant . . . ; the legislator that makes effectual laws for promoting of trade, increasing employment, improving of land by more or better tillage, providing more food by fisheries, securing property, etc.; and the man that invents new trades, arts, or manufactures, or new improvements in husbandry, may be properly called fathers of their nation, as they are the cause of generation of multitudes, by the encouragement they afford to marriage."

Correspondingly, he argued the need to legislate a system of economy guaranteeing such prosperity and population growth.

"Laws, therefore, that prevent such [needless] importations, and on the *contrary promote the exportation of* manufactures to be consumed in foreign countries, may be called, with respect to the people that make them, generative laws, as, by increasing subsistence they encourage marriage."

Had the gentlemen at Ottawa but taken this sage as their guide, they would not have fallen into the error of supposing that the world's difficulties are caused by too many people, when it might better be said there are too few who know how to do what must be done.

Yr. obt. svt.,

Letters

Lousewort Laments

To the Editor:

Your "Lousewort Award" is appreciated (?), but a couple of questions are in order.

What kind of award do you deserve for grossly misquoting David Pimentel and me? Prof. Pimentel said that, if Americans were to reduce their annual protein intake, as much as 75 percent of the *energy used to produce food* could be saved. I said that *production, processing, and preparation of animal foods* consumes 14 percent of the national energy budget.

What is a Lousewort Award?

Alex Hershaft, PhD
Mitre Corporation
McLean, Va.

The Editor Replies

We feel that Alex Hershaft and David Pimentel were correctly cited in the Lousewort Laurels award for May. Basically, the Lousewort Award goes to persons or organizatons that propose retrogressive solutions to today's problems.

To the Editor:

I commend your choice of Elizabeth "Dottering" Gray for the July Lousewort Laurels, but I was surprised that you cited a relatively minor and insignificant contribution of Ms. Gray while ignoring the body of her work in ethics. Her cited initiation of a "rights for the stupid" campaign is but a minor aspect of her goal, which is a campaign for the *rites* for all.

Her primary concern, as I heard her shriek it at the April 14-15 meeting of the U.S. Association for the Club of Rome, is the total elimination of "the hierarchical ranking of the cosmos." She insists that the belief that any one existing thing—living, dead, organic, or inorganic—is morally superior to or has rights over any other thing must be eliminated.

She most emphatically campaigned for the extermination of the Judeo-Christian system, which she equates with Nazism because of the biblical injunction that man should rule nature.

Stanley Ezrol
Washington, D.C.

The Platonic Approach To Education

To the Editor:

You are to be commended for all you are doing to help our nation find its way back to the road of progress. Your efforts to enlighten us to the *rich bounty available from fusion energy* and space exploration is a great source of hope for civilization.

In spite of all the excellent guidance you provide regarding the proper thrust for our scientific research, there is one area of your "philosophy" I find very interesting and yet confusing. I am referring to your philosophy regarding cognitive development in education.

My questions are as follows:

1. Do you place little or no value

on development of deductive reasoning abilities?

2. If you regard logic as essential to mathematics and science, how do you suggest one develop logical, analytical abilities?

3. When you advocate development of creativity do you consider learning of problem solving heuristics (strategies) as useful? How would you recommend they be learned/developed?

4. Do you know of any books or programs that would be helpful in developing logical analytical skills and problem solving strategy development?

Rick Silvers
Fayetteville, N.C.

To the Editor:

As a math and science teacher, I find myself in accord with your ideas relative to education, government, and so on. My question is what books could you recommend covering the philosophy and approach to teaching science and math that best gets away from the present trend that's killing the intellect of our young people?

J. Mulholland
Anchorage, Alaska

To the Editor:

Children do not have the resource of experience to think like adults. Why does it take so many words to say "learn by rote first"? The theory of math's construction can be learned later after we have more resources and then, at that, many may never need learn it.

We certainly don't learn to drive a car by first taking it apart bolt by bolt to see what makes it work.

I hope after four generations of experimenting the educators will finally realize they had better get back to teaching a basic fundamental education first or we may have to reinvent the wheel.

Not "New Math," but "Backwards Math"!

John C. Carlson
Orangevale, Calif.

To the Editor:

I recently received the May issue of *Fusion*. I was very disappointed. On page 37 there is a discussion of Chomsky and Piaget. The author states, "Chomsky also divorces language from mind." Yet the entire contribution of Chomsky to linguistics has been to explore those ways in which language adumbrates the structure of mind.

In his book *Language and Mind*, Chomsky states: ". . . it is fair to suppose that the major contribution of the study of language will lie in the understanding it can provide as to the character of mental process and the structures they form and manipulate."

I received my PhD in linguistics from Ohio State, with a dissertation in the theory of transformational syntax. Since I know that linguistics has been seriously misrepresented in your magazine, how can I trust your articles on math and physics?

Dr. Ronald L. Neeld
New Orleans, La.

The Editor Replies

There is a better kind of mathematics than either the antimath of the "New Math" or the rote memorization advocated by the "back to basics" movement. For several thousands of years, a Platonic current in science—represented by Plato himself, Archimedes (but not Euclid), Leibniz (but not Newton), and Riemann (but not Maxwell)—has not only taught mathematics using this method but has been responsible for all the major advances in mathematical science.

The Platonic approach to education (sometimes called the Socratic method) starts from the realization that the subject of education is the process of concept formation. That is, a true teacher does not teach information, but rather, the self-knowledge required for a student to recreate those ideas for himself. A teacher must teach what Plato called the "hypothesis of the higher hypothesis"—the method of self-consciously generating qualititatively new knowledge.

There are many useful tools in the teacher's armamentarium, including algorithmic methods and deductive logic, but these are not the subject of education. They are tertiary aspects of some disciplines, instead. When these "logical" topics are turned into the subject of education, as is the essence of Piaget, Chomsky, and linguistics generally, not only is education destroyed, but also the capabilities for creative thought in the student are demolished.

Plato's dialogues remain the best source of education in this method—especially the *Timaeus*, the *Sophist*, and the *Parmenides*. There have also been inspired applications of good teaching in many other books, and the FEF is preparing a curriculum for science and mathematics based on these historical materials as part of its education campaign.

Contributions to the FEF are tax deductible!

Viewpoint

A Sensible Public Policy On Pesticides

by Jim Buck Ross

Under American law, an accused is presumed innocent until proven guilty. Under the scrutiny of the Environmental Protection Agency, any new pesticide, regardless of how great the need or good the intent, becomes an accused and is presumed guilty until proven innocent. Speculation as to harmful effects to any insect, bird, fish, wildlife in its entirety, water, air, soil, and, finally, people other than the target bug can raise more questions than can be answered in a reasonable length of time. The questions raised do not have to be germane to the problem and are seldom answered satisfactorily the first few tries.

Recent estimates are that it takes 8 to 10 years and costs $15 million to $20 million to develop a new crop protection chemical, and this does not include a plant to produce it. The time element is important in that our most experienced, wisest, and oldest scientists won't begin a new search that they can't expect to finish. In this way some of our best minds are lost to the battle of food production except in an advisory capacity.

Costs of finding, perfecting, and proving a chemical to the point of obtaining a label are greatly increased under Environmental Protection Agency regulations. The time element and proving a chemical "not guilty" of any accusation made are expensive activities. Scientists cost money, and the longer it takes the more it costs. Laboratories, personnel, and test plots extended in proving the chemical "not guilty" increase the costs for scientific and factual evaluation. The legal work of meeting the regulations, filing documents, and finalizing the application are expensive. Lawyers don't work for fun!

Another major effect of the present costly regulations is that minor crop uses, which are the primary cash crops for many farm producers, are neglected because it is not economical to pursue them. The costs in time and money exceed the expected return. Such crops—vegetables, nuts, and other minor crops—are very important in our diet. It may take wormy apples, peaches, tomatoes, and other accepted foods to convince people that such crops need chemical protection.

The only new crop protection chemicals being developed are those for major crop uses. Even these are slow in developing into usable compounds, not only because of the time and cost elements but because other chemicals—better or not as good—reach the acceptable stage earlier.

The unnecessary cancellations of new chemicals are based on suspicion, unfounded accusations, and, in the case of DDT, deliberate disregard for scientific fact. This is disarming the soldier before sending him into battle.

The Case of the Fire Ant

Not only do these cancellations hurt farmers; they also endanger human health and destroy the environment. A simple case is the EPA cancellation of Mirex for the fire ant infestation in nine states. The human population has suffered many deaths and thousands of cases requiring hospital and medical attention from fire ant stings, but not a single death from cancer directly attributed to Mirex. In addition, thousands of acres of land are lost to crop production, housing development, public, and private uses. The comparative use, volume, and profits were so small that Allied Chemical decided that it wasn't worth the cost of doing battle with the EPA and Environmental Defense Fund to prove the safety of Mirex.

The Mississippi Fire Ant Authority was created to provide interim protection and search for new solutions. Its resources, however, were inadequate for an extended confrontation, and, even if it had proven Mirex safe, the dictatorial power of the EPA administrator is such that he could have canceled the registration and use as in the case of DDT, which is still used around the rest of the world beneficially and without harm.

The EPA will proudly point out that it expedited the approval of a limited conditional label for Amdro to replace Mirex for fire ant control. Wonderful: We have a new tool temporarily to be fully approved in the future—maybe—but at what cost? The price of 1 pound of Mirex bait to treat an acre was 29¢. The price of the Amdro bait for the same acre is $2.95.

With the 1972 amendments to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Congress vested the authority for pesticide regulation in the U.S. Environmental Protection Agency and significantly extended the role of the federal government in pesticide regulations. Probably the most significant new concept contained in the 1972 act was the Pesticide Registration Authority and the concept that pesticide registration was, or should be, basically a scientific endeavor, based upon toxicology studies and their significance for the protection of man and the environment.

Continued on page 61

IQ of 145 and Can't Remember?

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Don Bolander, B.S., M.A., Litt.D.;
Director of the Memory Training Institute

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What Others Say

So far, I have progressed only through Session 5, but the course has already surpassed my expectations. —V. Martin, Lemoore, CA

The number system is unbelievable—and it works! The course is easy to understand and really does everything you said it would. —Mrs. W. Kutscher, Cape Girardeau, MO

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NSIPS

A spirited crowd of labor and industry representatives showing their support for Bailly Nuclear One in July.

News Briefs

WASHINGTON NUCLEAR UNITS THREATENED BY HIGH INTEREST RATES

Nuclear units 4 and 5 of Washington Public Power Supply System (WPPSS), the nation's largest municipal power utility, may be canceled for financial reasons. Citing mushrooming cost projections, the "Don't Waste Washington Initiative" is trying to halt construction on the plants by subjecting every state bond issue, including future WPPSS bonds, to a public vote. Washington's Governor Spellman, meanwhile, has formed a commission of prominent businessmen who will conduct "a thorough economic analysis" of the plants and look at potential alternatives.

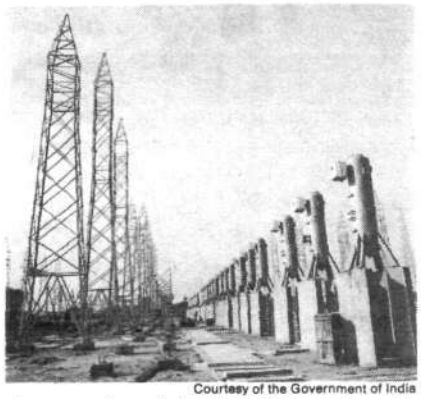
It won't take a major economic study to discover why the cost of the plants has escalated so dramatically over the last several years. For the $2.5 billion in principal borrowed to construct the plants, the utility will pay more than $8 billion in interest charges over the lifetime of the bonds, bringing the total cost up to nearly $11 billion. (The cost for five units is up to $23 billion.) Interest charges on WPPSS bonds have risen steadily since construction on units 4 and 5 began, from 5.86 percent for the first issue to 11 to 12 percent.

If the plants are the victim of the Federal Reserve's high interest rate policy, one result could be a serious power deficit in the industrial Northwest by the end of the decade. According to a recent report of the Pacific Northwest Utilities Conference Committee, without the addition of units 4 and 5, in a year in which hydroelectric power is in short supply, the area could experience as much as a 3,000-megawatt power deficit.

BAILLY NUCLEAR ONE—CASE STUDY IN ENVIRONMENTALIST BLOCKAGE

A decade of regulatory delays and environmentalist challenges may be responsible for the cancellation of a second nuclear project, Bailly Nuclear One under construction by Northern Indiana Public Service Company (NIPSCO). This plant was first announced in 1970, but it wasn't until 1974 that it was licensed by the Atomic Energy Commission (the predecessor of the Nuclear Regulatory Commission). NIPSCO has issued an instructive seven-page chronology of its unending court battles to build the plant. The upshot is that a plant originally scheduled for completion in 1976 is now estimated to be on line in 1989. The projected cost of the plant, a small, 600-megawatt facility, has risen from $705 million to $1.815 billion.

However, in issuing its second quarter report July 31, NIPSCO said that it may now have to terminate construction entirely because of continuing "political and emotional factors, regulatory delays and other hostility." So far the utility has invested $200 million in the plant, a sum that would have to be written off. The only construction that has taken place during the 11 years is the digging of the foundation hole and driving of some test pilings for the foundation. At one point there was even a court order against NIPSCO requiring it to fill up the foundation hole.



Courtesy of the Government of India

The switchyard for the Narora Atomic power station under construction in India.

U.S.-INDIAN NUCLEAR TALKS END IN STALEMATE

Talks held in New Delhi in late July on ending the 1963 Tarapur nuclear accord between India and the United States concluded in stalemate. Under the terms of the agreement, the United States was to supply India's U.S.-built Tarapur atomic power plant with enriched uranium until 1993. However, because of the Percy-Glenn Nuclear Nonproliferation Act, the Reagan administration is now arguing that it can no longer supply nuclear fuel to India. India grudgingly accepted the U.S. demand for "friendly termination" of the agreement at a first round of the talks in Washington earlier in the year. The deadlock in the second round of talks occurred when the U.S. delegation to New Delhi, led by Assistant Secretary of State James Malone, insisted that India maintain the safeguard obligations on the Tarapur plant and reprocessing of

spent fuel specified in the 1963 accord, even after the termination of the uranium supply agreement. This condition was unacceptable to India.

India has pledged nevertheless to keep the plant in operation either by reprocessing the spent fuel to manufacture a uranium-plutonium oxide fuel (using its own reprocessing plant), or by obtaining enriched uranium from another supplier, possibly the Soviet Union or a European country.

FUSION POPULATION STUDY SPARKS DEBATE

Fusion editor-in-chief Dr. Steven Bardwell held a briefing for press and diplomats at the United Engineering Center in New York City July 29 to release "The World Needs 10 Billion People," his economics/population study refuting the *Global 2000 Report*, which was featured in the September issue of *Fusion*.

The briefing was attended by representatives from UPI and Tass wire services, *Civil Engineering* and *Spectrum* magazines, and Dutch radio, and by diplomats from Egypt and Swaziland. Bardwell's hard hitting attack on the *Global 2000 Report* as the statement of a deliberate State Department policy for world population reduction, not an objective forecast, drew sharp questioning from the audience. "You mean scarce resources and water won't be a problem 20 years from now?" one reporter asked. "Whether we have the resources to support a growing world population at increasing standards of living is entirely a question of investment policy today," Bardwell answered. "The assumption of *Global 2000* is that we won't invest in new technology."

Stuart Lewis

Fusion editor-in-chief Dr. Steven Bardwell

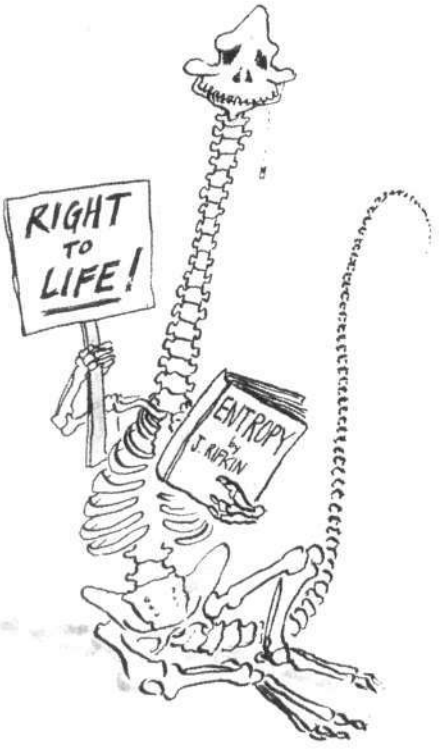
SYRIAN NUCLEAR PLANS ON TRACK

Just days after the Israeli air strike against Iraq's Osirak nuclear research reactor this summer, the Syrian Ministry of Electricity announced that it is proceeding with plans to select a contractor for preliminary work on building the country's first commercial nuclear power plant. Syrian plans tentatively call for having a nuclear power plant on line by 1991 to meet the country's growing power requirements. Syria's electricity consumption is now growing at a 21 percent annual rate, but its known oil reserves are mostly low grade and its hydroelectric power is declining.

READER'S DIGEST PRESENTS AN INDIGESTIBLE VIEW OF FUSION

Some time ago, *Reader's Digest* commissioned an article on fusion energy because, as editor David Minter told us, "Fusion seemed to be a possibility, and we wanted to bring it before our wide audience of 40 million readers." Although Minter and the author, Seamus McGrady, swear that they produced an "objective" and "favorable" article, their product, which appeared in the July 1981 issue, will give fusion supporters indigestion. First there is the choice of title, "Is Fusion a Falling Star?" Then there is the subtitle: "This Long-heralded nuclear process could—and may still—solve the world's energy problems. But the light at the end of fusion's tunnel remains disappointingly dim."

The author omits mention of the recent official and unofficial scientific reviews of fusion that recommend that the program move into the engineering phase. Instead he quotes from a gloomy 1978 report, produced under former energy secretary James Schlesinger. Overall, *Reader's Digest* conveys a negative, antiscience impression: Fusion is nice, but "after three decades and $3 billion in research, we still haven't achieved it."



LOUSEWORT LAURELS TO RIGHT TO LIFE GROUP

This month's Lousewort Laurels award goes to the National Right to Life group for selecting Dark Ages advocate Jeremy Rifkin as one of the main speakers at the group's national convention June 24. Rifkin, the author of *Entropy*, was a leading participant in the proterrorist People's Bicentennial movement in 1976 and is a board member of the Institute for Policy Studies, which supports many antinuclear groups. His speech to the Right to Lifers was about entropy (since the state of nature, God's original creation, must be the

most pure state, any man-induced changes represent decay), stewardship of nature, and the necessity to stop genetic engineering—all of which convey that man might as well be a beast.

NUCLEAR POWER AND THE MEDIA

Fusion Washington editor Marsha Freeman participated in a daylong conference on Informing the Public About Radiation and Nuclear Power in Maryland May 30. Sponsored by the Baltimore-Washington chapter of the Health Physics Society and the National Institutes of Health, the conference was organized by Dr. Allen Brodsky, president-elect of the society, to bring together representatives of the nuclear industry, scientific community, and media to develop better ways of informing the public about nuclear energy. Claims by the media representatives—who included former *New York Times* reporter David Burnham, Stuart Diamond of *Newsday* of Long Island, and solar-power advocate Richard Pollack of *Critical Mass*, a Naderite publication—that reportage on nuclear power has been objective went largely unchallenged by the utility executives. Freeman, on the other hand, described the mobilization launched by the FEF following the Three Mile Island incident in 1979 to counter the media distortions. "There is a reason we titled our coverage of TMI the 'Harrisburg Hoax'," she said. "On the side of the media, there was almost no attempt to present facts, only create hysteria and fear."

The only other speaker to address the political nature of the fight for and against nuclear power was the noted physicist Dr. Bernard Cohen.

BUDGET CUTS THREATEN BARNWELL REPROCESSING FACILITY

Allied Chemical and General Atomic Co. may be forced to close the nation's only commercial nuclear fuel reprocessing facility at Barnwell, S.C., officials of the companies announced during the budget debate in Congress. The Reagan administration budget for 1982 eliminates the paltry $11 million for Barnwell that was recommended by the Carter budget. As a result, the Reagan administration is in the paradoxical situation of being committed to continuing the Clinch River Breeder Reactor project, but of having de facto killed the full fuel cycle reprocessing technology for the U.S. breeder. Because of the strict guidelines of the Percy-Glenn Nuclear Nonproliferation Act of 1978, industry representatives have maintained that it is impossible for the private sector to develop reprocessing technology on its own.

The lack of reprocessing technology over the next decade or so not only will contribute to upward price inflation of uranium fuel costs, but also will exclude the most effective solution to the nuclear waste problem—recycling.

PETER FONDA: A WHALE OF A STORY

Many readers probably heard or read the national news story about actor Peter Fonda, who went bananas in the Denver airport July 24 and pulled a pocket knife out to slash the FEF's poster "Go Nuclear—Feed Jane Fonda to the Whales." Fonda was given a summons for destruction of private property. Not reported was the sequel to the story. Peter called the Los Angeles Police Department July 27 to try to file charges against FEF airport organizers in that city for endangering the life of his sister. This attempt failed, however, when the police intelligence division reported back that there were "no whales known to be in the vicinity of the Los Angeles airport."

FEF INDIAN TOUR: A CORRECTION

During his tour of India last spring, FEF organizing director for India Ramtanu Maitra addressed audiences at the Indian National Science Academy in New Delhi, the Saha Institute of Nuclear Physics in Calcutta, the Indian Institute of Science in Bangalore, and the Physical Research Laboratory in Ahmedabad. We regret the errors in the names of some of these institutions in the September issue.

Restoring Scientific Rigor in Education

The Fusion Energy Foundation has launched a campaign to restore to American schools the classical curriculum of von Humboldt and Benjamin Franklin. Centered on the FEF's children's magazine, The Young Scientist, *the campaign will include conferences and seminars around the country. Readers interested in participating should call or write the FEF in New York. Carol White, editor of* The Young Scientist, *is coordinating the education campaign.*

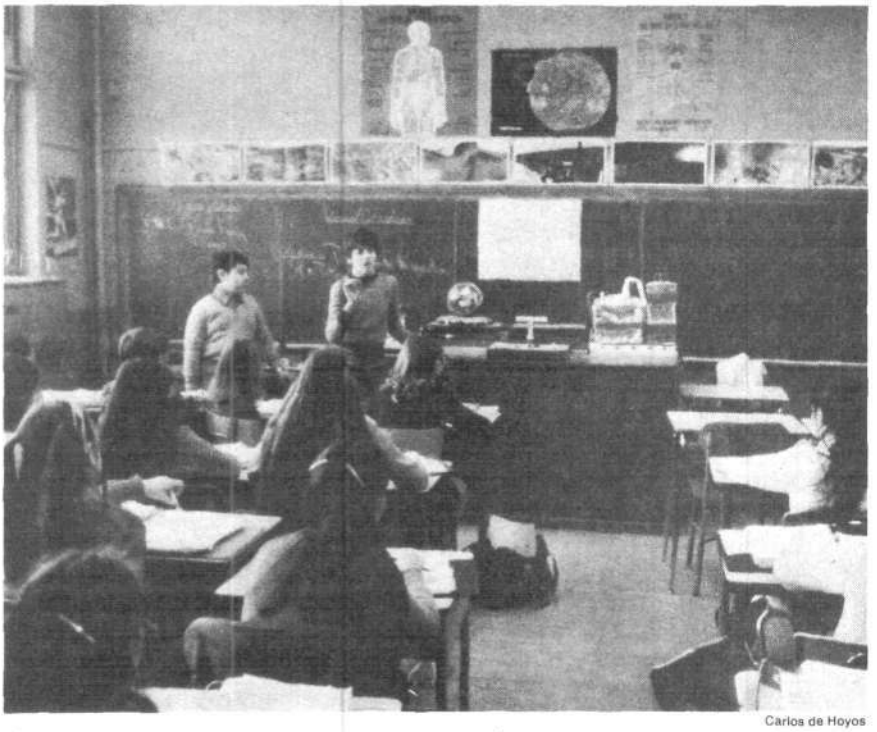
* * *

In his recent article "War Against Liberal Education Reforms," FEF founder and board member Lyndon H. LaRouche, Jr. has laid down the gauntlet to the pot-smoking teachers, pederasts, and basket-weavers who are close to taking over our schools and are destroying the minds of those students who otherwise have escaped the plague of drugs and rock music.*

LaRouche exposes the forces who are responsible for destroying the tradition of classical education in the United States, and he proposes major curriculum revisions that are essential to reverse the present national slide toward moral decadence.

It is indeed no exaggeration to state that present-day liberal education is one factor driving young people to the use of drugs, not only because it deliberately erodes moral values by preaching tolerance for alternate lifestyles, but also because such noneducation evokes sheer boredom.

The schools are so bad that it is almost possible to sympathize with those members of the Moral Majority who have succumbed to the shibboleths of the fundamentalist and back-to-basics movements. But closer inspection shows their remedies to be as bad as the disease; their apparent conservatism, thinly disguised liberalism.



Carlos de Hoyos

The FEF campaign to restore scientific excellence to the American classroom will lead off with the publication of The Young Scientist *magazine for children 10 and up. Here a seventh-grade science class at Intermediate School 187 in New York City listens to Michael Masterov and Yaroslav Shoikhet discuss their fusion science project, which is based on the premier issue of* The Young Scientist.

Science Versus Opinion

The Creationists in California who won a court case requiring that all theories of evolution be taught as mere opinion, on a par scientifically with the account in the Book of Genesis in the Bible, are introducing precisely that liberal pluralism that they claim to oppose, under the plausible cover of fighting the admittedly pernicious ideology of Darwinism. The Creationists are in fact undermining the notion of scientific rigor that, more than any particular facts the student may learn, is the essential content of any adequate science course.

Science is not a mere matter of opinion. Darwinism is wrong precisely because it does not explain evolution. Even by the standards of his day, Darwin was a vicious fraud who used the well-known fossil record of evolution to introduce a bestial ideology,[1] as readers can confirm by reading Alexander von Humboldt's beautiful book *Cosmos*, published before *The Origin of the Species*.[2]

As the report on U.S. science education commissioned by President Carter in Feb. 1980 warned, any fur-

*Lyndon H. LaRouche, Jr., "War Against 'Liberal Education Reforms' " and "Principles of the New Kameralist Curriculum," *The Campaigner*, Aug. 1981.

Carlos de Hoyos

A Tokamak Model in Every Science Classroom!

The September issue of The Young Scientist magazine features in its Experiments section a detailed account of how two 13-year-olds designed and built a simulated fusion tokamak power plant. The prize-winning project (shown here) got its start after their science teacher at Manhattan's Intermediate School 187, Herb Friedman, taught a class on fusion energy based on an article in *The Young Scientist*.

Published five times a year, *The Young Scientist* covers the frontiers of science—news and features on the topics students need to know to make tomorrow's breakthroughs. For information on bulk orders of *The Young Scientist*, call or write the Fusion Energy Foundation.

ther erosion in science education in the United States will destroy the capacity of the average citizen to deliberate rationally on science policy.[3]

The Classical Curriculum

The claim of the fundamentalists that they would return American education to some mythical, halcyon past is destroyed, happily, by a look at the actual content of education in 19th-century America.

American education in that period was modeled upon the best classical traditions of European education. The following course of study for a 14-year-old is taken not from the Wirszup report on present-day Soviet education, although it compares favorably; it was typical of the 6,085 academies employing 12,260 teachers, enrolling 263,096 pupils, and turning out thousands of elementary school teachers in the year 1850. Latin, Greek, French, German, Spanish, mechanics, hydromatics, pneumatics, light and color, optics, perspective, spherical trigonometry, astronomy, the natural history of vegetables and animals, chemistry, and architecture with fortifications were typically taught in three-year programs modeled on Benjamin Franklin's academy in Philadelphia.

Franklin's academy was directly modeled upon the academy proposal of Gottfried von Leibniz, which was familiar to Franklin through his connection to James Logan.

It is the same program for Leibnizian academies that LaRouche now proposes as essential if this nation is to reclaim its posterity. He chooses as a 20th-century point of comparison the German educational system that survived until the 1960s, which was based upon the 19th-century educa-

tional reforms instituted by the von Humboldt brothers.

As LaRouche writes: "Examining the postwar Federal Republic of Germany at closer range, there is no doubt but that it was chiefly the German educational system, based on the Humboldt program, which enabled the nation's people to rebuild successfully after the treble horrors of Hitler, World War II, and the British-directed postwar occupation."

In an accompanying piece, "Principles of the New Kameralist Curriculum," LaRouche develops in detail a positive proposal for the reform of the nation's schools. In his introductory remarks he states:

"The key to all education, both general and later specialist programs, is a rigorous redefinition of what constitutes the body of knowledge which must be mastered by any person *as precondition for full rights of citizenship.*

"The education of all citizens of future true democratic republics is based on the assimilation of a *science of history* of the struggle to create such republics, against irrationalism and 'feudalist' oligarchism. The assimilation of a science of history cannot occur without a cohering mastering of the true potential powers of literate language. This must be *language* in the proper broadest sense of that term: *classical philology, classical poetry, classical musical composition* according to the well-tempered laws of composition typified by Bach, Mozart, and Beethoven, *and mastery of the principles of physical geometry.*"

If we are to win the war against liberal education, this program must receive the widest possible circulation. There is not much time to waste.

—*Carol White*

Notes

1. See Carol Cleary, "Darwin: A Victim of His Unfit Theory," *Fusion*, Jan. 1981, p. 82.
2. The 1852 English translation of *Cosmos* by E.C. Otté is recommended.
3. *Science and Engineering Education for the 1980s and Beyond*, prepared by the National Science Foundation and the Department of Education, Oct. 1980.
4. Unpublished research of Mary Gilbertson and Jon Pike.

What's Behind the Science Magazine Attack?

Reviewing Laser Fusion Progress

A derogatory review of the U.S. inertial confinement effort that appeared in the May 1 issue of *Science, the weekly magazine of the American* Association for the Advancement of Science, presents an opportunity to review the actual status of the inertial fusion effort and examine the ideology of the antifusion faction. The article, authored by William D. Metz, is titled "Ambitious Energy Project Loses Luster," with the subheading "Laser fusion, touted as a new energy source, has produced only fizzles; its military implications now predominate."

The *Science* article is curious not only because it deliberately lies, but also because the magazine recently turned down a factual article on the state of inertial fusion research by Dr. John Foster, a vice president at TRW, who had headed up the DOE's inertial fusion review committee during the Carter administration.

Metz's apparent purpose in attacking laser fusion is to bring about the complete classification of the program, ditching the civilian energy applications and making it solely a military effort. Needless to say, such a move would retard fusion progress and prevent the kind of scientific exchange of ideas that historically has fostered breakthroughs at the frontiers of science. Metz has set up his technical arguments against the program to put fusion scientists in a Catch 22: To refute his arguments, it is necessary to report on material that is currently classified top secret.

As Metz does *not* report, every major industrial-scientific panel that has reviewed the inertial fusion program over the past decade has concluded

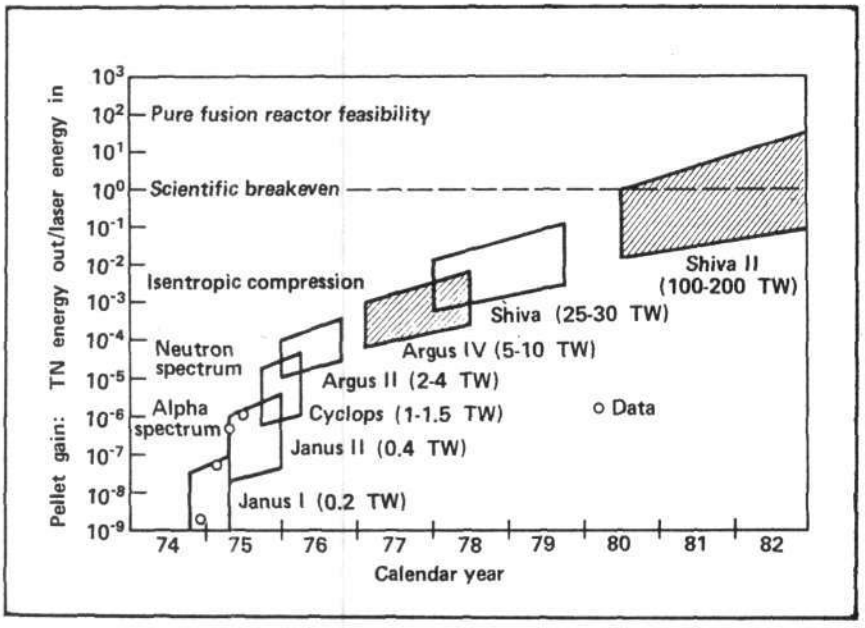


Figure 1

This 1976 projection for the succession of laser fusion experiments at Lawrence Livermore was presented by Dr. John L. Emmett, director of the Livermore Laser program, before Congress March 11, 1976. The results projected for the Shiva laser have been achieved.

that there has been significant progress toward harnessing inertial fusion as an energy source, and that this program, along with the mainline magnetic confinement effort, should be vigorously pursued as an essential national security goal.

Metz begins by stating that the laser fusion program "has suffered a number of setbacks . . . and the program is falling out of favor in some quarters of Washington." The facts are that the "setbacks" are largely the result of schedule changes forced by inflation's increasing bite on the budget, and that the "disfavor" is coming from those forces, like Metz, who don't see the need for new high-technology energy sources and want to make laser fusion military only. "Development of basic laser technology 'is a military program and it always has been,' " Metz quotes one such source as saying.

The other arguments Metz marshals are that the leading pioneers of inertial confinement research, Edward Teller and Hans Bethe, feel that it has always been technically unfeasible as an energy source; that the large amounts of radioactive debris from the "burned-up" fusion pellets would lead to a significant waste disposal problem; and that coupling the energy from the laser beams into the fusion pellet to produce the compressions needed for net fusion energy generation has not been accomplished as promised.

His conclusion is that laser fusion programs such as that maintained by what he calls the "brash California weapons facility, the Lawrence Livermore Laboratory" (the leading U.S. inertial fusion research facility), should be returned "to the veiled world of classical research from which it originated" —in other words, classified research. Metz also all but openly states that the top laser fusion scientists lied about their efforts to apply inertial confinement techniques to the search for peaceful energy sources in order to draw both funds and bright young scientists into weapons research.

Far from being interested in expanding their "veiled world" of secret-military research, fusion scientists at the national laboratories of Lawrence Livermore and Los Alamos since the beginning of the Manhattan Project have been primarily concerned with the peaceful application of their scientific work.

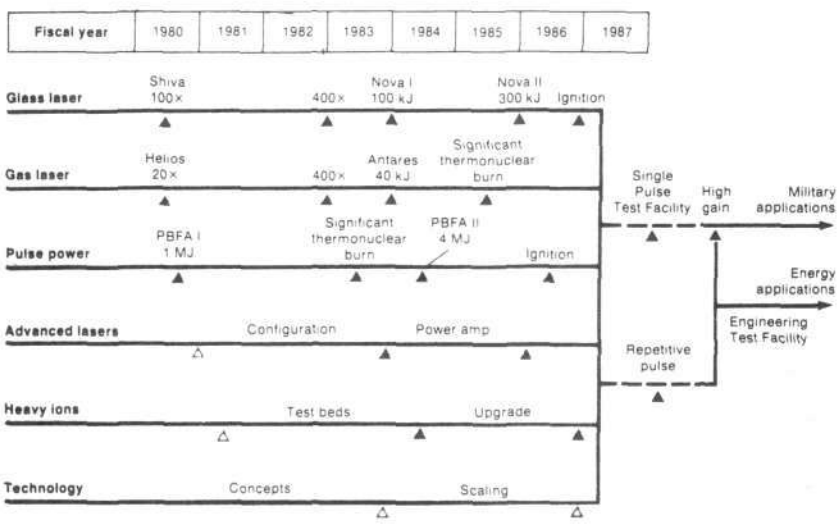


Figure 2

The most recent review of inertial confinement fusion, that by the director of the DOE inertial confinement program, Dr. Gregory H. Canavan, appeared in the March-April 1981 Fusion. *Nova 2, the upgrade of the Shiva laser to higher power levels, is now predicted to go beyond breakeven in the mid-1980s. If not for inflation, Nova would have reached this goal in the early 1980s.*

Some Real History

Historically, the antiscience faction that has classified scientific research has also continuously fought to prevent the development of nuclear fission and fusion energy because these conflict with their aim of retarding world development. If not for the success of this faction, fusion could be used today in the form of peaceful nuclear explosives to build canals, harbors, dams, and reservoirs, or to mine low grade ore deposits, enhance the recovery of oil and natural gas, and retort oil shale in situ. Replacing the fission bomb with an intense beam of light or particles will provide the basis for the development of clean hydrogen bombs for peaceful and military purposes as well as for a new type of inertial fusion energy.

In the early 1970s, the inertial fusion pioneers won a major struggle to obtain significant declassification of inertial research and concepts to initiate this primarily energy-directed effort. One result of this declassification was the publication in 1972 of a comprehensive article on laser fusion published in *Nature* (Vol. 239, p. 139, Sept. 15) that is universally recognized as the first general overview of laser fusion by supercompression.

Here's what Metz says: "In the first major publication after secrecy was lifted in 1972, two scientists from Livermore, John Nuckolls and Lowell Wood, projected that breakeven-level experiments would occur during 1973 and the next step, net energy production, would occur 'sometime around 1975.' "

In fact, the Nuckolls-Wood article does *not* give specific dates for predicting when "breakeven" or "energy production" would be achieved. It does point to the *possiblility* that as little as 1 kilojoule of light energy may be sufficient to generate an equal

quantity of thermonuclear energy, "if optimally employed."

The real yardstick in terms of measuring the consistency of projections for fusion research is to be found in terms of what is predicted for the final parameters of a power reactor. Nuckolls and Wood state: "Thermonuclear microexplosions producing on the order of 10^7 to 10^9 (5 to 10 pounds TNT equivalent) are suitable for commercial power production. . . . L[aser energy] = 10^6 J." The latest laser fusion reactor designs, which consist of detailed studies, project laser energies of about 2×10^6 joules, and similar types of pellet gains of 50 to 100.

Bending Facts

Furthermore, contrary to what Metz reports, the inertial fusion program has been able to stay pretty much on schedule, despite major budget curtailments and numerous new scientific problems. Efficient coupling of laser energy to pellets has been achieved for both the classified soft X-ray and the unclassified direct beam approaches. Also, researchers have reached isentropic compression (that with no entropy change) of up to 100 times liquid density.

The accompanying figures give the projected status of the mainline inertial fusion program for 1976 and 1981. The projection in Figure 1 was presented to Congress in March 1976 by Dr. John L. Emmett, director of the Livermore Laser Program. The results predicted for the Shiva laser have been achieved. The projections in Figure 2 are from the most recently published review of the inertial fusion program, that of Dr. Gregory H. Canavan in the March-April 1981 issue of *Fusion*. As can be seen, Nova 2, the upgrade of the Shiva laser to higher power levels, is predicted to go beyond breakeven when completed in the mid-1980s. The change in the projection date from the early-1980s is primarily the result of inflation slowing down construction.

As for Metz's negative statements about the practicality of laser fusion reactor designs, Metz quotes not one of the scores of detailed studies that have been carried out over the past decade. The waste question, furthermore, is entirely spurious, since the amounts involved are small, and the technologies for waste exist today. And Teller and Bethe are both on record supporting a fusion-fission hybrid system and have stated that this could be accomplished in a decade.

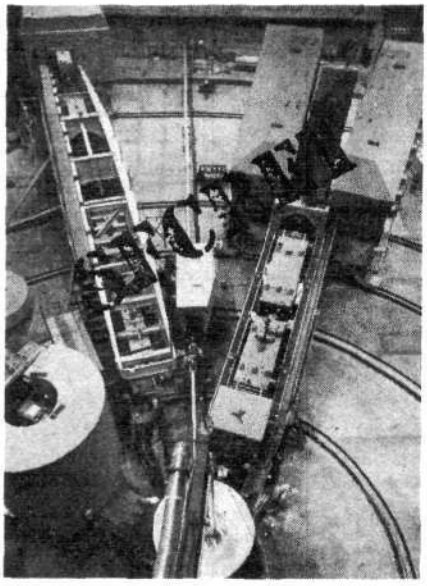
As *Fusion* has consistently reported, it would be false to say that there are no basic scientific or technological questions still to be answered in inertial confinement research. In fact, the opposite is the case for inertial as well as magnetic confinement. As fusion research has progressed over the past decade, the number of unanswered basic scientific questions has increased.

This in no way undermines the contention that practical forms of fusion energy generation can be confidently predicted as being within our grasp today. The open-endedness of the scientific questions raised by fusion and plasma physics research actually points to fusion's most attractive attribute: It can be continuously perfected to more and more advanced forms of cheaper, cleaner, and more efficient energy generation.

Leading scientists and government program administrators have alleged that the *Science* article may have been the product of direct collusion between Metz and the antiscience forces who want to classify advanced science and contain the kind of breakthrough developments that would permit economic and population growth. Given the role of Metz's previous articles in *Science* that attacked the magnetic fusion program at the same time that former secretary of energy James Schlesinger was trying to kill the program, such collusion would not be surprising.

It is also probable that the anti-fusion campaign, including Metz's article, intends to impugn the credibility of the inertial confinement scientists within the new Reagan administration who have an influential voice on crucial military and technology decisions.

—Charles B. Stevens



Classifying Scientific Progress: A Case Example

This exchange of letters is a recent case example that demonstrates the chilling effect of classification on the advancement of science and technology. Dr. Friedwardt Winterberg of the University of Nevada's Desert Research Institute in Reno proposed in a Dec. 2, 1980 letter to the Department of Energy Office of Inertial Fusion director, Gregory H. Canavan, that the DOE undertake a new and economical method to test inertial confinement. His letter and Canavan's Feb. 20, 1981 reply appear here in full.

* * *

Dear Dr. Canavan:

The most critical question regarding the feasibility of beam induced ICF [inertial confinement fusion] is not so much the feasibility of the laser or accelerator technology but the feasibility of the high-density pellet compression. Many scientists, like Dr. Teller (but also myself), feel uneasy about the prospect to reach $\sim 10^3$ times solid density by ablative implosion. But since the cost of the required laser or particle beam accel-

erator is very large, a test of the crucial pellet implosion feasibility will be very expensive this way.

Now, several scientists (including myself) have proposed to use soft X-rays rather than laser or particle beam energy for compression, however, with the beams providing the primary energy source to produce the soft X-rays (or 10^6 to 10^7 °K black body radiation).

I therefore suggest as an economical way to test the pellet implosion concept to use soft X-rays from a nuclear underground explosion. In this proposal, the pellet would have to be separated by many meters from the fission explosion, with narrow soft X-ray reflecting tubes of different path-length going from the fission explosive to the chamber containing the pellet. By using several tubes of different path-length, in combination with X-ray absorbing foils placed in these tubes and to be burned out by the intense X-ray flux, the required time dependence of the compression pulse could probably be produced.

I do not know exactly how costly an underground test really is, but it appears to me much less costly than the several hundred million up to a billion dollars required for a laser or heavy ion linac [accelerator] of the required energy output. Such a test at least could decide the feasibility once and for all before going into large expenditures.

In case there is DOE interest, the Desert Research Institute would ask to obtain, if possible, a modest subcontract, maybe in cooperation with EGG, to do some diagnostic work or work related to it. Please let me know if we even *can* submit a proposal.

I also forward a copy of this letter to some prominent scientists who may be interested in this.

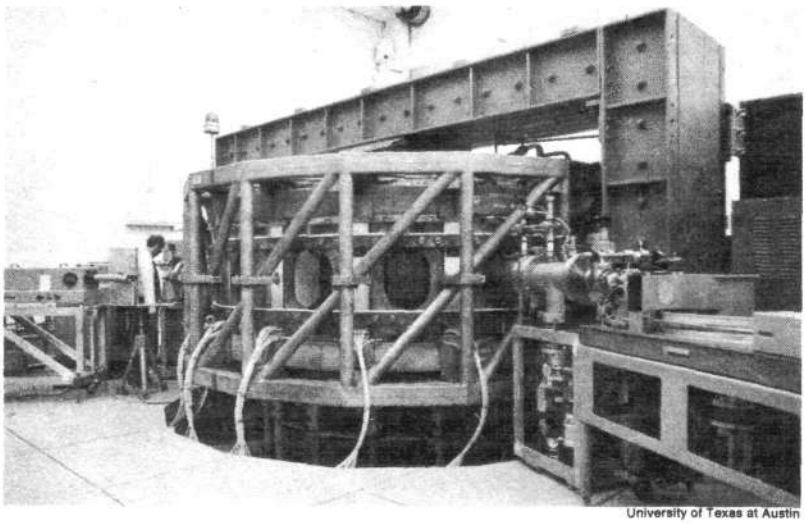
[Signed] *Dr. F. Winterberg*

Dear Dr. Winterberg:

This is in reply to your recent letter dated Dec. 2, 1980. Under DOE policy, we are unable to comment on certain categories of information to persons who have not been granted access to Restricted Data or Formerly Restricted Data. Included in these categories is information which describes or attempts to describe the design or operation of X-ray driven inertial fusion targets. This policy is necessary to prevent the use of our comments as a basis to develop, by an iterative process, a design or concept that could compromise classified information.

For reasons stated above, we cannot comment on the contents of your letter; similarly, it would not be possible for us to respond, on an unclassified basis, to a contractual proposal from you.

[Signed] *Gregory H. Canavan*



University of Texas at Austin

Texas Tokamak Dedicated

Three hundred people attended dedication ceremonies for the new experimental tokamak fusion reactor at the University of Texas at Austin on May 28. Built with a $10 million grant from the Department of Energy, the experimental device is available for research and training to all U.S. universities. The device has been operating under the direction of Dr. Kenneth Gentle since Nov. 1981, and more than 2,000 experimental "shots" have been conducted to date.

Dr. John Clarke, deputy director of the DOE Office of Fusion Energy, was the keynote speaker at the event. Fusion is the "ultimate energy source," promising a virtually unlimited supply of cheap energy, capable of raising the standard of living of the entire human race, he said. Asked about the threat of cuts in the fiscal 1982 fusion budget by the Reagan administration, Clarke said that the new administration, in his view, is committed to the development of fusion and the "spirit" of the landmark 1980 Magnetic Fusion Energy Engineering Act. Clarke said that the current economic situation, typified by high interest rates, has caused Reagan to feel a necessity to cut government spending across the board.

Dr. William E. Drummond, director of the Fusion Research Center at the Austin campus of the University of Texas, praised the Texas Atomic Research Foundation for supporting fusion research at the university for the last 20 years. Presiding over the dedication, Dr. Gerhard J. Fonken, vice president for academic affairs at the university, extended an invitation to all present to the dedication of the first operative fusion reactor in Texas. "I can't tell you exactly when, but it will be sometime 10 or 15 years from now," he promised.

DOE Stalls on FED; Bouquard Reconvenes Advisory Panel

The Fusion Engineering Device mandated by the 1980 fusion legislation is in danger of being stalled, at least for the next year, because of delays in setting up its management structure, funding, and design, as well as the stated reluctance of the DOE to pursue the project.

The Magnetic Fusion Energy Engineering Act of 1980 mandates that the DOE have a Fusion Engineering Device (FED) on line by 1990 to demonstrate the feasibility of integrating the complex fusion systems and produce net power. The first stage in this process, the law specifies, is "the creation of a national magnetic fusion engineering center for the purpose of accelerating fusion technology development."

The legislation requires that the secretary of energy submit to Congress by July 1 a plan for establishing the Center for Fusion Engineering, or CFE, which is to direct the engineering phase of magnetic fusion development.

The DOE report submitted to Congress July 7, however, stated that the department had not yet come to "a judgment on the advisability of establishing such a center"—even though the CFE is not only mandated by the law, but was recommended in the DOE's own review of the fusion program completed a year ago.

Critical for meeting the 1990 schedule is the DOE funding of and commitment to design and build the FED, and here progress has been most disappointing. In the letter of transmittal to the July 7 DOE report to Congress, Acting Energy Research Director N. Douglas Pewitt said that the Reagan administration's policy is in "consonance" with the law, "but because of overriding fiscal constraints now placed on government activities, we are proceeding at a lower rate of acceleration toward the same objective."

Marsha Freeman

No friend of fusion: Dr. N. Douglas Pewitt, acting director of the DOE Office of Energy Research.

Stuart Lewis/NSIPS

Fusion supporter: Leonard F. C. Reichle of Ebasco, new head of the fusion advisory panel.

Pewitt, a holdover from the Carter administration, is no friend of fusion. He stated repeatedly during budget hearings earlier this year that the fusion law was a "permissive piece of legislation" and that the administration would not make a commitment to build the FED. Without such a commitment, of course, there is no point in establishing a new center to manage fusion engineering.

As an "interim" policy, Pewitt's July report proposed to establish an "Engineering Feasibility Preparations Project" located at one of the national laboratories. But this proposal is simply another stalling tactic. It has already been agreed that the FED will *not* be located at a national laboratory, so it is very unlikely that Congress will accede to this type of delay.

Hirsch Panel Reconvened

As the DOE report was being prepared, Congresswoman Marilyn Bouquard (D-Tenn.) reconvened the fusion advisory panel of the House Science and Technology Committee's Subcommittee on Energy Research and Production to study the feasibility of "fast-tracking" the fusion program. Formerly headed by Dr. Robert Hirsch, a past director of the U.S. magnetic fusion program, the panel was commissioned in 1979 by former congressman Mike McCormack when he chaired the energy subcommittee that Bouquard now chairs. The Hirsch panel, as it was known, played an important role in preparing the way for the 1980 fusion legislation. McCormack was the law's chief sponsor.

Now headed by Leonard F. C. Reichle, executive vice president of Ebasco Services Inc., the panel includes prominent fusion scientists, industry leaders, and Mike McCormack. Ebasco is the chief contractor building Princeton's TFTR tokamak.

"The taxpayer can be saved 2 billion 1980 dollars if the DOE will stop dragging its feet and move now into the engineering phase of fusion energy development," Bouquard said in announcing the panel's June 29 meeting.

Sources on Capitol Hill report that Bouquard has written a letter to Energy Secretary Edwards protesting the content of Pewitt's report to Congress and that she may hold public hearings on fusion in the fall to continue to put pressure on the administration to meet the requirements of the fusion law.

How Much Industry Control?

At the June 29 hearings, the panel heard a broad range of views from industry representatives on the involvement of industry in fusion engineering development, specifically in the establishment of the Center for Fusion Engineering, the CFE.

Two industry groups, the Atomic Industrial Forum and Fusion Power Associates, stated that industry is

Continued on page 60

An FEF Proposal Based on Riemann's Method

Breaking the Impasse in Inertial Confinement Fusion

by Dr. Steven Bardwell and Uwe Parpart

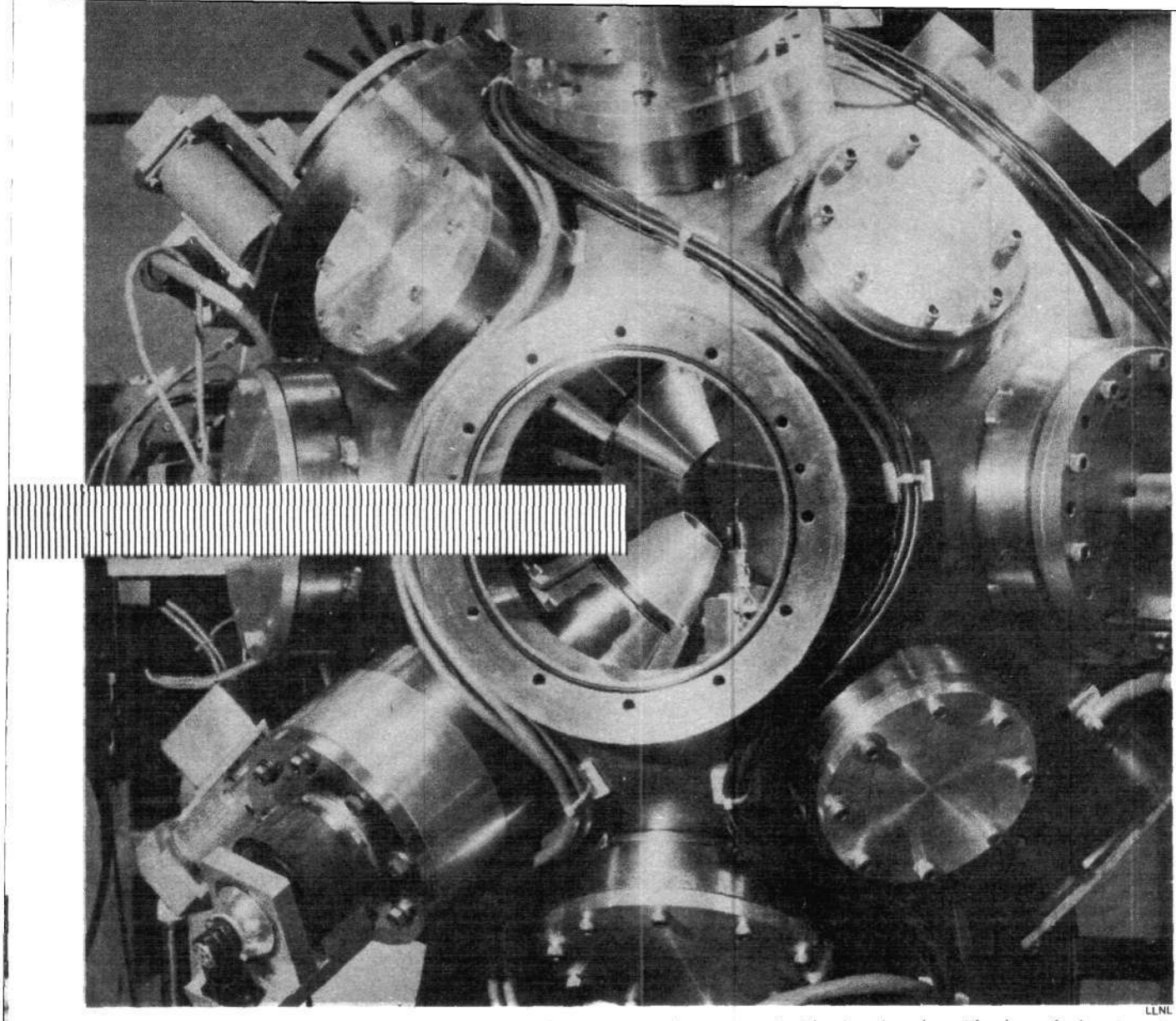
Two years ago the Fusion Energy Foundation published a proposal for a new direction in American laser fusion research. This article, which appeared in the March-April 1979 issue of Fusion, *was the first public discussion of the foundation's proposal to use strong shock waves to induce isentropic compression of laser fusion targets. The dominant line of research, then and now, has been to use a sequence of weak shock waves to accomplish the required heating and compression. During the past two years, the proposal has generated an intense, ongoing discussion among physicists internationally. This article is a summary of these discussions and an invitation for further commentary.*

* * *

THE PERSISTENT PROBLEM in the achievement of cheap, unlimited energy from laser or inertial confinement fusion research is the ignition energy. Ignition can be initiated only by a sharp, controlled, well-focused burst of energy sufficient to heat and compress a small amount of fusion fuel, and this energy must do this at a repetition rate of several times per second and an efficiency of conversion of input energy to target energy of 1 percent. That is, 10 percent of the input energy must be converted to driver energy, and 10 percent of this driver energy must be converted to pellet compression. If these conditions can be realized, as one well-known plasma physicist said, the difference between laser fusion and magnetic fusion will be as great as the difference between the Concorde and the Zeppelin!

The lasers now used to heat these fusion fuel targets are impressive machines. They are capable of delivering more energy to the surface of the fuel pellet in one pulse that lasts a billionth of a second than the total energy the rest of the world consumes during that billionth of a second. But this is not enough. These lasers are still a factor of 10 away from laboratory achievement of breakeven, and even more removed from the conditions required for commercial fusion.

In two articles that appeared in spring and fall 1979, Uwe Parpart proposed a new approach to achieve a more efficient coupling of the laser energy to the pellet that might significantly increase the present tiny percentage of driver energy that actually goes to the compression and heating of the target.[1] The second article was titled "The Theoretical Impasse in Inertial Confinement Fusion." That there was at that time—and still is—a serious impasse in laser fusion is not a matter of debate. The question under debate is how to overcome that impasse.



Shiva laser target chamber. A needlelike target positioner is at the center, inside the chamber. The laser fusion targets, each about the size of a grain of sand, are mounted on the tip of the positioner.

The strategy pursued by the national laboratories in the United States has been a "brute force" approach, building bigger drivers (lasers) on the assumption that the basic physics of the target-driver interaction is understood and that the problem is one of engineering optimal targets coupled with bigger lasers. Our proposal was that the basic physics of the driver-pellet interaction was insufficiently understood, that the methods used by the national laboratories were insufficient for understanding this physics (specifically that the computer code used, LASNEX, was insufficient), and, finally, that there were several new lines of research that should be followed up because they offered good reason to think that the power requirements for laser fusion could be substantially reduced.

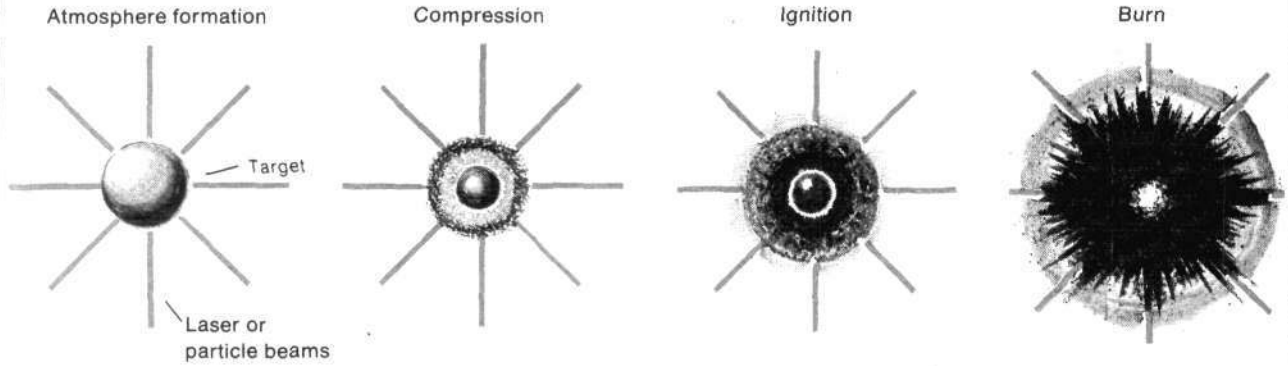
The Basics of Laser Fusion

The basic considerations that determine the physics of inertial confinement fusion were outlined in an article that appeared in a spring 1972 *Nature* magazine by John Nuckolls and Lowell Wood, both from Lawrence Livermore National Laboratory.[2] Their article not only remains today the best introduction to the problems of laser fusion, it is also surprisingly prescient of the difficulties encountered in the succeeding 10 years of the fusion research program. If their article is read with an appreciation of the government security classification of scientific facts that still plagues the program, it clearly lays out the basic considerations of laser-induced fusion.

The fundamental difficulty to overcome in the use of intense laser beams (or particle beams) as the spark for a fusion reaction is that it requires a high-density fuel. Since the amount of fuel that actually ignites is proportional to the density and the cross section for the fusion reaction

$$\Phi \sim \eta \langle \sigma \rangle,$$

where Φ is fraction of burn, η is density, and σ is the cross section (the probability that colliding fuel and nuclei will



The Principles of Laser Fusion Target Design

The laser fusion targets used today are built so that the fuel does not actually absorb the laser light. Instead, there is a two-stage process of radiation absorption that transfers the laser energy to the pellet. Initially, the laser light illuminates the outside of the pellet; the energy must be absorbed as efficiently as possible at this point. However, this energy is relatively low grade (high entropy) and not suited for compression of the fuel itself. Therefore, a second layer of the target is used to convert this laser energy into soft X-rays that then actually implode the fuel.

This arrangement solves several problems inherent in the laser fusion process: It provides a highly isotropic and uniform deposition of energy on the fuel, and it is a highly efficient converter of electromagnetic energy to the hydrodynamic energy of compression.

The target designs using this intermediate stage of an equilibrium spectrum of X-rays (blackbody radiation targets, also called holsraum targets) are classified, but it is publicly known that the generation of an intermediate X-ray spectrum is used in advanced target design. This idea was originated outside the national laboratories by Dr. Friedwardt Winterberg, and is described in *Fusion,* Jan. 1981.

This fact solves the mystery of the construction of the Shiva target chamber illumination (see page 25) in which, in spite of the laser fusion community's prolix comments on the necessity of spherical deposition of energy on the target, uses a highly anisotropic geometry for laser illumination of the target. It seems likely that a cylindrical target is used to maximize the conversion of the laser light into X-radiation and that then this X-radiation is contained inside the target shells, heating and compressing the fuel at the center of the pellet.

Note that this principle is almost identical to that used in the construction of the hydrogen bomb, where the laser driver is replaced by a fission explosion whose radiative energy is converted to X-radiation using a metallically doped foam or multifoil configuration.

A small part of this information was declassified in fall 1980 when the Department of Energy publicly acknowledged the role of soft X-rays and radiation in conversion in the design of advanced targets for inertial confinement fusion. (This is reported in the April 1981 *Fusion.*)

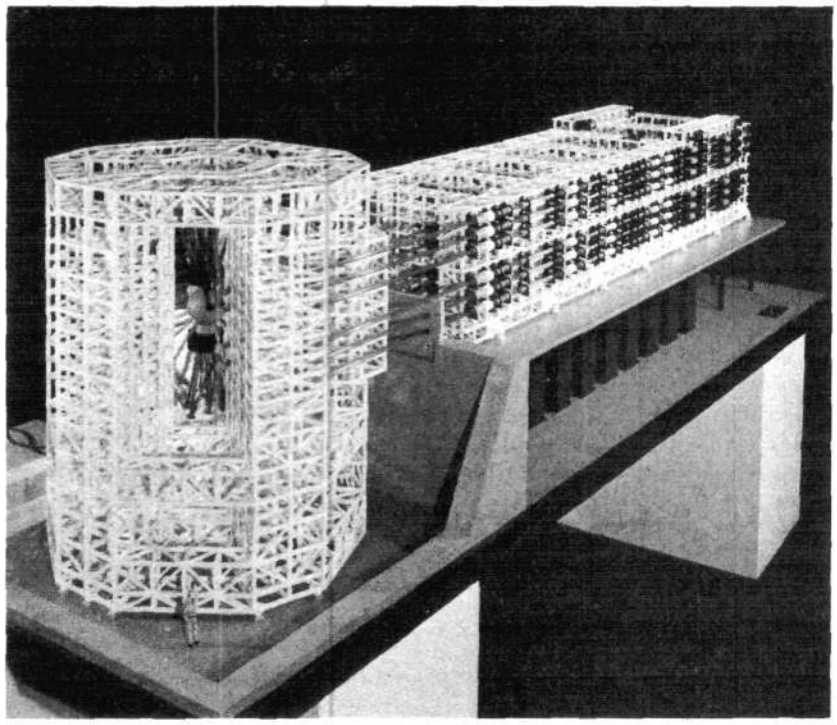
fuse), a simple calculation shows that for ignition to occur on time scales less than the inertial disassembly time (the time it takes the pellet of fuel to explode), the density of the fuel must be greater than 10^{26} particles per cubic centimeter. That is, at the point that it ignites, the fuel must be at a density approximately 1,000 times liquid density.

This means that the driver energy must simultaneously provide the ignition energy for the fusion reaction and compress the fuel to the high density. The overall efficiency of the ignition process, then, is the product of three efficiencies, the efficiency of the conversion of electrical energy into laser light, E_l, the efficiency of conversion of laser energy into pellet energy (basically, a factor of the absorption of light in the pellet), E_r, and the efficiency with which the absorbed energy is used for creation of the conditions for ignition of the fuel, E_h. (See box on laser fusion targets.)

Of most immediate concern is this last efficiency, E_h, or the efficiency of the hydrodynamic processes used to convert the absorbed laser energy into compression of the pellet. The physics of this energy transfer revolves around the physics of the shock wave created by the absorbed radiation. This is the shock wave that performs the actual compression. To determine the properties of this shock compression, Nuckolls and Wood used the following argument:

(1) To be ignited, the fuel must be at a density of 600 grams per cubic centimeter throughout the entire mass of fuel.

(2) The most efficient compression of this fuel will occur if the fuel can be maintained in its Fermi degenerate state.



The Shiva-Nova laser at Lawrence Livermore. The most remarkable thing about the laser is the arrangement of the beams for illuminating the target in the target chamber. Despite much public discussion about the necessity for spherical illumination of the fusion target, the beam ports on Shiva are not spherically symmetric. This indicates that, contrary to the public literature, the fusion fuel pellets are also assymmetric. However, spherically symmetric illumination of the fuel is achieved by the generation of soft X-rays.

That is, the conditions for most efficiently compressing the fuel exist when the fuel has a temperature low enough to be maintained in this high-density, relatively low temperature regime. If the fuel is heated above approximately 100 electron volts at this density, it will lose its Fermi degeneracy and become difficult to compress.

(3) The actual ignition temperature of 10 million electron volts need be achieved only in a small central core of the pellet, which represents about 0.1 percent of the total fuel mass. The burn of this small "trigger" will then ignite the rest of the fuel.

The problem of maximizing the compression efficiency of the pellet then becomes reduced to finding a way of compressing the fuel to very high densities without heating it significantly. There are several issues that must be addressed on this question of heating, but most important for this discussion is the question of the properties of the shock wave required to achieve this compression.[3] The desired shock wave is called *isentropic* because there is zero entropy change (or no heat generation) across the shock front. The achievement of isentropic compression has been the goal of the laser fusion program for more than 10 years.

Where the Inertial Confinement Program Stands Today

Using this conception of the experimental conditions that it must reach, the laser fusion program has progressed considerably toward the achievement of these goals.[4] However, the ignition of significant thermonuclear burn in a fuel pellet remains far off. Current estimates are that the laser energy must increase by a factor of 5 to 10, the density of compression by a factor of 10, and the temperature by another factor of 10. The result of these combined increases will be a 1,000-fold increase in the burn (the amount of fusion energy) achieved. The strategy used by the mainstream of the U.S. fusion effort to achieve isentropic compression has been dependent on a basic property of shock waves—that a shock wave will propagate isentropically if the pressure differential between the undisturbed medium and the shock itself is small. This differential is usually called ξ:

$$\xi = P_1/P_0.$$

If this ratio is nearly 1, the shock wave will propagate isentropically through any medium, regardless of the relations among pressure, compression, and temperature in the medium (its equation of state).[5] Thus, Nuckolls and Wood's original idea was to use a series of carefully shaped and timed laser pulses to generate a series of weak shock waves. These shock waves would be timed so that they would all converge at the center of the pellet simultaneously, mimicking the compressional effects of a strong shock wave, but without subjecting the pellet to the nonisentropic compression that a strong shock wave would have induced. In fact, this idea of a tailored pulse to produce nearly isentropic compression is the original contribution of Nuckolls and Wood upon which all subsequent optimistic forecasts of laser fusion have been based.

The hope of the U.S. laser fusion researchers is that if they use these tailored pulses, the only significant problem remaining is to construct large enough drivers to ignite the fusion reaction. They are convinced that the basic

physics involved in the pellet compression and ignition is understood and that the process of isentropic compression by weak shock waves is sufficient to achieve ignition.

The FEF's 1979 Proposal

To understand the new approach to laser fusion suggested by Uwe Parpart and the Fusion Energy Foundation in 1979 requires a more detailed picture of the energy requirements for the compression process.

Figure 1 shows the relationship between pressure and volume for several different strategies of compression. On the left, a, is the trajectory in the state space for a medium undergoing isentropic compression, where all the energy goes into the compression of the medium and the minimum possible goes into its heating. In the center, *b*, is the trajectory of a strong shock wave compression, starting from the same pressure and volume, with the assumption that the medium behaves like a gas (that is, has an equation of state like a gas). In the case of the strong shock wave, it can be shown that the energy used in the *compression is divided equally between compression and* heating. Thus, as the figure shows, the final volume achieved along this trajectory, called a *Hugonoit adiabat*, is larger than that achieved by the isentropic compression, and so the compression is smaller. In other words, half of the compression energy was "wasted" on heating the gas.

On the right, *c*, the figure illustrates the strategy of the national laboratories for achieving isentropic compression. Strictly speaking, it can be shown that isentropic compression can be attained only when there is no discontinuity at the shock front; that is, when there is no shock wave. However, the amount of entropy produced goes as the third power of the pressure discontinuity:[6]

$$(S_1 - S_0) = 1/\,12T_0\,(\partial^2 V/\partial\, P^2)_s(P_1 - P_0)^3$$

where *S* equals entropy and *T* is temperature. That is, the change in entropy before and after the shock wave is proportional to the third power of the pressure change. Therefore, a weak shock wave can very closely approximate the isentropic trajectory. Note that the slope of the Hugonoit adiabat at the initial point in state space is the same as that of the isentropic trajectory, so that if a weak shock wave is used for a very short compression (a small change in pressure), the resulting change in volume will be very close to that achieved by the isentropic compression. As shown in the figure, a series of weak shock waves can then provide nearly isentropic compression.

Mathematically, the change in pressure provided by the shock wave is related to the change in volume by the following expansion, in terms of volume and entropy, in the neighborhood of the initial point:[7]

$$P_1 - P_0 = (\partial P/\partial V)_s\,(V_1 - V_0) + \tfrac{1}{2}(\partial^2 P/\partial V^2)_s(V_1 - V_0)^2 + \tfrac{1}{6}(\partial^3 P/\partial V^3)_s(V_1 - V_0)^3 + (\partial P/\partial S)_v(S_1 - S_0) + \ldots.$$

Now, in the case of the isentropic trajectory, by definition $S_1 - S_0 = 0$, so that the maximum compression is defined by the condition

$$P_1 - P_0 = (\partial P/\partial V)_s(V_1 - V_0) + \tfrac{1}{2}(\partial^2 P/\partial V^2)_s\,(V_1 - V_0)^2 + \tfrac{1}{6}(\partial^3 P/\partial V^3)_s(V_1 - V_0)^3 + \ldots.$$

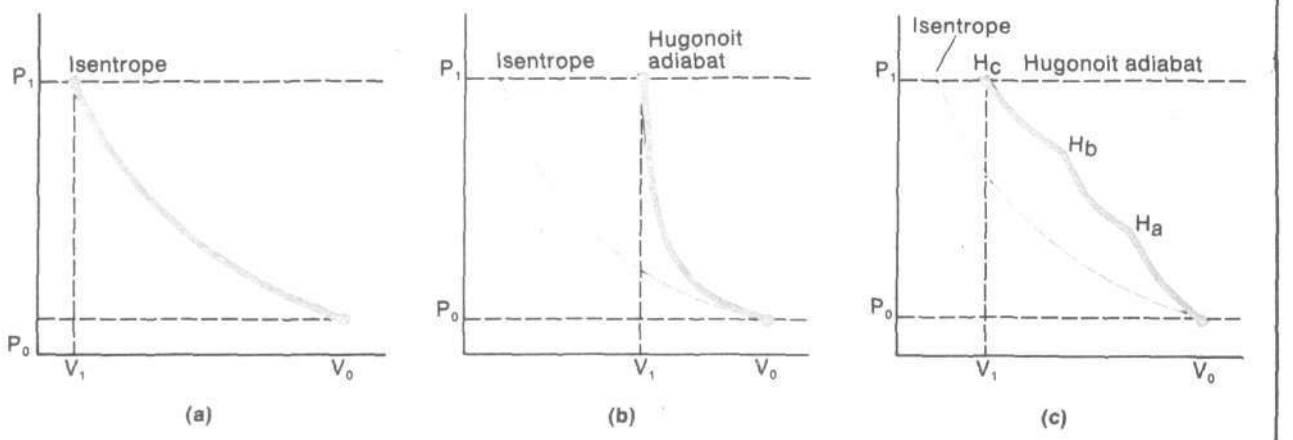


Figure 1
TRAJECTORIES FOR COMPRESSION OF A GAS

The "state space" plotting the volume against the pressure of a gas is a useful way of comparing different compression strategies. These three graphs show the possible compression techniques for a gas starting from a given volume (X axis) and pressure (y axis) P_0, V_0. Figure a shows the path for isentropic compression, which achieves the maximum volume change for a given pressure difference, $P_1 - P_0$. A shock wave, which must produce some entropy during compression, cannot result in as great a compression, as shown in b, where the Hugonoit adiabat is traced along with the isentrope (the dashed line). Figure c shows the approximation of the isentrope with three shock waves, each of which propagates along the Hugoniot adiabat, H_a, H_b, and H_c.

It is not hard to show, on the other hand, that in the general case for any shock wave

$$P_1 - P_0 = (\partial P/\partial V)_s(V_1 - V_0) + \tfrac{1}{2}(\partial^2 P/\partial V^2)_s(V_1 - V_0)^2 + (V_1 - V_0)^3 [\tfrac{1}{6} (\partial^3 P/V^3)_s - 1/12T_0 (\partial P/\partial S)_v]. \ldots$$

The compression from a shock wave is the sum, first of all, of three terms that appear in the zero entropy equation (above) plus another term proportional to $(\partial P/\partial S)_v$. Thus, there are three salient points about the comparison of the *isentropic trajectory with the Hugonoit trajectory.*

(1) Since we are compressing the gas, $V_1 - V_0$ is negative, and the negative sign on the term proportional to $(\partial P/\partial S)_v$ means that the entropy increases as the shock wave propagates through the medium.

(2) This increase in entropy decreases the volume change achievable by a given change in pressure. This is the result of the diversion of some of the energy from compressing the medium to heating it. The greatest compression achievable occurs when all the terms proportional to $(S_1 - S_0)$ are zero.

(3) There are two ways to make these terms zero. First, the change in entropy itself may be zero, as in the isentropic case. However, these terms would also be zero if the partial derivative $(\partial P/\partial S)_v$ were zero. This is the crux of the matter. The Nuckolls and Wood strategy is to approximate the conditions of $(S_1 - S_0)$ by using weak shock waves. *Our proposal took the opposite course. We* proposed to arrange the compression so that the derivative $(\partial P/\partial S)_v$ is zero.

The Equation of State of the Fusion Fuel

The Fusion Energy Foundation proposal was motivated by a detailed reexamination of Bernhard Riemann's 1859 paper, which assumes, in effect, that the second condition is always satisfied and the isentropic conditions always occur in the formation of a shock wave.[8] Since the early 1900s, *Riemann's paper has been extensively criticized* because of his allegedly incorrect treatment of the energy and entropy jump-conditions. However, the essential point is that Riemann's treatment of the shock wave, as we shall show, more closely approximates the important features of the most interesting shock waves than the currently accepted treatment does. The difficulty turns on the correct equation of state to use in describing the medium through which the shock wave propagates.[9] In general, the equation of state is a function

$$P(V,S) = \text{pressure.}$$

That is, the pressure is some function of the volume and entropy. This equation is not, strictly speaking, a thermodynamics equation; rather, it is usually a phenomenological description of the system, containing an implicit description of the elastic forces that hold it together.

In the case of a gas, the pressure depends on both the volume and entropy in some tightly coupled way. For an ideal gas, for example, the equation of state is

AIP

Bernhard Riemann: His method is essential for fusion research today.

$$E(S,V) = 1/(\gamma - 1)V^{1-\gamma} \exp [(\gamma - 1)\, S/R],\ \gamma = C_p/C_v,$$

where *S* equals entropy, *V* is volume, *R* is gas constant, and *C* is heat capacity. This is equivalent to the more well-known form $PV = nRT$, (where *n* is the number of particles).

However, as Hans Bethe seems to have been the first to note, for liquids this equation of state is dramatically different, because the energy depends on the addition of *two terms*[10]

$E = A(S) + B(V)$, where A and B are arbitrary functions.

Therefore, the equation of state is in the form of two independent equations:

$$P = -\partial B/\partial V \text{ and } T = \partial A/\partial S.$$

That is, the pressure and volume on the one hand, and the temperature and entropy on the other, form two pairs such that one member of each pair determines the other directly without any interaction from the other pair.

For a material with this equation of state, the key derivative $(\partial P/\partial S)_v$, is always equal to zero! In such a system then, strong shock waves would provide as efficient compression as weak shock waves, and would be equal to that of the isentropic compression for the same pressure difference. This phenomenon has been observed in several systems in which shock waves propagate through matter that is characterized by strong self-interactions. During World War II, for example, it was studied in connection with underwater detonations; more recently, it was studied in connection with the cores of collapsing stars.[11]

Riemann's essential physical insight was that a strong shock wave could create a change of state the result of which would be a new phase that had an equation of state characteristic of a liquid. This point is central: The shock wave does not function merely as the means by which energy is deposited on the laser fusion target. If this were its only purpose, then there would be no advantage to a strong shock wave over a weak one. But more is going on. The shock wave, if it is strong enough, will create a new condition of matter so that it can then compress the matter more efficiently.

The 1979 FEF proposal consisted then of the conjecture that the use of strong shock waves for laser fusion would have the advantage of creating a change of state in the fuel that would result in isentropic compression of the pellet regardless of the strength of the shock wave. This conjecture suggested that magnetic or quantum interactions within the pellet would change its equation of state from that characteristic of a gas—strongly coupled pressure and entropy—to that of a liquid—decoupled pressure and entropy.[12]

If this change of state occurred under the influence of a strong shock wave, it would open up a whole new area of experimental research, with new physics and new possibilities for coupling the radiation and the pellet. In addition, the compression of the pellet would be assured to be isentropic, and hence maximally efficient. The FEF proposal concluded that both the efficiency of radiation coupling, E_r, and the efficiency of compression, E_h, would be markedly increased by the use of strong shock waves for compression.

New Results on Fluidlike Equations of State

Further FEF research has provided two directions for the pursuit of this conjecture, both of which point toward the verification of the proposal concerning the relation between strong shock waves, changes of the equation of state, and efficient compression schemes.

In the early stages of the laser-pellet interaction, the radiation hitting the pellet creates a plasma that surrounds the fuel, called the corona. This ambient plasma, and not the cooler, un-ionized core of the pellet, is the part of the pellet that actually interacts with the incident radiation. Under some circumstances, it has also been observed experimentally that the interaction of the radiation and the plasma generates exceedingly intense magnetic fields, fields in excess of 1 to 10 megagauss. Some researchers suggest even higher fields in similar radiation-plasma interactions.[13]

It is clear, then, that the relevant equation of state for the compression process is not that of a gaslike plasma, but rather that of a magnetized plasma. Under the conditions found in the corona of some current targets, the magnetic energy density is roughly comparable to the plasma (kinetic) energy density, so that the effects of the magnetic fields must be taken into account. More important, the magnetic effects turn out to be tremendously beneficial for the compression process and should be encouraged. As we will now show, using the strong shock wave to produce a change from a gaslike plasma to a magnetized plasma induces a change in the equation of state such that the resultant plasma has a fluidlike equation of state and can be compressed isentropically with a strong shock wave. Here is a physical mechanism inducing the change described in the FEF's 1979 proposal.

When there is a strong magnetic field in a plasma, the motion of the plasma becomes almost two-dimensional. The particles are tied to the field lines and the energetics of the plasma are determined by the near impossibility of cross-field motion by the plasma. In effect, the field lines act like lines of charge that move in the field created by other line charges. The equation of state for this situation has been derived, and given the considerations above, can be applied to a laser-created plasma. The energy has the exact form required for the decoupling of pressure and entropy:[14]

$$E \approx E_0 \ln V - E_0 \ln(1 + E_0/kT) + C,$$

where E_0 and C are reference energies constant for our situation and k is Boltzmann's constant. Since it can also be shown that S is only a function of T,

$$S = k \ln (1 + E_0/kT) - E_0/T,$$

the derivative that determines the efficiency of compression can be evaluated and is found to be zero:

$$(\partial P/\partial S)_V = -[\partial/\partial S\ (\partial E/\partial V)_S]_V = 0.$$

Thus, the strong magnetic field creates a new kind of plasma, whose compression characteristics are those of a liquid rather than a gas.

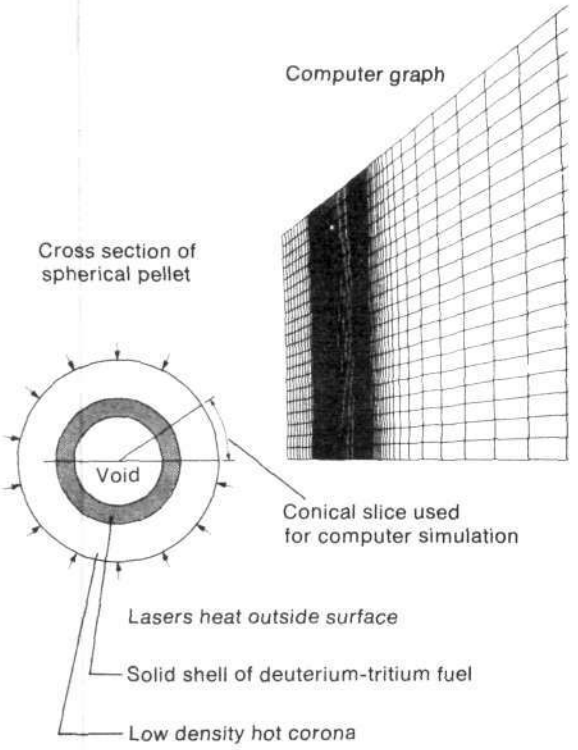
There is one complication with this equation of state that should be noted. If one tries to calculate the pressure directly in a "thermodynamic equation of state," the result is a negative or zero pressure. This is closely connected with the existence of a phase change predicted by the energy equation at a threshold value of the temperature. At this temperature the system condenses into a pair of counterrotating closed magnetic circulation cells. This condensation, well known in the hydrodynamics of two-dimensional fluids, has been shown in a number of numerical simulations, both of fluid equations and "particle" simulations using long charged rods or vortex lines.[15] This new state is difficult to analyze thermodynamically because it is characterized by a negative temperature and finite volume phase space, and hence has no quiescent equilibrium.[16] In this respect, it does closely model a highly magnetized plasma, which also is inherently dynamic, and in order to be "stable" it must have nonzero velocities and currents.

The Energy Question

For considerations here, the energy relation must be seen as primary, and it is the energy transfer characteristics of the medium that determine its behavior under compression by the shock wave. Thus, even without a

Figure 2
COMPUTER SIMULATION OF ISENTROPIC COMPRESSION USING WEAK SHOCK WAVES

This computer-produced graph shows a succession of two weak shock waves used in the isentropic compression of a spherical fuel pellet. The computer has plotted the density of the fusion fuel, which is indicated by the closeness of the contours, the lines perpendicular to the radial lines. The closer the lines are together, the higher the density. The two areas of closely spaced contours are shock waves propagating toward the center of the pellet. The simulation was done for a conical section of the spherical pellet only, since the same compression occurs for all such conical sections. The accompanying cross section of the pellet consists of a hollow fuel core and a spherical outer shell that is irradiated by the laser. The acceleration of this outer layer creates the shock wave and the resulting compression. The separate shock waves are produced by increases in the intensity of the laser pulse. The strength and timing of the shock waves is such that they converge at the center of the fuel pellet creating the density and temperature conditions necessary for a fusion reaction.



clearly identifiable equilibrium pressure, the considerations comparing isentropic compression still hold.

The generation of magnetic fields of such great intensity in the laser fusion plasma is the subject of much current research, but this research has generally been thought to show that the magnetic fields so generated are either too small to affect the absorption of the radiation by the pellet, or, on the other hand, are detrimental to this absorption. As a result, researchers have generally designed pellets that minimize the formation of magnetic fields; they have not tried to use these fields as part of an overall process of reconstruction of the plasma properties aimed at efficient compression.

It turns out, however, that the generation of these magnetic fields is closely connected to several mechanisms, all of which generate vorticity, large-scale order, and a cascade of energy toward these coherent magnetic field structures. The role of the shock wave itself in generating vorticity is not currently studied, but it figured largely in the initial studies of the relation between the equation of state and shock waves.[17] In fact, von Neumann showed that there is a close relationship between the equation of state, the conditions of isentropic compression, and the generation of vorticity by a shock wave.[18]

These considerations all lead in the same direction: The shock wave does more to a medium than deposit energy; it acts to restructure the medium, creating changes in state and large-scale ordered motion (like magnetic fields and vortices), and it introduces qualitatively new phenomena.

The example of a shock wave actually indicates a more general problem of the nature of energy in dynamic systems. Energy, properly considered, is not a scalar measure but rather an indicator of the capability of a system to undergo qualitative change. The deposition of a large amount of energy in a system results not so much in its undifferentiated heating but in changes of state, new modes of energy containment, and the like. *Energy must be conceived of as that potential of a system for continued evolution.* If the system does not have the means of "containing" that energy in its present form, it will evolve so as to be able to. This Leibnizian idea of energy as *potential work* is central to a correct understanding of shock waves.

There is a second direction in which the FEF shock wave proposal pointed out the possibility for a new equation of state, that of quantum interactions. The sort of new interactions that account for superconductivity seem ideal for inducing the strong coupling that would result in a liquid equation of state. In the case of the energy densities relevant for laser fusion, it was even remarked in the first Nuckolls and Wood paper that the later stages of compression would be conducted on a solid that was Fermi degenerate; that is, which had undergone a phase change (as a result of the shock wave!) to a state whose internal energy relations are determined by the quantum mechanics of electrons. This idea of Fermi degeneracy, it should

be noted, is not actually a description of what the electrons may be doing as much as a prescription for the calculation of appropriate averages approximating the bulk properties of electrons in this state. It leads to an equation for the pressure that satisfies the condition for isentropic compression:

$$P = \kappa N^{5-3} V^{5-3} + \pi^2/25\ [(kT)^2/\kappa^2\ (N/V)^{4-3}] + \ldots,$$
where κ is a constant.

That is, to first approximation—an approximation that gets more accurate the cooler the material, hence the imporance of isentropic compression—the pressure depends only on the volume, and the derivative $(\partial P/\partial S)_V$ is zero.[19]

This condition holds for the core of an isentropically compressed pellet and so provides a second example of an equation of state that would allow for further compression (after the onset of Fermi condensation) in the most efficient, isentropic way, regardless of the strength of the shock wave.

Reactions to the FEF Proposal

The hypothesis of strong shock wave isentropic compression, which, in the spirit of Riemann's method, places principal emphasis not on "brute force" but on a study of the detailed geometric and topological features of the compression process, was widely discussed with inertial fusion researchers in several national laboratories and universities. Although these discussions were always animated, the response was nonetheless largely negative. The gist of the criticism of the FEF proposal fell into three areas, the existence of other states of matter, the relative efficiencies of different compression strategies, and other target designs.

(1) *The existence of other states of matter.* Most researchers feel that the uncertainties in the equation of state of fusion fuel are not great enough to permit isentropic shock compression from normal densities to those required for ignition. The known processes for driving various plasma modes that might change the equation of state (magnetic fields, solitons, and so on), are too slow growing, too rapidly damped out, or provide too small an increase in the energy-containing ability of the plasma (its heat capacity) to be relevant. The only change of state that does occur is that to a Fermi degenerate state, and this is somewhat irrelevant to isentropic compression because the change cannot occur until after the plasma is compressed.

(2) *Relative efficiencies of different compression strategies.* Most fusion researchers pose the argument this way. If we compare two pellets—pellet *a*, which is compressed by a strong isentropic shock wave to densities of 1,000 grams per cubic centimeter and the necessary size, and pellet *b*, which reaches the same conditions using a series of weak shock waves—there are two possibilities.

First, if the new equation of state does not appreciably change the heat capacity for either *a* or *b*, then will *a* be more energy efficient than *b*? No, since both pellets will have achieved Fermi condensation, the minimum energy density is set by the Fermi equation of state. Is the compression efficiency E_r, different for *a*, and *b*? Again the answer is no, because both implosions are constrained by the condition that once the maximum driving pressure is reached, it must be sustained over most of the remaining implosion; otherwise the inside of the shell will run away from the outer part. Both *a* and *b* are also constrained by the requirement that the intensity be high enough so that there is enough thermal smoothing to achieve the required implosion symmetry, but not so high that it significantly degrades the absorption or significantly preheats the fuel. Because of these constraints, it is not possible for *a* and *b* to have significantly different implosion efficiencies.

Second, if the new plasma states do significantly change the heat capacity, will they be more strongly excited in *a* or *b*? Since *a* is much more abrupt, intuition would suggest that the new states would be harder to achieve in *a* than in *b*. In any case, the overall implosion times are set by the constraints noted above, and these apply to both *a* and *b*, making any difference in the excitement of these states minimal.

(3) *Other target designs.* In any case, fusion researchers have argued, classified target designs have largely mitigated the problems of nonisentropic compression, so that the existence of isentropic shocks and new states is not significant.

It is obviously difficult for us to intelligently discuss the third objection. It is conceivable that some clever target pellet design could overcome the mechanical considerations that mandate isentropic compression, but the same cannot be said for the new states of matter. It is certainly possible that scientists can design pellets for which these new states are suppressed; this proves not that the new states are unimportant, but rather that they have been ignored.

Large laser-generated magnetic fields are a case in point. The small pellets currently in favor in the public literature from the national laboratories do indeed suppress, among other things, the appearance of magnetic fields. But it is known that larger pellets, of the sort that the Soviet researchers favor, have much stronger magnetic interactions. The relevance of the new magnetic states, to take one example, is dependent on the experimental objective; if one wants to avoid the new magnetic states, they can probably be made irrelevant in fact.

The other two objections are more substantial and raise a number of interesting points.

First, the comparison of a strong shock wave scheme with the weak staged shock waves presumes that it is definitely possible to achieve the compressions required without a change of state. This assumption is plausible, but by no means to be taken for granted given the current impasse in laser fusion.

Second, assuming that it is possible, and that the relevant problem is a comparison between the two compression strategies, we can dispose immediately of the question of the existence of strictly entropy-independent compres-

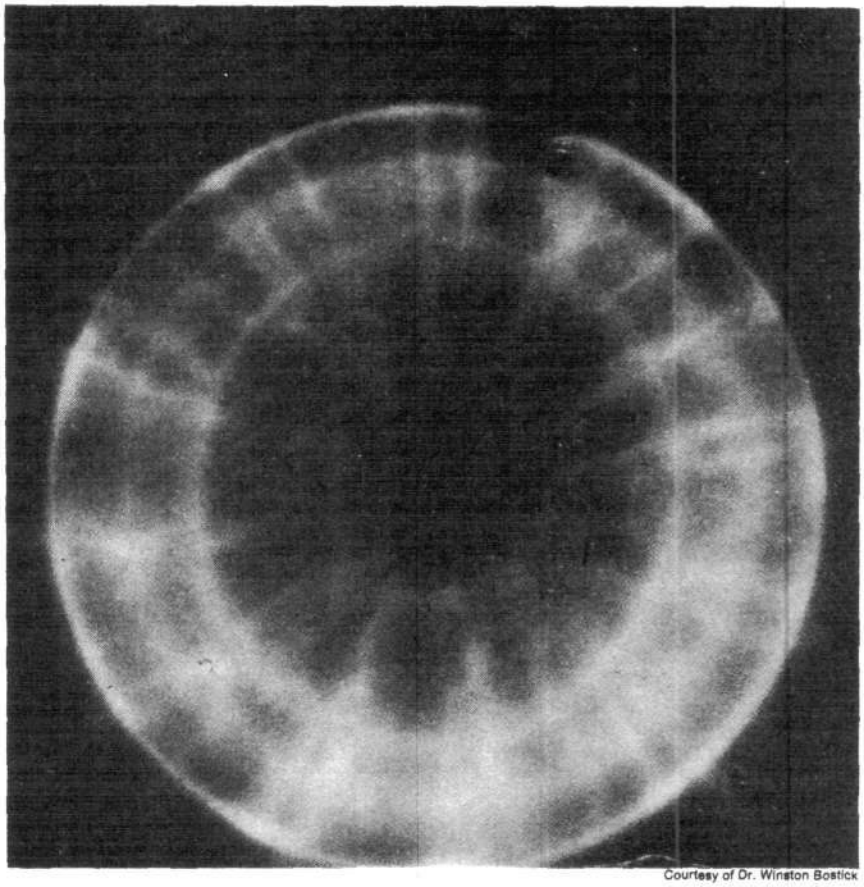
sion schemes by noting, as pointed out above, that a Fermi degenerate state will support isentropic compression from any strength shock wave because of the structure of its equation of state. Such compression exists; the question is how to obtain it both *before and after* Fermi condensation.

Third, the crux of the argument, then, is that we know the equation of state well enough to rule out the exotic states described above. This may perhaps be the case for the pellets now in use and for future target designs. But this fact is more a statement of the experimental philosophy of the program than a statement about physical possibility. The current research program depends very heavily on an interaction between a set of computer codes, most notably LASNEX, that are used to interpret experimental results and the experiments themselves. LASNEX is not a *theoretical* description of the laser fusion process as much as it is a phenomenological collection of previous experimental results. The next experiment is thus always constrained to reproduce previous results and so cannot, in this conservative environment, ever produce anything qualitatively new. When anomalous results are seen experimentally, results that do not conform to the predictions of the computer code, they are downplayed. If they do not offer the immediate possibility of more efficient compression, they are ignored.

Similarly, experiments are designed, of necessity, within the bounds of the existing computer codes. New interactions that are not in the computer codes will be excluded from the considerations affecting new target designs. Thus, experimental progress becomes a self-fulfilling prophecy to a large extent. A small, well-delineated area of possible parameter space gets very thoroughly mapped out and pellet design, driver, and geometry get optimized within this goldfish bowl; this is a local optimization that has little sense of the global configuration. Might there not exist new regimes that differ in some parameter by an order of magnitude from the current experiments (like magnetic field) and that would totally change the physics of compression and absorption?[20] In principle, such regimes cannot be ruled out, but the current research strategy will not find them. Of course, the equation of state for the current regimes is reasonably well known, but what does this say about other possibilities?

Fourth, the Fermi equation of state certainly seems to be an exception to what we have just said. Here is an equation of state that is well known and well tested. We can reply only that such confidence perhaps is a good hypothesis but is not sufficient to rule out other possibilities. Our ignorance of the actual dynamics of the electron itself, which can be described by no existing theory, or high-density collections of electrons, is a fact. Perhaps high magnetic fields change the statistical considerations on which the Fermi equation of state is based. Perhaps the rapidly changing temperatures and pressures result in the Fermi equation of state (an equilibrium law) being overwhelmed by other phenomena. Perhaps, more important, the equilibrium predictions of the equation are relevant on different length scales, whereas the energetics of the fusion pellet are determined by localized energy considerations of solitons, filaments, or the like. All these possibilities are at least as plausible as the current assumption that the equilibrium statistical mechanics of a Fermi gas apply to the electrons in a fusion target.

Fifth, the final objection to our proposal is that even if isentropic compression and new states of matter exist, they are not fundamentally different from the normal ones; that is, they contain energy in the same way and result in the same final compression and heating. This argument



Courtesy of Dr. Winston Bostick

A stably self-organized magnetic structure in a plasma. Fusion scientist Dr. Winston Bostick, who has described the physics of these self-generating magnetic filaments in a fusion plasma, has proposed a "hybrid" approach to fusion combining magnetic and inertial techniques. This approach has also been proposed by Dr. Friedwardt Winterberg.

amounts to saying that if the new states behaved in the same way as the classical ones, there would be no difference between them. This may be true, but our point is that the new states are *different*. At the very least, they have the potential of concentrating energy in very highly nonequilibrium structures. These nonlinear structures are characteristic of physical systems whose internal energy is dominated by strong "interparticle" interaction, the same general condition necessary for liquid equations of state.

Some researchers pursuing this line of thinking have proposed a "hybrid" approach to fusion combining magnetic and inertial techniques. Winston Bostick and Friedwardt Winterberg have described different aspects of the physics of compression of intense, self-generated magnetic fields that might ultimately provide the most efficient path to fusion ignition. The idea is to take the short time scale, high energy densities that inertial confinement offers, and combine these with the possibility of long-lived, stable self-sustaining magnetic structures that the plasma creates itself.

Some General Considerations

The inertial confinement program historically grew out of the nuclear weapons design program and continues to exist in close symbiosis with it. This close relationship has been beneficial in many respects, but it has also bred an unjustified smugness about the physics of laser fusion. To be sure, our scientists are probably smart enough to make laser fusion work like a small bomb, but most likely there are better ways of accomplishing the same end, a few of which we have proposed here.

New physics like that of solitons, high magnetic fields, and so on, must be investigated. Regimes in which these phenomena are dominant need to be studied. New computer codes that allow global studies of these other states need to be written and experiments need to be performed to test them.

Specifically, we think that a series of experiments to study high-intensity laser-generated magnetic fields in laser fusion pellets would be very profitable. Here are the sorts of questions that must be answered:

What is the relevant physics of this field generation in different temperature density regimes?

How can magnetic fields be increased in laser-created plasmas?

What is the equation of state of a strongly magnetized plasma? What are its compression characteristics?

How does the changed plasma affect overall pellet efficiencies?

We suspect that the design and study of pellets that are made to optimize magnetic field generation will be strikingly different from small bombs. They will be bigger than conventional pellets, they may benefit from longer wavelength irradiation, and they may be much less demanding in terms of surface finish.

The challenge of Riemann's method for inertial confinement fusion research, however, runs deeper than a new experiment or new equations. Riemann proposes a different conception of energy—energy seen as the potential for transformation. In this sense, energy does not so much affect existing particles or modes of a system as it changes those modes or creates new particles. It is the generator of new interactions. Energy pushes forward organization of matter.[21]

The example of the strong shock wave is an explicit case in which energy, if intense enough, can be used not simply for the quantitative increase of density and temperature—as in the weak shock-heating of a pellet—but where it changes the qualitative characteristics of the system. These new states can then interact totally differently from the way they do in the original system.

To take an example from a different range of energy densities: Atoms don't bark, but some collections of atoms do. We suspect the same is true of plasmas.

Steven Bardwell is editor-in-chief of Fusion *magazine, and Uwe Parpart is director of research for the FEF.*

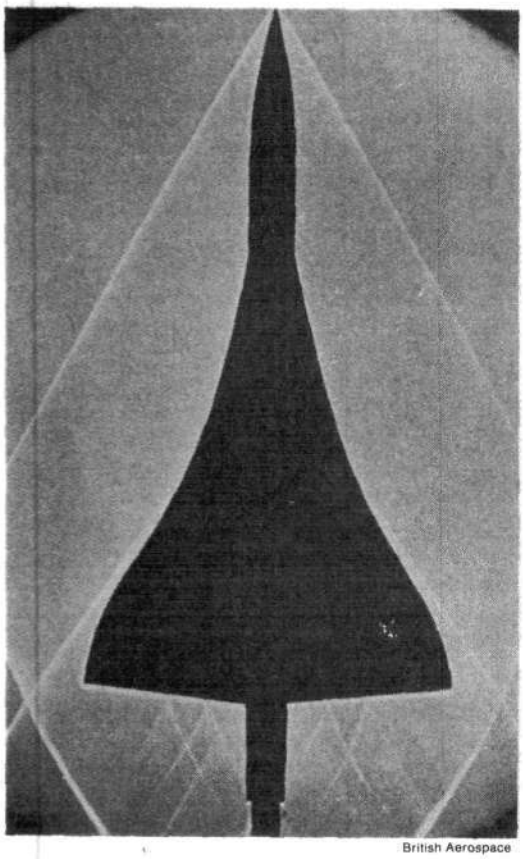
Notes

1. The first article, "Riemann Declassified— His Method and Program for the Natural Sciences," appeared in the March-April 1979 issue of *Fusion*, p. 24. The second article, "The Theoretical Impasse in Inertial Confinement Fusion," appeared in the Nov. 1979 issue of *Fusion*, p. 30. The FEF proposal was also presented at the American Physical Society Nov. 1979 meeting of the plasma physics division in Boston, Mass., and appears as an abstract in the APS Bulletin the same month.
2. J. Nuckolls, L. Wood, A. Thiessen, and G. Zimmerman, "Laser Compression of Matter to Super-High Densities: Thermonuclear (CTR) Applications," *Nature*, 239:139 (1972).
3. This is described in detail in Charles B. Stevens's article on the annual plasma physics meeting of the America Physical Society, *Fusion*, March-April 1981, p. 21.
4. For a summary of this progress, see G. Canavan, "The Prospects for Inertial Confinement Fusion," *Fusion*, March-April 1981, p. 30.
5. For a standard reference on shock waves, see Ya. Zel'dovich and Yu. Raizer, *Physics of Shock Waves and High-Temperature Hydrodynamic Phenomena* (New York: Academic Press, 1966).
6. Zel'dovich, p. 59.
7. Zel'dovich, p. 64.
8. This article, "On the Propagation of Plane Air Waves of Finite Amplitude," was translated by the authors and appears in the *International Journal of Fusion Energy*, 2:1 (1980).
9. See H. Bethe, "The Theory of Shock Waves for an Arbitrary Equation of State," National Defense Research Committee, Division B. Report 171 (1942); also, J. von Neumann, "Theory of Shock Waves," in *Collected Works*, pp. 178-202.
10. Bethe, "The Theory of Shock Waves."
11. H. Bethe et al., "The Pressure Wave Produced by an Underwater Explosion, I, II," National Defense Research Committee, Division B. Reports Nos. 252, 281.
12. This insight resulted from discussions with Dr. Friedwardt Winterberg.
13. See "The Pinch Effect Revisited" by Winston Bostick in the *International Journal of Fusion Energy*, 1:1 (1977), in addition to the references Bostick mentions.
14. C. Seyler, Jr., "Partition Function for a Two-Dimensional Plasma in the Random-Phase Approximation," *Physical Review Letters* 32:515 (1974).
15. Y. Salu and G. Knorr, "Numerical Solutions of the Three-Dimensional Electrostatic Guiding Center Plasma," *Plasma Physics* 18: 769 (1975), in addition to the references therein.
16. D. Montgomery and G. Joyce, "Statistical Mechanics of 'Negative Temperature' States," *Physics of Fluids*, 17:1139 (1974).
17. Von Neumann, "Theory of Shock Waves," pp. 182-184.
18. Von Neumann, "Theory of Shock Waves," pp. 189-190..
19. See, for example, Nuckolls, Wood, et al., "Laser Compression of Matter."
20. See R. Kirkpatrick, "An Overview of Design Space for Small Fusion Targets," *Nuclear Fusion* 19:69 (1979).
21. Note that we are *not* referring here to the Prigogine-inspired theories of dissipative structure.

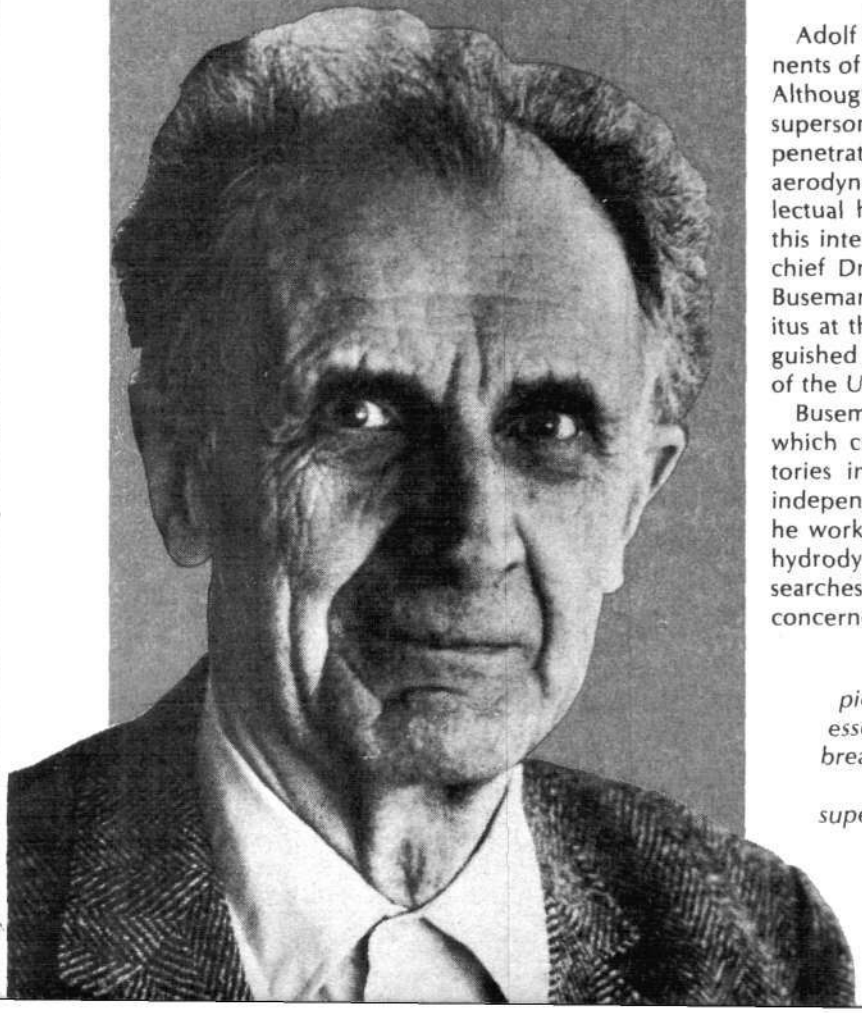
An Interview with

Adolf Busemann

Pioneer in Shock Waves, Supersonic Flight, and Fusion Power



British Aerospace



Editor's Note

Adolf Busemann is one of the most outstanding exponents of Riemann's hydrodynamic method in this century. Although he is not well known outside the realm of supersonic hydrodynamics, his intellectual influence has penetrated deeply into all aspects of plasma physics, aerodynamics, and the theory of shock waves. The intellectual history of this remarkable figure is recounted in this interview, which was conducted by *Fusion* editor-in-chief Dr. Steven Bardwell in the summer of 1979 when Busemann was 78. Busemann is currently professor emeritus at the University of Colorado. He holds many distinguished honors from various countries and is a member of the U.S. Academy of Engineering.

Busemann's research falls into three general areas, which coincide with the three primary research laboratories in which he worked. The first of these was an independent institute near Göttingen University, where he worked under Ludwig Prandtl, leader of the German hydrodynamicist school; Busemann continued these researches in Dresden. This first period of his research concerned the formation and propagation of shock waves.

Adolf Busemann, summer 1979. Busemann's pioneering work on aerodynamics in the 1930s was essential in the development of airplanes that could break the sound barrier without crashing. At the top of the page, a schlieren photograph of a model supersonic plane showing the shock waves that form when the plane is tested in a wind tunnel.

The immediate context for the research was work on the aerodynamic problems of wing design and jet turbine construction for flight at supersonic speeds.

The problem of supersonic flight had fascinated researchers and military thinkers since the first days of flight. But one outstanding feature of the problem had dominated all considerations: At velocities greater than the speed of sound, shock waves are generated. And these shock waves, because of the nearly singular nature of the air disturbances they generate, make it difficult to maintain stable, controllable flight at supersonic velocities. Even so, the fabled Mach 1 (the Mach number is the ratio of the speed of the aircraft to the speed of sound) was nearly reached by a German airplane using jet engines in 1945—the ME-163, which reached Mach 0.86.

Concentrating on the problem of the optimal design of turbine blades, Busemann discovered during the Göttingen-Dresden phase of his work some of the critical features of steady-state shock waves. The most famous of the results of this research was his development of the Busemann biplane, a configuration of two aircraft wings that completely eliminates drag at supersonic speeds (see Figure 1). Although this plane was never built, it had a tremendous impact on the design of supersonic aircraft, on the scientific understanding of aerodynamic drag, and on the general problem of the propagation of shock waves in two dimensions.

The insight into Busemann's method provided by his comments in this interview is quite striking: His primary motivation in the development of his theory was to eliminate the inefficiencies in turbines. To accomplish this end, Busemann realized that the properties of shocks upon reflection and turning were essential. This realization led to the experiments and the analysis of schlieren photographs of "dark spots" in the wind-tunnel flows. Using a quite intuitive geometric interpretation of the motion of the shock waves, Busemann realized that it should be possible to completely eliminate the trailing shock lines if a set of "interfering" shocks could be produced by a second wing. The Busemann biplane was the result.

Out of this research, Busemann became interested in the focusing of shock waves as well as their destructive interference. This extrapolation of his work on aerodynamics was taken up in his work at the German rocket laboratory at Peenemünde just before and during World War II. Busemann's comments on the Nazis' science program are revealing.

As can be seen, the results of the work that Busemann did during that period have had a tremendous influence on the course of inertial confinement fusion research. Busemann wrote several papers on the focusing of shock waves, partly as a study of how to avoid the concentration of shock waves in flight and how to design "shaped charges," configurations of chemical explosives that focus the detonation of shock waves on a target. These papers have become essential ingredients in the design of advanced fusion fuel targets in inertial confinement fusion (see Figure 2). The energy concentrating capabilities of these configurations, especially Busemann's conical configuration, have led many researchers to expect that chemical explosives can be used to ignite a fusion reaction. In fact, a Polish team of scientists reported in 1978 that they had generated a significant number of fusion neutrons in an experiment using high explosives in Busemann's conical configuration!

After World War II, Busemann moved to the United States in 1947 and worked with NASA at Langley Field in Virginia. There, Busemann studied the aerodynamic forces and surface heating of the starting and landing of space vehicles, while his more famous colleague, Wernher von Braun, designed the propulsion systems at NASA's Houston research center. As a sideline of this work, Busemann directed a seminar on electrodynamics, in the course of which he made some critically important discoveries on the existence and properties of magnetohydrodynamic (MHD) vortices. These vortices, which he compares to their hydrodynamic analogues, have turned out to be a central feature in most high-energy plasmas. In the past two years, Busemann's work in this area has received renewed interest because it is now thought that the fusion machine that can most closely approximate the "natural" plasma vortex configuration will be the easiest to control and heat to ignition conditions. These new machine designs, like the spheromak and the reversed field pinch, are all variations on Busemann's MHD vortex.

* * *

Question: The Fusion Energy Foundation has done a considerable amount of historical research on Riemann and the Göttingen school of mathematical physics. Our work has shown over and over again that the work that the Göttingen school undertook was the most productive, containing the deepest insights into scientific questions of fusion, for example. More recently, we have done some very specific research on the role of shock waves and shock phenomena in laser fusion. Out of that work came our attempt to do a new appreciation of Riemann's work. In doing that, we came across a whole series of researches that I think are largely unknown—in the United States, at least—by yourself, Karl Guderley, and the people in Germany in the 1920s, 1930s, and 1940s, researches that are not appreciated in this country at all. A lot of current research seems to be going through that same material again. What I would like to do in this discussion with you today is to get your insight into that history—why certain things were done, what was done, and the importance of those things today.

In the early years, in 1914, we already had a wind tunnel for studying supersonic speeds. We saw a lot of black things in the photos that were not always shocks. Sometimes it was when the humidity of the air was high; then there would be some black spots on the photographs, too. But the important thing was the shock. In supersonic situations, you cannot avoid getting shocks, no matter how low the angle of the tip [the wing].

This was already Prandtl's main interest at Göttingen.

Courtesy of Adolf Busemann

The seminal Volta meeting on supersonic aerodynamics in 1935. Busemann is second from the left, second row. To his left is Karl Wieselsberger, von Karman's successor at the University of Aachen. In the front row are General Crocco (right), president of the meeting, and his son.

He had lots of people working on high speeds during World War I. After the war was over, Germany wasn't allowed to work on practical airplanes anymore. Of course, in turbines, too, you very often have supersonic speeds, at least in the first stages of the turbine—not in the later ones. But Prandtl's researchers just wanted to get an idea of the compressible flow for any kind of application. The application for airplanes seemed out of reach or suppressed.

Question: Was there already research on supersonic flow in turbines, say in the 1920s?

Yes. I worked as an engineer and had learned in college, of course, about steam turbines and things like that. They were already invented. Therefore, we wanted to see how to make them most efficient—how to get the most energy out, put the least into a reversed flow, and reduce energy losses. But Prandtl's researchers were a little bit spoiled, because at the first Mach, at around 1.6, when two lines indicating pressure changes are going through each other, they stay straight—it doesn't look like they interfere with each other. They were spoiled because that was where the lines should have changed their curvature from one side to the other, but near the turning point there was just no curvature at all.

Therefore, when I came I wasn't so spoiled. I said when this is not so linearized, finite disturbances have to interfere with each other. When one goes through the other one, it has to change its direction. And of course, the Mach number in the wind tunnel that I had at that time was already a little bit lower. There was already a visible curvature in a certain direction, and therefore when I came in I worked a little bit more on how to produce a picture predicting the interference of two crossing Mach waves.

Question: What year was that?

I got my doctorate in 1924, and then I went to work with Prandtl in 1925. I stayed with him until 1931, when he "sold" me to Dresden. Those were bad times.

There was a young assistant there at Dresden who died before he was 33, and then there was a free opening. Those were pretty bad years. Some people didn't know if they should change their subject of study. America also had very bad times then. But when you lose a war, you can't be so much better—even when Germany had just recovered in 1929-30 and therefore seemed kind of high up, and America seemed to be very low.

Because of the economy, Prandtl couldn't keep so many people at his institute. The ones who could got other jobs. At a certain institution for aerodynamic research, they told three people, "One of you has to go. You select him." The workers came back and said, "Well, we would rather take two thirds of our salaries and stay on here."

Question: When did you go to Dresden?

Prandtl couldn't keep everybody at Göttingen, so I went to Dresden. I had already agreed to a 10 percent smaller salary there. And then all of a sudden, one year or another, the governor of Saxony said that everyone had to give up one tenth of his salary. So I lost not only my voluntary 10 percent at Göttingen, but another 10 percent. One or two people said it was illegal. But they said it couldn't be helped; it was the government's order. So I lost 20 percent.

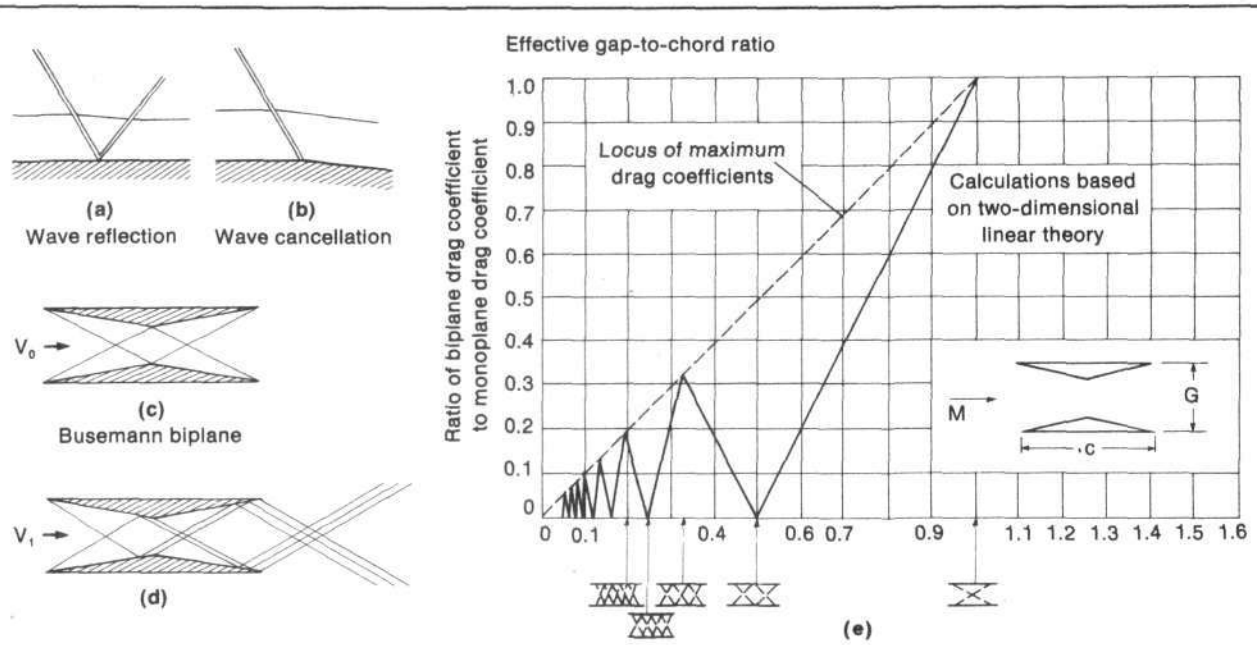


Figure 1
THE BUSEMANN SUPERSONIC BIPLANE

Busemann's design of a drag-free supersonic wing is a classical study in shock wave dynamics. The ordinary reflection of a shock is shown in a. *The arrows show the direction of the fluid flow (the flow of air around the wing): As long as the flow is parallel to the wall (or wing), there is no shock wave. Thus, as shown in* b, *by bending the wall, the reflected shock can be "canceled" by an expansion at the corner.*

The Busemann biplane at zero lift is shown in c. *As the wings travel through the air at a velocity V_0, part of the expansion wave at the corner cancels the compression wave from the leading edge of the opposite plane and produces the symmetrical pressure distribution shown. The wave drag is zero.*

At slightly different speeds, the waves begin to leak out, as shown in d. *Busemann describes this as the wings acting like a nozzle. The graph,* e, *shows the drag as a function of the geometry of the wings, along with the reflections of the shock waves required to produce the various occurrences of zero drag.*

Surprises like this don't go so well when you can't afford to live on less than the total amount of your salary.

Question: Was there a laboratory there in Dresden?

In Dresden there was a laboratory for applications of aerodynamics for engineering turbines and things like that. And although you weren't supposed to say it, it was for airplanes, too. While I was at Dresden I got invited to the Volta meeting [the 1935 European meeting in Italy that laid the foundation for supersonic aerodynamics]. And there we could say that Dresden was working on applications to aviation—but for 100 years in the future. But it didn't take long—just 10 years later Germany had a war.

Question: Were you thinking of those turbines for jet engines, or was it still the aerodynamic question of wing design?

We had supersonic wing shapes, to have less drag and lots of lift. That was the subject I got to talk about at Volta, since I had worked on that. They invited all the people who had worked on high speeds to the meeting in Volta, Italy in 1935. The subject was high-speed subsonic and supersonic flight. And they invited all the winners of the Schneider Cup to talk about how they had built their airplanes for this special use and what their thinking was about engine changes, the wings, and things like that.

Question: Did Germany enter the Schneider Cup race?

No. We were not allowed to enter. The first race was in 1913, I think, and the last one was in 1931. But during the First World War, there were no Schneider Cup races. I don't know whether Germany had a chance to take part between 1913 and 1914; and in 1918, they told Germany in the peace treaty, "no more airplanes anymore for you." We would supposedly only try to make war with them, to shoot things and throw things at other countries.

Prandtl, Ackeret, and I were invited to Volta. Ackeret was another pupil of Prandtl. He is now 80 years old. He's alive in Switzerland.* He talked about wind tunnels. Prandtl talked about the experience of the early years. I talked about lift at supersonic speeds. And von Karman [Theodor von Karman, a Hungarian scientist working in Germany who emigrated to the United States before World War II] talked about drag at supersonic speeds.

* Ackeret died March 27, 1981 at the age of 83.

I had the Busemann biplane. The idea was, when you are interested in getting no lift, you can use two surfaces and send the waves back, and they cancel each other out in between.

You can have this cancellation at lower Mach numbers, at a higher concentration of shock waves, so that you can have a finite volume of parameters that makes no wave drag.

Of course, it makes a lot of friction drag, especially when you have four surfaces instead of two—the outside and the inside. The friction drag is at least doubled. And when you have separation, you may have more than just friction drag; therefore, you have to be very careful about it. That was von Karman's idea; it was his business to talk about that.

Question: What about your work on the conical focusing of shock waves?

During the war I wanted to write a book about my new ideas, but I wasn't allowed to do it, since I was so much involved in secret things that even when I didn't intend it, they might just pop out.

I gave the introduction to a secret meeting about shaped charges. The Academy [German Academy of Sciences] wanted one speaker, as a member of the Academy, and they chose me. These [pointing to one of the view-graphs he used in his talk] are steady flows, and I made another view-graph to represent nonsteady flows. I wanted to publish this, but they didn't allow me.

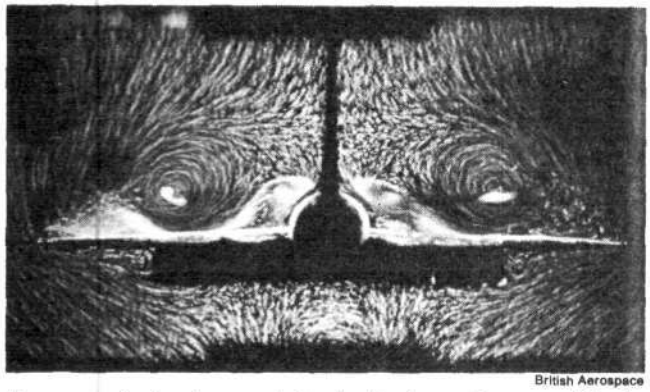
In this nonsteady flow, if you want to put it on two-dimensional paper, you can put the time in one direction and then there's only one direction left. Therefore, you can study nonsteady pipe flow created by pistons on both ends. I extended my studies to nonsteady waves going through a conical pipe. This focuses the pressure. (That's what people like—to make shaped charges, so that they can put them on a jeep or something, and then it really makes a hole.)

Question: This is the idea the Russians use extensively in their work on fusion. This idea of the conical focusing of shock waves comes from you. Is that right?

Yes. Since I had only one direction left, I could only make a circle—a cylindrical one or spherical one, so that I didn't have to make changes except on one radius. It is usually nicer to have one dimension, or three dimensions, or something odd-numbered. If it's even numbered, the mathematics of it is sometimes a bit harder. Therefore, when I make a steady flow, I can make it only two dimensions. I make the drawing on a plane, and then I can show the space in one direction only, and there must be an identical thing around in however many directions you may wish [that is, it must be independent of the other coordinates]. Therefore, I could make it spherical, and that was what they liked best.

Question: When did you start that work?

After I was through with the work on the steady flow one, I started work on nonsteady flow in Dresden.



British Aerospace

Busemann's background in hydrodynamics, specifically the dynamics of fluid vortices, led naturally to his discovery of plasma vortices that today have important applications in magnetic fusion. The photograph here shows flow patterns forming around a model aircraft being tested in a water tunnel. The vortices generated over both wings provide aerodynamic lift.

Question: You had a paper in 1942 or 1943 on self-similar solutions to spherical shock waves?

Yes. That was my introduction lecture at the secret meeting I mentioned, since I wasn't working on explosives, but on nonsteady gas dynamics.

Question: So it was in the late 1930s in Dresden that you started on this research on shaped charges?

No. Just on nonsteady gas dynamics. The steady dynamics were now finished—at least what you could put down in two dimensions—and the other ones had to wait until they invented movable wings. For nonsteady dynamics, you'd have to open the wing up and close it, and how can you do that on an airplane? And you'd have to make hinges on it, doing that when you have no lift.

But, you see, the flow that I drew on that biplane is not unique. It can be what I'd like it to be. It can be at the same time a choked thing; and then it would spill the air around on the sides instead of going through the middle. When the flow in the inside is not exactly what I want it to be, then it doesn't go through—the same amount of fluid doesn't go through, but comes back. You see, when we choke the flow for a while, then the airplane goes through sonic speeds. Then the flow goes around, and it doesn't come back to this one [pointing to one wing of the biplane] unless it starts from the sides where there is an opening and then goes around; and it doesn't come back to this one [pointing to the other wing in the biplane (see Figure 1c)] unless it starts from the sides where there is an opening, and then goes slowly through the middle.

Question: So it was in the late 1930s that they were working on these supersonic wing designs and the rest in their wind tunnel. Were you still at Dresden then?

Yes, and I built my wind tunnel. But then, when Hitler didn't care about the conditions of the peace treaty and

started to fly again, there was a new center in Braunschweig. There I built my own wind tunnels. I came to Braunschweig in 1936. Then I had a really different, transsonic kind of a tunnel, with a very large diameter, and a supersonic tunnel with a small cross section. And I also had a rocket test facility in the country. It was in the country, because a lot of people who invented rockets died from the explosions; therefore, we couldn't build in the neighborhood of the town. But I had to go there a couple of times every month to see what they were doing.

Therefore, my problem was at that time not only wind tunnels, but rocketry, too. It was then that I got to know von Braun. We Germans talked to each other so that we didn't spend a million reichsmarks on the same experiment. When they had experience, they told me about it, and when we wanted a new experiment, we told each other. Of course, it is sometimes very good for two different people to test the same thing. But we were not supposed to do that.

Question: What was the motivation for the research you did on self-similar solutions in spherical geometry?

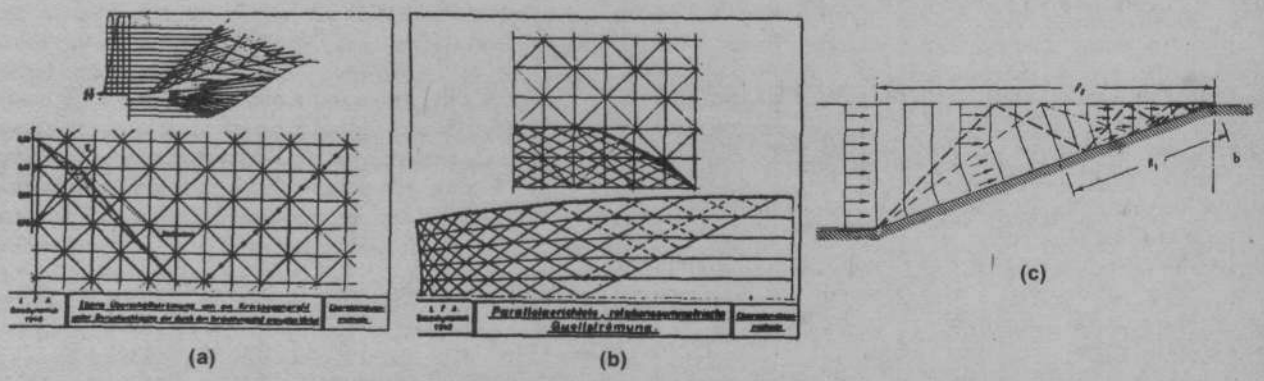
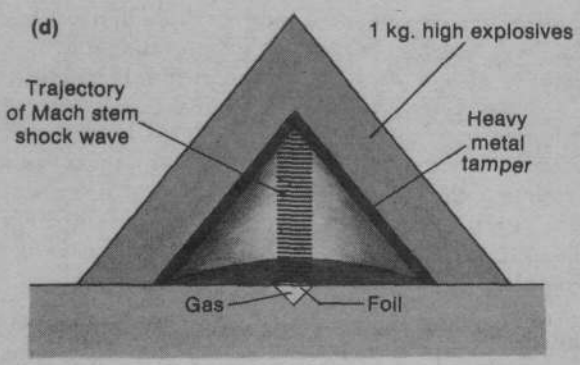


Figure 2
CONICAL FOCUSING OF SHOCK WAVES

Busemann's design of a conical focus for shock waves was published in 1942 in Luftfarhrtforschung *(vol. 19, p. 137), the same journal that published K. Guderley's famous paper on self-similar solutions to the focusing of shock waves in a spherical geometry. Two of the view-graphs used in Busemann's secret 1940 talk on shaped charges are reproduced in* a *and* b. *Busemann reports that the initial motivation for these focusing ideas came from the conception of a dimensional constraint on the propagation of shock waves. Thus, a highly symmetrical geometry is chosen, such as a sphere, cylinder, or cone. The cone and sphere share the property of having a zero-dimensional focus (a point), as opposed to the cylinder with a line focus. The result in practical terms is a technique for the generation of almost unlimited pressures at the focus. Some of the geometrical considerations in the reflection, interference, and concentration of shock waves are shown in* a *and* b. *These flows are all steady, but it is possible to generalize these techniques if the number of space dimensions is reduced by one, and then to treat nonsteady flows. Busemann notes that his first nonsteady solutions, which are important in aerodynamics, were just adaptations of the conical supersonic solutions.*

Laser fusion research today uses this idea to generate the pressures and temperatures necessary for ignition in a spherical target. The figure on page 29 shows a spherical compression scheme used at Lawrence Livermore National Laboratory for laser-compressed fusion fuel, using the geometry of Guderley.

The conical geometry proposed by Busemann has been extensively investigated in the Soviet Union, and has resulted in the first fusion reactions produced by an electron beam (by Leonid Rudakov in 1976) and by chemical explosives (by a Polish group under the direction of General Kaliski). The theoretical work on the Soviet conical pellet design appeared in a paper by V. A. Belokogne in 1965 (see c). The Polish configuration is shown in d.



The similar solution was, I had no more than two dimensions.

Question: But did this come out of research for explosive design, or for jet engines? I am thinking of the paper by Guderley, for example, that appeared at the same time as your paper in the Luftfahrtforschung on cylindrical focus?

Zylindrische Verdichtungschicht. Yes, sometimes we had real vortices; sometimes we had questions in our wind tunnel—there was not an understandable way of how the flow went around certain bodies we put in there. Sometimes we had people during the war who wanted to build a new kind of airplane for the Germans, and then we had real problems. They were, of course, secret, and we couldn't talk about them. But they needed our wind tunnels, because they did not have wind tunnels for all speeds in their own factories. And then they came to us.

Guderley was very good at applied mathematics. I talked to him, and I could use him for a lot of problems. I was more in mechanical engineering work than elasticity. When I earned my doctor's degree and came to Prandtl, I learned to have ideas about the flows, so that I had it in my head and didn't need wind tunnels for everything. In that way, I learned to construct them; but, of course, you cannot construct wind tunnels in three or four dimensions on your drawing board. Therefore, it was a little bit oversimplified when we did it in two dimensions. But we had ideas about what would happen at the end of the airplane, when the air can go around it instead of the other way. Then there were the vortices that Prandtl needed in order to explain the drag related to the lift.

Question: There's a lot of work that was done on the focusing of shock waves—cylindrical spherical focusing. What was that directed toward? In fusion research, this is really the key problem. Can you concentrate the compression from a shock wave? Can you use reflections to amplify it? Can you bring it down to a point? And that work was already going on in the 1940s in Germany. To me, that's fascinating, because the basic problem today was researched 25 or 30 years ago in tremendous detail.

At that time our idea was more to get rid of strong shocks, not to make them stronger. It was only my cone that couldn't help but to get stronger and stronger all the time.

Question: But nobody looked at that for compression research?

We sometimes were interested in finding out how difficult it is to live with these detached strong shocks, to see whether to make a wedge or something. We wanted to know whether that really helps to reduce the drag, or whether these things have a boundary layer separation as a part of what happens there, too, so that the drag looks much higher than it really should be by itself. We did a lot of things in our workplaces with just mathematics and thinking, but when there was a problem that really had to be solved, we could get enough money to put it in the wind tunnel. That was usually a little bit more expensive. On the other hand, when anybody didn't have a problem to work on, he would be drafted.

Question: Did anybody think at that time of something like a fusion reaction—of using the very high densities of high temperatures that these focused shock waves could generate?

Not for fusion, but we thought about making the explosions a little more concentrated, so that when somebody had a big shield, any bullet would make a big hole in it.

But, of course, every day it was different, and there could be a change. If anybody who worked on these problems was not important anymore, he would have to go to the war. And then we would have to change our subject to something that Hitler thought was important. But he really had few ideas that we thought were important overall. Only when the Americans came over there flying higher up and we had no guns that could shoot that high, only rockets that could fly that high, did Hitler call for a meeting. His people came to ask us to improve the bullets and the cannons, to kill the enemies that were flying so high. And then afterwards they said to Hitler, "Yes, we can make it." "And how long will it take?" Hitler would ask. "Three years," they said. "Oh! Three months, that's all I can give you," Hitler would say. So they had to pretend that they could find something in three months. He was a crazy guy. Therefore, it was very hard to have a certain group of people working for you.

Question: So that work was mostly for the design of supersonic airplanes?

There were people in Munich or Nuremberg who worked on supersonic airplanes. Oh, there was also this thing called a buzz bomb that flew with a high velocity. And the one that flew with really supersonic speed was, of course, von Braun's. In order to try out Hitler's bombs, they had to have an airplane to put them underneath.

Question: The same idea today is the Cruise missile. . . .

We were really interested in having a good picture of what goes on in supersonic flight, or what happens when you get closer to the velocity of sound—what makes you unstable, or gets the lift down or the drag so high that nothing can help you.

But in order to keep my people paid, I had to adjust them to what Hitler thought was important. Therefore, when those people couldn't make any kind of gun with the necessary range, Hitler asked whether von Braun could make a rocket that would go high enough to kill the airplanes that were coming and throwing bombs.

We even had this silly thing—the buzz bomb—that had a gasoline engine that went putt, putt. It made a lot of noise, because it opened and closed in alternation. Its path was controlled by its tail, and when the tail got stuck on one side, it made a circle. And the circle was exactly the total length at which distance it was supposed to explode the bomb. So it fell on the people who sent it up! The silly tail was supposed to steer the thing to the right point, but it very often got stuck on the left-hand

side. It made an exact circle and boom! That was the buzz bomb. And from Belgium, where they tried to launch the bombs against London, they made the circle so large that it was just the distance from where they were to London.

There were lots of things we had to do during the war. And they threw out even von Braun because von Braun said: "When you send a bomb against a foreign country, an enemy country, you have to put it on the target—you cannot just throw it, because London is too big—a 10-mile radius circle is too big. It is illegal to kill people too; you should kill things that are made for the war." Therefore, von Braun tried to make a guidance on the bomb, and after one year when the guidance didn't work, Hitler said, "He's delaying the thing," and sent him away.

Hitler put in another man, the man who made the trains for Russia. (The Russians had a different kind of track, and therefore this man had to make trains that worked only on the Russian track, or that could change from one track to the other.) This man got the job to make the bombs ready in three months; they said von Braun was not interested in wars, because he was so slow.

Under Hitler, you really could get into trouble without doing anything bad. People would finger you because of something you did for a different reason. At that time, our publications were often secret. Therefore, I cannot always find the work I did at that time—unless my papers were in a big box that the Americans found so that they were not burned.

Question: I think that much of that research is still secret in the United States.

Some was translated after the war.

Question: But it's still secret here. You say that most of your work was done not for research on shaped charges, however, but mostly for aerodynamic research?

Yes, the part I did on it. But when I was supposed to give an introductory talk on these shaped charges, I just demonstrated the things you can do with the waves that go in focus.

Question: Did you come to the United States in 1945?

No. I was on the English list. The English soldiers saw that America was getting all the German scientists, and they knew that the British needed some too. So they put me as one of the first scientists on the British list. But the people in Britain said, the thing that we need is not chiefs—what we need is Indians to help. During the war they had a lot of women and others who wanted to help, but they went home after the war and didn't work in the laboratories anymore.

After six months, there I was in several different places just talking about results that we got during the war. They brought me to a lot of universities, but nobody wanted me. So I finally asked my American friends whether there was still a chance to come to America. And then, because I did that by going to the American embassy, I was—what do they call it in England when they don't trust you any more?—a persona non grata. I was sent back home to Germany the same day, when they found out through the Secret Service that I had contacted the Americans.

While in England, I had wanted to raise a little bit of money. I had three girls almost at the end of school—college age—and, of course, we had lost all of our savings in the inflation right after the war. I just wanted to tell them, look, in America I could get a job for more money. They actually told me they tried very hard to "sell" me, but nobody wanted me; no university, no other place of research. So the British allowed me to go away, but they called me, of course, a persona non grata.

I was in England from June 1946 until February 1947. Then they sent me home, and in May 1947, the U.S. Occupation forces picked me up to be transported to America. I came to NASA, since both the Navy and the Air Force were fighting over who would get me—neither got me.

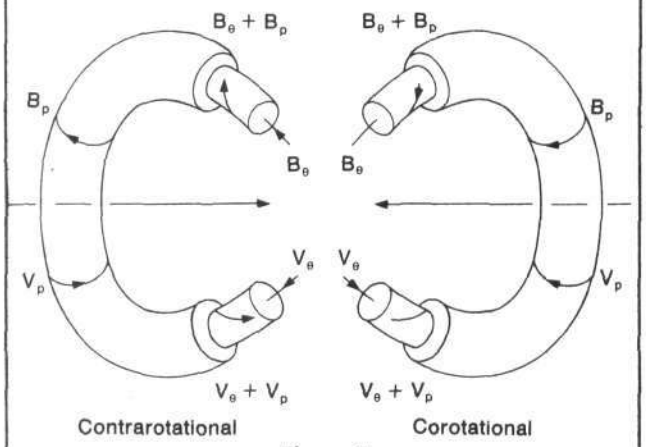


Figure 3
MAGNETOHYDRODYNAMIC VORTICES

Busemann's training in fluid dynamics and drag calculations made it natural for him to develop the idea of magnetohydrodynamic vortices. These structures are, as in a fluid, highly stable, dynamically low energy persistent features of high-energy plasmas. They are as characteristic of energetic plasmas as their analogues are of strongly turbulent fluids. This natural stability is the basis for a number of new machine designs: The basic MHD vortex (above) taken from Dan Wells, who has done scientific studies of these vortices over the past 15 years, is contained within a toroidal geometry, like a spheromak. Other variations on this idea are under active investigation at a number of fusion laboratories.

Each of these devices takes advantage of the self-generated closed magnetic field structure in the vortex, and its "force-free" current distribution, to attain what is expected to be long confinement times and enhanced energy stability. Busemann's work on MHD vortices was first published in 1961 at the Air Force Office of Scientific Research lecture in honor of the 80th birthday of Theodor von Karman.

Question: In some of the research I've done in plasma physics, your work in magnetohydrodynamics in the 1950s on vortex formation is very important. How did that work start—the work you did on plasma or magnetohydrodynamic vortex motion? That work seems very different from aerodynamics.

Yes, but it was a new subject, and in research you have to keep up to date when you are a senior research man. Therefore, I had seminars with people who worked on this problem. You see, at first I was an electrical engineer, because when Germany lost the First World War, I took every subject that I thought was important for Germany. Therefore, I studied electrical engineering too, including electrical physics. My physics teacher in the Technische Hochschule (high school) was very nice to me and taught me everything about relativity, which was new at that time. I studied it in 1923-24. I had learned fluid dynamics more from electricity, and, therefore, when they started this magnetohydrodynamics, I would go back and do it the proper way. I mean that electricity is not a real flow, but for magnetism, you need electricity. And that was my old subject, which I used to compare hydrodynamics with electricity. Therefore, it was easy for me to be the boss of the magnetohydrodynamics seminar in Langley Field.

You see, when you begin a new subject, the young people have no prior experience; they've learned it only from books, but I could compare it with the things I had learned before and played with already, so I could be an important man in this seminar.

Question: What relation do you see between the research on vortex motion and shock waves?

The electricity had no shocks. I don't know; we never made a real application. There were other NASA centers that were working on magnetohydrodynamics. I worked on magneto only for a short time, and then I came to Boulder in order to make this a center of excellence in aerospace. Well, the space things were so important that we worked on vortices only on the side. We had to make real space progress.

Question: Did you work with von Braun on space rockets and that kind of thing?

No. He was in another area. I was in Langley Field, where we did see supersonic parts and things like that where they built the equipment for Langley. Magneto was just a side subject that we worked on. You see, when you work on the same chapter day and night, you get yourself into a corner. Sometimes you are better off if you leave it and come back after a week and you say, why didn't I see this before? Of course, when it's a very important subject, and has to be done by October, say, you can't go into something else at night. At Langley we sometimes had to work on a certain problem that they gave us, and sometimes in between we had a little bit of time off, so that we were not stuck on the same old thing. Very often NASA asked us to tell them about supersonics or about how to get out to space. The different space research centers didn't get money for everything. They had a special subject matter in which they had to prove they could work well. We worked in this aerodynamics business, what goes into space and gets out of orbit into the atmosphere. As for rockets, of course, it was von Braun's problem in Houston. Some guidance people were somewhere else—at the Ames Research Center, I think.

But when von Braun had a question about supersonic drag or lift or whatever, or whether the proper flows would come automatically or had to be readjusted, of course he would direct the question to the Langley Center.

Question: How long were you at NASA?

I was with NASA from 1947 to 1964, and then I came here, to the aerospace section of the University of Colorado. My problem was that because I had secret information, I was not allowed at Langley to tell the Germans to give me my earned retirement pension. They told me that I couldn't be dependent on a foreign government. I was to be retired from Langley Field not later than age 70, but before I reached their retirement age, I accepted the invitation of the University of Colorado to come and hold a "lifetime" job.

Adolf Busemann: A Tribute

Busemann was a giant in the field of aerodynamics. He was able to use applied mathematics and simple geometrical constructions to solve the most complicated of nonlinear aerodynamic and fluid dynamic problems. For example, he created the now-famous Busemann "apple curve"—mathematical-geometrical constructions that very cleverly allow you to follow isentropic flows through parameter space. At Langley Field, where he was chief scientist, Busemann taught dozens of classes in many areas—kinetic theory, electrodynamics, the physics of aerodynamics and applied mechanics. He was able to take very complicated physics problems and draw analogies to simpler mathematical systems, which could then be solved. If you were to ask Busemann, he would tell you that Theodor von Karman was one of the greatest aerodynamicists of this century. Yet von Karman was a generalist; he worked in a number of areas of applied mechanics. Busemann worked in fewer areas, but his physical insights far outshone those of others in the field.

—Dr. William Grossman, research professor of plasma science, New York University, Courant Institute of Mathematical Science.

On Nov. 5, 1981, the Fusion Energy Foundation will honor Adolf Busemann and his work in a special dinner and award ceremony in New York City. We would appreciate letters and greetings for presentation at the event from readers who worked with Busemann.

Exploding the H-Bomb

by Charles B. Stevens

*The Secret That Exploded,** the recently published autobiographical account by Howard Morland of the 1979 *Progressive* magazine court case, detonates a number of bombshells about the celebrated case in which the government attempted to block publication of Morland's article "The H-Bomb Secret." But the book leaves unexploded a number of even bigger bombshells about the classification of vital scientific information—in particular, that pertaining to the development of fusion energy.

As Morland's book recounts, in spring through fall 1979, the U.S. Justice Department waged a six-month civil law suit to bar *The Progressive*, a Wisconsin-based antinuclear magazine, from publishing Morland's article, arguing that the article contained sensitive information on the workings of the hydrogen bomb.

The Fusion Energy Foundation entered an *amicus curiae* brief, showing that the so-called secrets that the government wanted to keep classified had been out in the open scientific literature for more than a century and that what was really at issue was a deliberate policy of classifying research vital for broad-based scientific progress. The FEF had already published a series of articles that made public for the first time the scientific origins of the H-bomb in the 1859 paper on shock waves by the German mathematical physicist Bernard Riemann and the development of those ideas by leading German hydrodynamicists and aerodynamicists of the Göttingen school during the 20th century.

After the U.S. government abruptly dropped its case against the *The Progressive* in Sept. 1979, the magazine's managing editor, Samuel Day, Jr., reported that both the FEF's friend-of-the-court brief and the government's unwillingness to take on the FEF's arguments directly had been pivotal in the government's decision.

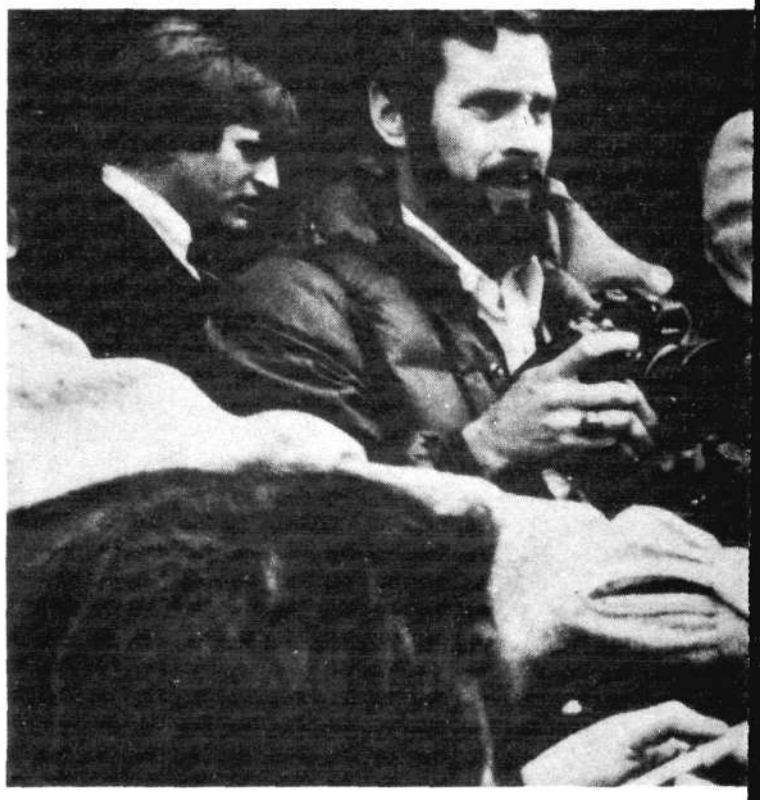
Now, Morland's book fills in many details of this story. First, *The Secret That Exploded* confirms that it was the wide circulation of articles on the H-bomb in *Fusion* magazine and in *New Solidarity*, an independent semiweekly newspaper that had published the story by FEF authors, that led the government to abruptly pull out of the case.

Second, Morland certifies that *Fusion* and *New Solidarity* were the first to publish the essential details of the H-bomb design developed by Edward Teller, Stan Ulam, and their collaborators in the late 1940s and early 1950s.

Third, evidence contained in Morland's book demonstrates conclusively that the entire *Progressive* case episode was in fact targeted against *Fusion* and *New Solidarity's* revelations about (1) the connection between Riemann's theoretical work and the development of the hydrogen bomb, and (2) the contemporary work of Soviet scientist Dr. Leonid Rudakov on inertial confinement fusion, drawing on the same German hydrodynamicist tradition.

The most explosive point raised by the *Progressive* case, though this is not recognized by Morland, was, in fact, that the FEF analysts had been able to arrive at their understanding of the secret H-bomb design through their appreciation of Riemann's method, specifically, his work on shock waves.

Morland's book, furthermore, contains sufficient evidence, when combined with other crucial evidence that will be presented here, to demonstrate that the *"Progressive assignment"* was run under the direct management of leaders of what might be called the antiscience "Wellsian" tradition—technocrats like Fabian Society member H.G. Wells himself, who are dedicated to containing the spread of advanced technology, and cite the threat of nuclear proliferation and other bogus considerations to justify their suppression of technological advances. The



* Howard Moreland, *The Secret That Exploded* (New York: Random House, May 1981).

Secret

A firsthand account of the 1979 Progressive *magazine court case provides some clues as to why the U.S. government went to such lengths to block publication of a technically incorrect article on the H-bomb.*

Progressive operation was conceived and run by McGeorge Bundy, former head of the Ford Foundation, and Morton Halperin, of the Washington-based Center for National Security Studies. Both individuals are former National Security Council members and play a controlling, behind-the-scenes role in guiding the street-level activities of the environmentalist groups.

The Real H-Bomb Secret

The diagram of the H-bomb on page 45 is taken from Morland's book. As author Morland notes, the diagram was first published in the Oct. 15, 1976 issue of *New Solidarity* in an article by Uwe Parpart, the FEF's research director. Morland reports that he did not realize when he saw it that this diagram "was the most explicit of all, and apparently the most complete and correct"—until government scientists unintentionally certified that this was the case during the *Progressive* case litigation in 1979.

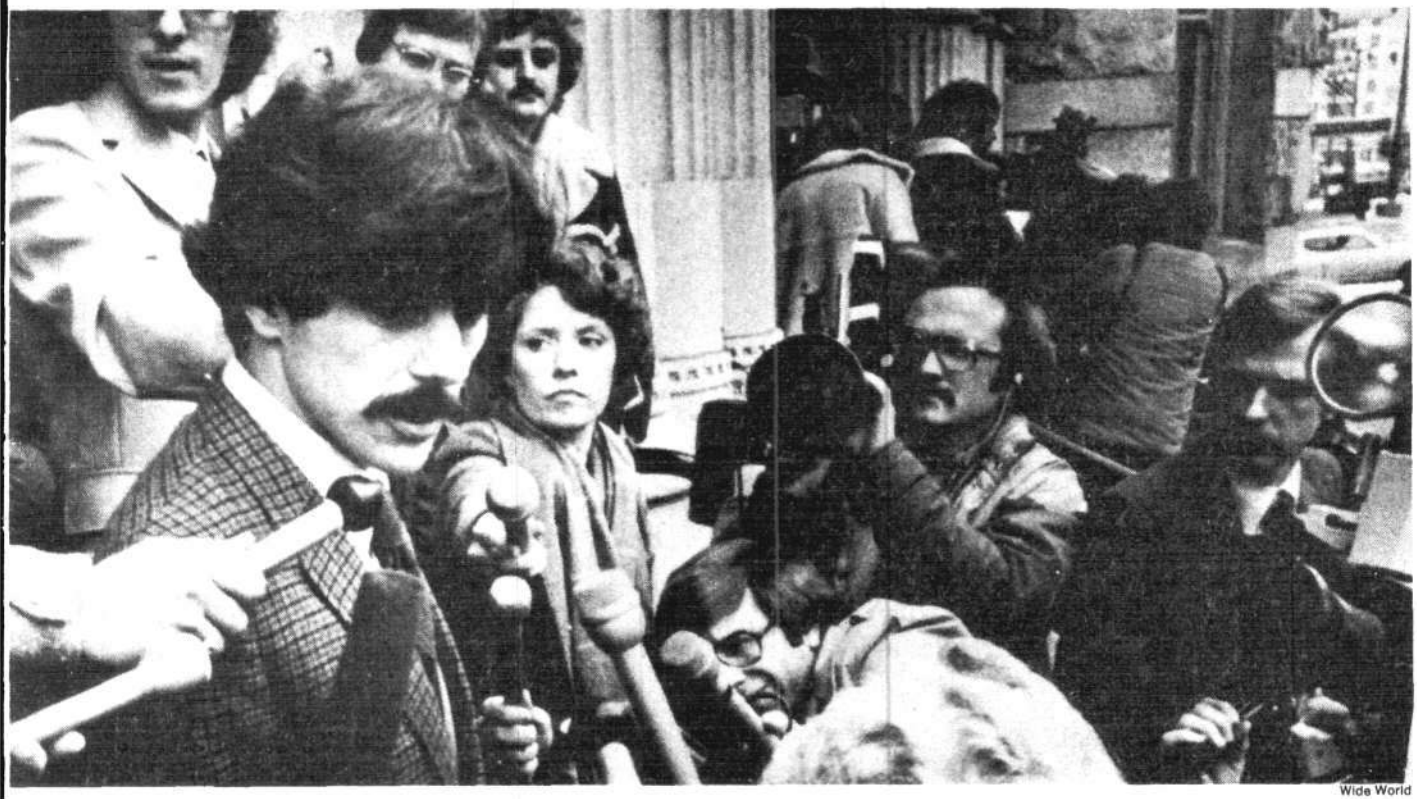
Ironically, as Morland states in his book, his own article "The H-Bomb Secret; How we got it—why we're telling it," was incorrect on two key points concerning the design of hydrogen bombs. These two points had been the major concern of the *Fusion* and *New Solidarity* articles.

The first point was that soft X-ray radiation generated by an atomic fission bomb explosion plays a key role in igniting the fusion fuel in a hydrogen bomb.

The second point was how that particular form of energy is utilized to generate shock compression of fusion fuel to high densities.

The FEF analysts' insights on these two points were related to their 1975 prediction that Rudakov, the leader of the Soviet electron-beam fusion research effort, and his team of scientists at the I.V. Kurchatov Laboratory in Moscow could be expected to make key experimental breakthroughs in the near future. This prescient remark was based on a general analysis of Rudakov's theoretical

What the government wanted to keep secret in the Progressive *case has been in the open literature since the 1850s—the scientific method of Bernhard Riemann. Here, author Howard Morland is the center of attraction in Milwaukee March 27, 1979, after a U.S. district judge issued a preliminary injunction to keep* The Progressive *magazine from publishing his article.*



Wide World

work on the nonlinear mathematics and physics of plasma beam injections—work that the FEF analysts had determined to be qualitatively similar to Riemann's work.

Furthermore, the FEF analysts had come to the general conclusion that the type of fusion research involved in both the development of the H-bomb and laser fusion—that is, inertial confinement fusion—represented the most fruitful area of investigation for extending the frontiers of basic scientific research. The work and concepts of Riemann, moreover, would be essential for any theoretical comprehension of the processes and problems arising in inertial fusion research.

When the FEF communicated this analysis to the leading American inertial fusion scientists, they responded quite skeptically. However, Rudakov's subsequent announcement that he had indeed achieved a significant experimental breakthrough triggered a storm of discussion and controversy in these scientific circles.

The storm was heightened when Rudakov, during a July 1976 visit to the United States, gave a series of public lectures at the U.S. fusion labs describing how he had utilized soft X-rays generated by the interaction of his electron beam with a thin gold foil to achieve minute amounts of fusion reactions.

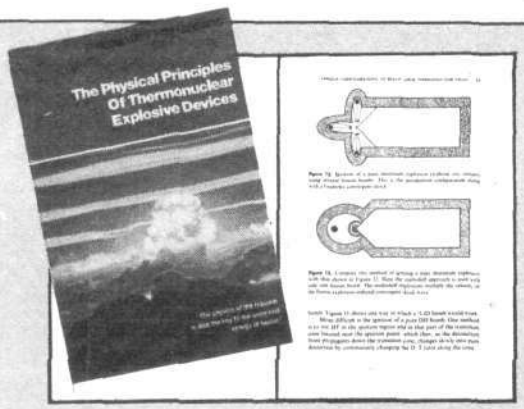
When the FEF's Oct. 1976 *Newsletter* (the predecessor to *Fusion* magazine) and *New Solidarity* reported on the contents of Rudakov's presentations and its implications for the development of inertial fusion as an energy source as well as for military applications, the Rudakov revelations became the subject of major news stories across the United States.

During 1977 and 1978, the FEF obtained official U.S. government documents, under a Freedom of Information Act request, that demonstrated that there had been a concerted effort to suppress all evidence of Rudakov's presentations. In particular, the documents showed that the attempted suppression was originally demanded by and to some extent directed by the Atomic Weapons Research Establishment of the British government.

But it was not actually until Dec. 1978 that the FEF analysts discovered the direct link between Riemann's work and the development of the crucial concepts upon which both the H-bomb and inertial fusion are based. This was an 1859 paper in which Riemann developed for the first time the concept of shock wave and then applied it to determine how to achieve the isentropic compression of matter—the densification of matter without an increase in its entropy.[1] In order to achieve the supercompression of matter to high densities—the most critical condition to produce successful H-bombs and inertial fusion systems—it is essential that the entropy of the matter not increase during the compression.

The relevance of Riemann's work to fusion, it should be noted, was pointed out 30 years before in the 1949 remark of John von Neumann, one of the leading mathematicians who worked with Edward Teller on the development of

Demystifying the Science of the H-Bomb

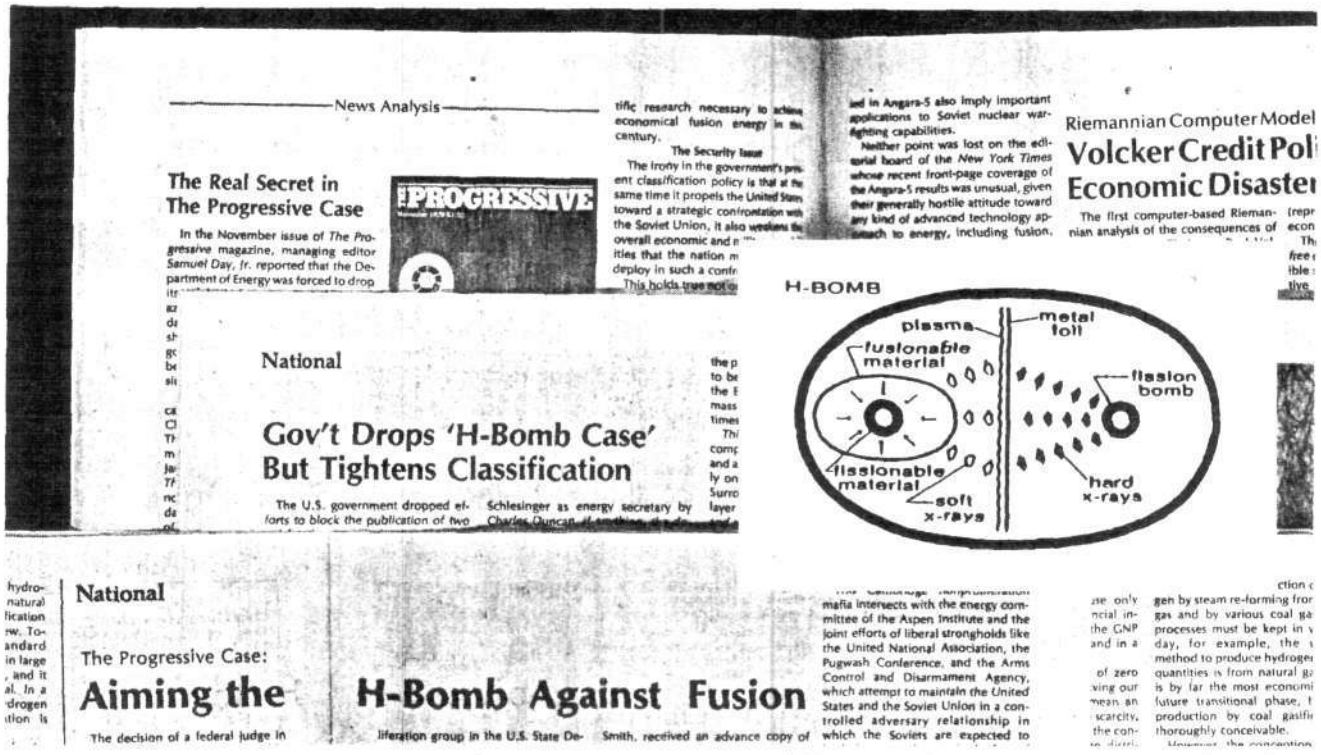


The physics involved in the various configurations of hydrogen fusion weapons is described in detail for the first time in public literature in a new book titled *The Physical Principles of Thermonuclear Explosive Devices* by the distinguished fusion scientist Dr. Friedwardt Winterberg. This book, published by the Fusion Energy Foundation in August, describes the basic physical principles upon which the most concentrated energy source—inertial confinement fusion—as well as the most destructive weapon are based. As Winterberg explains in the introduction, his purpose in writing the book was to demonstrate that

> *there are no secrets surrounding thermonuclear explosive devices* and that *all the basic physics is accessible in the open, published scientific literature. . . .*
>
> My purpose is not to be sensational but, rather, to demystify the secret of the H-bomb. For it is not the secret of the H-bomb that protects us from thermonuclear annihilation but, rather, the correct political decisions by our leaders. To cover up their own political inability it is, of course, understandable that governments try to make their people believe it is secrets that protect them. I hope that the publication of this book will not only contribute in demystifying the whole business of secrets, but also make the public aware that a belief in secrets is dangerous, wishful thinking.

The FEF is publishing Winterberg's remarkable book on the physics of thermonuclear explosions to make accessible to working scientists outside the classified government programs, as well as to the layman, the scientific principles that are the basis of the most promising energy source of the future—controlled fusion, in particular inertial confinement fusion.

The Physical Principles of Thermonuclear Explosive Devices can be ordered from the FEF for $11.50 postpaid.



News Analysis

The Real Secret in The Progressive Case

In the November issue of *The Progressive* magazine, managing editor *Samuel Day, Jr.* reported that the Department of Energy was forced to drop

National

Gov't Drops 'H-Bomb Case' But Tightens Classification

The U.S. government dropped efforts to block the publication of two

Schlesinger as energy secretary by Charles Duncan

tific research necessary to achieve economical fusion energy in the century.

The Security Issue

The irony in the government's present classification policy is that at the same time it propels the United States toward a strategic confrontation with the Soviet Union, it also weakens the overall economic and

deploy in such a confr

This holds true not o

ed in Angara-5 also imply important applications to Soviet nuclear warfighting capabilities.

Neither point was lost on the editorial board of the *New York Times* whose recent front-page coverage of the Angara-5 results was unusual, given their generally hostile attitude toward any kind of advanced technology approach to energy, including fusion.

Riemannian Computer Model

Volcker Credit Poli

Economic Disaste

The first computer-based Riemannian analysis of the consequences of

H-BOMB

National

The Progressive Case:

Aiming the H-Bomb Against Fusion

The decision of a federal judge in

liferation group in the U.S. State De-

Smith, received an advance copy of

mafia intersects with the energy committee of the Aspen Institute and the joint efforts of liberal strongholds like the United National Association, the Pugwash Conference, and the Arms Control and Disarmament Agency, which attempt to maintain the United States and the Soviet Union in a controlled adversary relationship in which the Soviets are expected to

gen by steam re-forming fro gas and by various coal ga processes must be kept in day, for example, the method to produce hydroge quantities is from natural ga is by far the most economi future transitional phase, production by coal gasifi thoroughly conceivable.

Fusion has argued that the real issue in the Progressive *case was a deliberate policy of classifying research vital for scientific progress. The correct diagram of the H-bomb (above), which was reprinted by Morland from the Oct. 15, 1976 issue of* New Solidarity, *was drawn on the basis of an appreciation of Riemann's work, not any classified secrets.*

U.S. hydrogen bomb. During a symposium on "Problems of Cosmical Aerodynamics" in August of that year—three years before the United States exploded its first H-bomb—von Neumann commented: "To this day, the only thing of any degree of generality we possess is the classical discussion by Riemann, and this very strictly in the isentropic case."

There are two levels of secrecy involved in the above. The first level is that of the technical aspects of the H-bomb—how it works: the use of soft X-rays to generate an isentropic shock wave compression of the fusion fuel to arrive at the required super densities.

The second level, and by far the more significant, is the fact that Riemann's most advanced theoretical work was essential to achieving this application.

The reason that this second level is of such great import—and in fact the real H-bomb secret—is that the general approach and method embodied in Riemann's 1859 shock wave paper is in direct opposition to the prevailing scientific methodology of British empiricism. The empirical vindication of Riemann's approach represented by the successful design of the H-bomb, therefore, threatens to shatter the credibility of the ideological edifice that dominates modern physics and mathematics.

The Progressive Case

The *Progressive* court case was intended to set a precedent for keeping classified research vital for scientific progress; it was very specifically directed against Riemann's method and against the implementation of his ideas to realize significant breakthroughs in inertial confinement fusion research. This is the real story that comes through Morland's firsthand account of the case and of certain facts that appear to be of only secondary significance in Morland's account.

As Morland quite honestly relates, he was an easily manipulated personality. In the mid-1960s, he was an Air Force pilot who was given "an honorable discharge for psychiatric reasons." He then joined various encounter groups, affinity groups, and sensitivity groups, as he says, in order "to ward off anxiety about my future." This was followed by a trip around the world with "a stint in a kibbutz" in Israel.

Morland ended up in Hawaii, where he happened to run into Professor Denis Meadows who, together with his wife Donella, had authored the *Limits to Growth* study for the Club of Rome, the bible of the zero-growth movement.

In fall 1974, at Meadows's suggestion, Morland went on to Dartmouth College in New Hampshire to do graduate work. After this, Morland became deeply involved with every major branch of the antinuclear environmentalist movement—the Clamshell Alliance (which carried out several raids on the Seabrook, N.H. nuclear plant), the Audubon Society, the American Friends Service Committee, and with *Flying, Mother Jones,* and *Playboy* magazines.

Chapter three of *The Secret That Exploded* is appropriately titled "The Assignment." As Morland describes, Dave Johnson of the Washington, D.C.-based Center for De-

fense Information, a private think tank that is one of the kingpins in the international disarmament movement, gave Morland his assignment; it was Johnson who put Morland in touch with Sam Day, the managing editor of *The Progressive,* and arranged for Morland to write the H-bomb secrets article. (As for Johnson's think tank, *Der Stern* magazine reported in early 1981 that the Center for Defense Information had provided the West German "greenies" with the maps of German nuclear weapons installations that the environmentalist groups have used to plan occupations of those sites.)

Sam Day was very quickly able to fulfill Morland's open ambition to become an "amateur atom spy." Despite the radical antinuclear associations of Day, Morland, and *The Progressive,* Day was able to arrange a complete nationwide VIP tour of the U.S. nuclear weapons productions facilities for Morland.

After his tour, Morland wrote his H-bomb secrets article. As Morland reports and documents, the article was technically wrong. Despite this, however, the government, after getting hold of a prepublication draft from Day, went to court to suppress the article's publication. This action was directed by then secretary of energy James R. Schlesinger.

The course of the case, as Morland relates it, is a bit confusing—and this is clearly because Morland didn't fully know what he was in the middle of. The chief point that Morland makes is that the government based its case for suppression on the fact that his article was technically flawed:

> The government's affidavits . . . contended that I could not possibly have derived the conclusions in my article from the sources I had enumerated, and that I therefore must have had access to secret documents. . . . In their secret affidavit . . . the interesting assertion [was made] that there were errors in my description that did not follow logically from anything I cited, and which I must therefore have purposely introduced to conceal my sources.

As Morland's book tells in detail, in the course of the court proceedings, the government itself corrected *The Progressive* article's flaws! Even stranger, the correct design for the H-bomb was submitted to the open court record during the proceedings, but it was never commented upon by the government. The correct design is that which had appeared in *Fusion, New Solidarity,* and in the FEF's *amicus curiae* brief.

Morland states in his book that he was mailed the correct diagram in an envelope with the return address of the Naval Research Laboratory on it. An accompanying unsigned letter pointed out that the enclosed diagram from the *New Solidarity* article "would have been stamped SECRET (CNWDI)" had it been submitted to the Department of Energy for classification.

At this point it should be noted that Dave Johnson, who originally set up Morland to write the article, is the former brother-in-law of this writer. I know that he was informed about the 1976 *New Solidarity* article, and that he was also very well informed about the article's pertinence to the design of H-bombs.

In a telephone interview with me this spring, Howard Morland was quite surprised to learn this, since, according to him, "Dave never told me about that." Johnson, who set Morland up to do a story exposing the H-bomb secret, had never mentioned any of this information to Morland!

The pieces of the *Progressive* case fall into place once Johnson and Day's connections are established. Johnson works closely with Morton Halperin, and Day is closely associated with McGeorge Bundy. As noted above, Halperin and Bundy are both figures who are at the helm of command of the zero-growth, antinuclear, and nonproliferation groups.

As Morland relates in his book, Halperin directly involved himself in the court case. And the book also provides circumstantial evidence of McGeorge Bundy's input into Day's activities.

Backtracking

As *Fusion* had maintained from the beginning of the *Progressive* case, the case was at least indirectly targeted against the Fusion Energy Foundation and its efforts to end the classification of scientific research that is critical to the inertial confinement fusion program. Now, through the publication of Morland's book, it appears that this operation was successfully stymied by the timely action of the FEF in publicly responding to the attempted setup. Even *Progressive* managing editor Day had to note the key role of the FEF's *amicus curiae* brief in determining the outcome of the legal proceedings. And author Morland has now begun to suspect that he was used from the start as an unwitting patsy to get the case into court. Apparently, the optimal scenario was to have the article published and then have the government win the case and proceed with the prosecution of the FEF.

This plan was upset when in the March-April 1979 issue of *Fusion,* Uwe Parpart detailed the connection between Riemann—and his published writings—and the development of inertial confinement fusion. The plan was further upset when Dr. Friedwardt Winterberg, professor of physics at the Desert Research Institute at the University of Nevada and a pioneer in inertial confinement fusion outside the government-controlled programs, collaborated with the FEF in getting out the story of the scientific roots of the H-bomb.[2]

Therefore, the *Progressive* operation was turned into a smokescreen: The H-bomb secrets story with its antinuclear angle was used to cover up the real secret of the importance of Riemann's method for scientific progress today.

Notes

1. "On the Propagation of Plane Air Waves of Finite Amplitude." The article was translated into English for the first time by Uwe Parpart and Dr. Steven Bardwell of the FEF, and appeared in the *International Journal of Fusion Energy,* 2:1 (1980).
2. See for example Winterberg's "Some Reminiscences About the Origins of Inertial Confinement," *Fusion,* Nov. 1979, p. 41.

Launch of Ariane Rocket Puts Europe in Space Business

With the second successful test launch of the European-built Ariane rocket on June 19, it is now clear that Europe is in the space business to stay.

The Ariane rocket, a cooperative effort of the 11-member European Space Agency (ESA), is an expendable rocket that will for the first time give Europe the independent capability to launch satellites into space.

In a recent interview, Wilfred Mellors, director of ESA's Washington, D.C., office, told *Fusion* that there were three main ways in which the launch was significant.

"The overriding importance of the successful launch," he stated, "is that it proves that the modifications that were made after the second test launch failed last year were correct. The burn of the rocket was extremely smooth.

"Second, this is the first time that Europe has effected the launch of two satellites with one vehicle." This is important for reasons of economics.

"Third," Mellors commented, "we now have a geostationary meteorological satellite over Europe that will be working within a month. Meteorologists have been waiting anxiously for this satellite to go up, and we hope to get data starting in mid-August."

Mellors explained that the United States had launched a weather satellite for the Europeans in 1977, but the imager failed after two years, hampering continuous weather forecasting for the continent. Until now only the United States and Soviet Union have had reliable launch capabilities.

The Ariane

The Ariane, which is being built for ESA by Aerospatiale of France, is a liquid-fuel three-stage rocket, similar to the U.S. Delta and Centaur expendable rockets. ESA expects the Ariane to be competitive with the comparable U.S. rockets when it becomes operational in 1982. It may also be competitive with the reusable Space Shuttle for certain kinds of payloads.

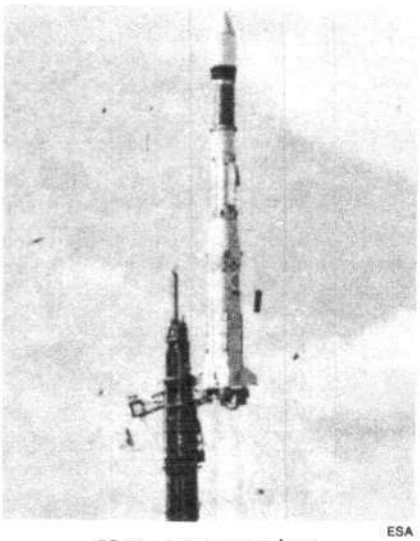
The Ariane's payload capacity is now 3,749 pounds but second and third-generation Ariane rockets are planned that will bring the capacity up to 5,324. Even with the current technology, Ariane can put two satellites into geosynchronous orbit above a spot on the Earth 16 minutes after liftoff.

ESA has scheduled the last test flight for Feb. 1982 and hopes to put the system into operation immediately after that.

International Competition

The 6th to 23rd flights of the Ariane scheduled through Dec. 1985 are already booked solid. These launches will include ESA's Halley's Comet mission scheduled for 1985 and other scientific missions. But the greatest interest is coming from developing sector nations, which have previously been dependent upon the U.S. space agency for satellite launches.

A consortium of Arab nations has contracted to launch two communications satellites—Arabsat 1 and 2—in 1983 and 1984. The second satellite launched by the Ariane in June was an Indian-built Apple communications satellite.



ESA

ESA's Ariane rocket.

Aerospatiale has set up a new company called Arianspace to market space on the Ariane, and on June 11 the French company signed a memorandum of understanding with Boeing Aerospace in the United States for joint marketing. Boeing is building a platform for the Ariane that will allow the multiple stacking and servicing of satellites.

—Marsha Freeman

Mexico: Economic Warfare Threatens Oil-for Technology

Severe economic warfare has thrown some obstacles in the way of Mexico's economic growth, making it more difficult in the near term for Mexico to achieve an "oil-for-technology" trade framework with the United States.

In late May, a group of oil multinationals led by Exxon began to pressure Mexico to slash its oil prices, justifying their demands by citing the temporary world oil glut.

At first, Jorge Diaz Serrano, director of Petroleos Mexicanos, the national oil industry, acceded to the pressure, dropping Mexico's prices a full $4 per barrel. But the Mexican economic cabinet, headed by President José López Portillo, charged that the action was "precipitous," and in something of a political earthquake, Diaz Serrano was relieved of his duties June 7. On July 1, the new Pemex director, Moctezuma Cid, announced that negotiations were underway to raise the price back up $2 per barrel.

All-out oil warfare immediately began. Exxon canceled 175,000 barrels

per day (bpd) of imports, the second largest Pemex contract. (Spain is the largest with 200,000 bpd.) Several other U.S. multis joined the de facto boycott, plus several governments, including, most surprisingly, France. The French cancellation of its 100,000 bpd contract badly tarnished the image of "friend of the Third World" that Socialist President François Mitterrand had assiduously cultivated.

The fact that the boycott had nothing to do with so-called blind market forces became apparent with the simultaneous appearance of a rumor campaign designed to collapse the parity of the peso with the dollar. Foreign exchange traders in New York soon revealed the real game being played by saying, in a series of interviews in the weekly *Executive Intelligence Review*, that there was only one thing Mexico could do to keep its head above water: cut back on its industrial development plan.

Blackmail

This is the same type of blackmail that earned former energy secretary James Schlesinger such opprobrium in 1977, when he used the pretext of price to rip up already negotiated U.S.-Mexican gas contracts, derailing economic cooperation between the two nations for more than two years. Schlesinger's real policy, as stated in private, was to prevent the emergence of a new "Japan" south of the border.

The fact is, however, that every dollar Mexico does not get for its oil is a dollar Mexico does not spend purchasing capital goods and other imports abroad, 70 percent of which come from the United States. U.S.-Mexican trade soared to $32 billion in 1980, making Mexico the third largest trade partner of the United States.

More important, Mexico's oil-based industrialization program is the key to its continuing political stability—more than an indifferent topic for a northern neighbor that shares a 2,000-mile border.

Mexico Strikes Back

Mexico seized on France for its initial counterattack. On July 4, Mexico's Industry Ministry issued a terse 87-word announcement stating that because of the French cancellation, Mexico was prohibiting French bidding in major Mexican development projects, worth an estimated $1 billion.

The root issue, as López Portillo explained later at a press conference, was that Mexico's sales of oil to France were embedded in an oil-for-technology framework that had been negotiated state to state. One portion of the deal could not be canceled without the rest tumbling down as well. The original deal, negotiated by former French president Giscard d'Estaing and López Portillo in March 1979, was a model for North-South relations based on transfer of industrial technology.

The vehemence of the Mexican countermove caught French President Mitterrand and his ministers off guard. There was a flurry of diplomatic activity, and on July 18, the French and Mexican foreign ministers announced in Paris that the 100,000 bpd of oil imports would be resumed on mutually acceptable terms as of Aug. 1, 1981. Several U.S. multis took the hint and also made their peace with Mexico.

In late July, President López Portillo denounced what he termed "an international plot against the peso," reserving special words of condemnation for Mexicans who fell for "information terrorism" coming from outside the country and had begun to sell the peso for dollars.

But López's strongest condemnation was for the pincer movement against all Third World economies—the simultaneous decline in Third World commodity prices and the rise in their borrowing costs resulting from the high interest rate policy of the U.S. Federal Reserve.

The Damage

Price and export declines of the post-May period have cut into Mexico's oil revenues, and on July 10 López Portillo announced a 4 percent cut in the government budget, the first since Mexico's oil takeoff four years ago and probably only the first taste of further austerity measures that will be required.

Nevertheless, Mexico's development is not fundamentally breaking stride. Growth is still expected to reach 7 percent this year, led by the energy sector, petrochemicals, and capital goods. This projection is down only slightly from the past three years' extraordinary 8 percent per year growth rate.

López Portillo has repeatedly distinguished between the Reagan administration and those financial interests running the economic warfare against his country. The goodwill seems based on the successful personal meeting of the Presidents at Camp David the second week of June, and, if reinforced through further personal diplomacy, could cushion some of the recent damage.

—Timothy Rush

Uwe Parpart

Reduced oil revenues may force cutbacks in Mexico's capital goods imports. Above, the Pemex petrochemical facility in Veracruz.

Bossu/Sygma

A tour group sponsored by the CGT trade union federation views a model of the Cattenom project.

Group Formed to Defend French Nuclear Program

A "Committee to Save Cattenom" has been formed to defend a vital nuclear complex in northeastern France against the attempts of the government of Socialist President François Mitterrand to halt its construction.

The Cattenom complex, which is projected to include four 1,300-megawatt reactors, is located in the Lorraine region, near the coal and steel regions of Luxembourg and the Saar district of West Germany. When completed, Cattenom will enable France to export nuclear power to this entire industrial belt.

Two of the four reactors, owned by the state utility company, Electricité de France, are nearing completion and employ 1,800 workers. A total workforce of 4,000 will be required to complete construction of the four-reactor installation.

Cross-Party Support

The committee was initiated by leaders of the French affiliate of the Fusion Energy Foundation, the European Labor Party, and the Metz branch of the "Young Giscardians," the youth group that backed former president Giscard d'Estaing in his bid for reelection last spring. It has since been joined by the Gaullist mayor of Cattenom and the head of the Republican Party in the Moselle department in Lorraine.

Broad support for the project already exists among area residents. For example, the Communist Party-linked trade union federation, the CGT, organized a 1,400-strong demonstration in the nearby town of Thionville in favor of completing all four reactors when the government threatened to cut back the project for environmentalist and budgetary reasons this summer. And the Lorraine Chamber of Commerce unanimously voted up a resolution urging the government in Paris to maintain the construction schedule because the complex is vital to the region's economy and employment.

According to one of the project's subcontractors, September is the turning point in deciding whether the final two reactors can be built, as it is the deadline for the civil engineering plan and assembly of 2,200 additional workers. If decisions are not made quickly, the workforce will scatter and cost overruns will become more likely.

Supporters of Cattenom fear that delay is precisely the tactic the government will use to kill the project—by holding a long debate, during which time the necessary deadlines are missed. They also note that President Mitterrand, who campaigned on a platform of full employment, cannot assail this nuclear project directly without discrediting his government in the politically important Lorraine region.

Iraqi Reactor Could Not Build Bombs

Iraq's French-built nuclear research reactor, Osirak, destroyed by Israeli jets June 7, was not part of any nuclear weapons-building program. This is the conclusion of a technical report prepared by Fusion Energy Foundation specialists in June, which explained how the technical specifications of the reactor itself, as well as the safeguards surrounding its use, make it highly unlikely that the facility was being used to produce a bomb.

The Iraqi facility is a 70-megawatt swimming pool-type reactor, a standard design for a research facility. The fuel for the reactor consists of about 25 pounds of highly enriched uranium-235, irradiated in France.

The FEF technical report explained that Iraq does not have the capability to handle the fuel for any purpose other than loading it into the reactor core; this would require the use of hot cell, a heavily shielded apparatus for remote-control handling of radioactive material, which Iraq presently does not possess. Iraq also lacks the chemical processing facilities to convert the U-235 reactor fuel into the pure uranium metal required for an atomic bomb. Nor does the country have the industrial capability to machine the uranium metal into the precision shapes that must combine into a perfectly shaped sphere just prior to detonation of an atomic bomb.

Even if the Iraqis overcame these

Continued on page 61

Columbia Readied for Its Second Flight

When the Space Shuttle Orbiter Columbia takes off on its second flight Sept. 30, it will be the first time in history that a spacecraft has flown on a second mission. In fact, the minimal damage to the orbiter on its maiden voyage April 12 enabled NASA to move up the time schedule on the second flight, STS-2, to a 24-week turnaround.

The second flight will last nearly 125 hours, or 83 orbits, compared with the 54-hour first flight. Whereas the initial Columbia flight was aimed at testing the orbiter's main system, proceeding "by the book," the second flight is designed to submit the vehicle to potential problems that could arise and to enhance the capability of the system.

For example, the commander of the STS-2, Air Force Col. Joe Engle, will test the automatic landing system, which Commander John Young did not use on the first flight. This computer-guided system will be used to land the Shuttle when the spacecraft begins operating on a routine basis.

NASA also plans to transfer 1,000 pounds of propellant used in the Orbital Maneuvering System (OMS) to an alternate control system, thereby simulating a situation in which one of the OMS units fails. This simulated failure will take place when the orbiter is preparing to reenter the Earth's atmosphere and needs the OMS to make orbital changes.

The Payload

The main change on the second flight will be the addition of a scientific payload in the cargo bay, bringing the total payload weight up to an estimated 17,676 pounds.

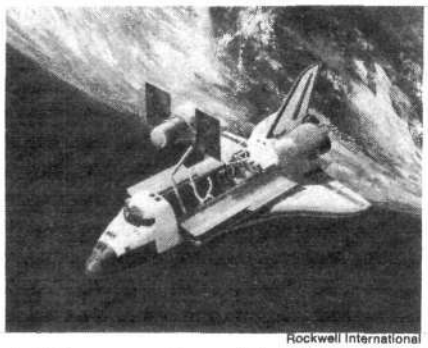
The bay will hold two important pieces of equipment: a Remote Manipulator Arm built in Canada and a pallet built by the European Space Agency (ESA) with five experiments mounted on it. These will be exposed to the space atmosphere when the payload bay's doors are opened.

The experiment package, known as OSTA-1 for the first payload of NASA's Office of Space and Terrestrial Applications, will consist of new types of Earth remote-sensing technology for improved observations by future satellite systems.

The largest piece of equipment on the OSTA-1 pallet is the **Shuttle Imaging Radar Experiment.** This 30-foot long antenna will send and receive radar signals that will be used to create images of the Earth's surface for use in geological exploration. When combined with Landsat imagery, scientists hope to be able to locate minerals with the radar data.

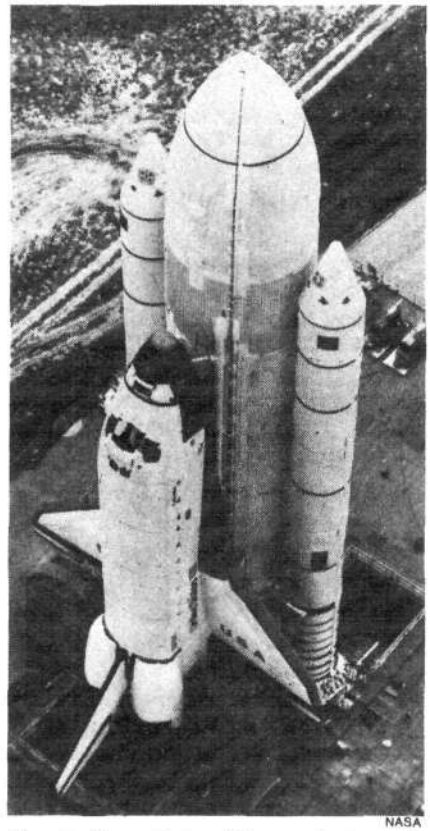
The **Shuttle Multispectral Infrared Radiometer** (SMIRR) will also carry out geological mapping from space. Ground-based data have indicated that the infrared range is preferentially absorbed by rocks containing different minerals, so the SMIRR could help determine the electromagnetic signature of various rock types and their mineral contents.

FILE, or **Feature Identification and Location Experiment,** is an on-board data management technique that is designed to aid sensors such as SMIRR and the Imaging Radar Experiment identify specific kinds of scenes from which to gather data. FILE will attempt to select for specific data, such as vegetation, bare ground, water, snow, or clouds. Other data will be suppressed by the system. If, for example, a scientist wanted information on wheat growth, FILE could help him sift the data for images with few clouds in areas where wheat is the primary crop.



Rockwell International

Artist's conception of the manipulator arm, to be tested on STS-2.



NASA

The Orbiter Columbia on the launch pad for STS-1. The boosters on either side are designed for 20 launches.

An experiment for the ***Measurement of Air Pollution from Satellites*** (MAPS) will measure the unique radiation absorption lines that carbon monoxide forms as it travels upwards through the Earth's atmosphere. MAPS will measure the carbon monoxide level at an altitude of 4.3 to 4.9 miles and 6 to 7 miles, in the Earth's troposphere.

Finally, the fifth pallet experiment is an **Ocean Color Experiment** that

Continued on page 59

Inside Energy

Natural Gas: Our Barely Tapped Energy Resource

by William Engdahl

Natural gas is potentially one of the world's most valuable primary energy resources, even though historically, it has been treated as a "poor cousin" to crude oil.

Its actual supply and attractiveness have yet to be realized. In fact, until the 1973 OPEC oil embargo, U.S. natural gas was regarded largely as an obstruction in the search for oil. However, natural gas, or methane, is one of the few primary energy sources that represents useful energy in its natural form. (Oil must be refined, uranium converted into thermal energy, coal into heat, and so forth). For this reason, it is the fuel preferred by industry and other end-users when it is available.

Despite natural gas's extreme attractiveness, political pricing restrictions in effect since the 1950s have successfully kept one of the world's most useful and abundant energy resources from its logical development. The subordination of this particular hydrocarbon by both the multinational oil majors and parochial coal interests is a fascinating story.

Today, because of the Natural Gas Policy Act of 1978—an almost accidental product of the Carter era of energy policy chaos—natural gas drilling has begun to increase significantly, especially in uncontrolled, deep (below 15,000 feet) formations, where the high exploration costs and risks are somewhat offset by the ability to command upwards of $8 per 1,000 cubic feet of gas. Yet, the vast potential of U.S. natural gas reserves is still largely untapped.

A comprehensive report recently released by Dr. Wolf Haefele states that we have consumed less than "8 percent of the estimated global resources [of natural gas] with a good part of this being burned away wastefully in the major gas-producing regions of northern Africa and the Persian Gulf because there have been no means for transporting the gas to distant markets such as those in Western Europe."[1]

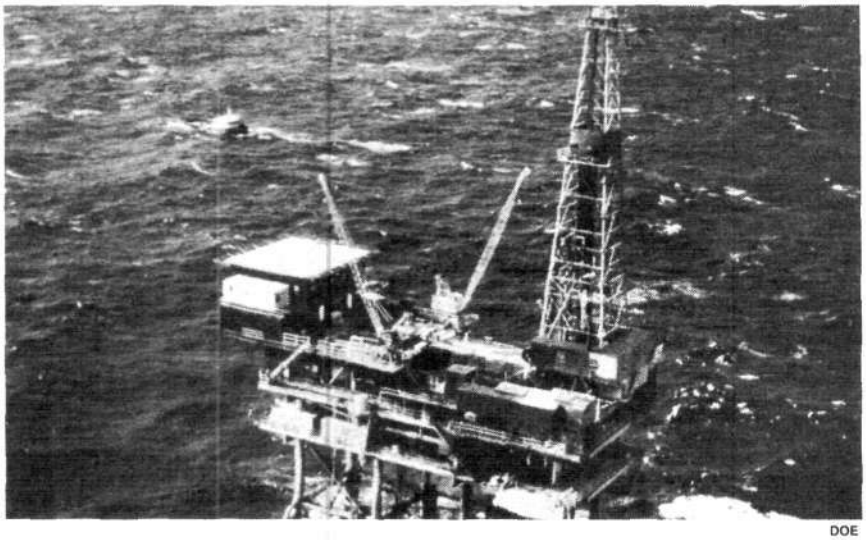
The Haefele report, which sees natural gas emerging as a major energy source over the next decades, estimates global conventional gas resources at some 9889.6 trillion cubic feet (tcf). For comparison, total U.S. natural gas consumption runs about 20 tcf/year.

In the United States alone, reserves are equally impressive. In a speech last spring, Harry C. Kent, director of the Potential Gas Agency at the Colorado School of Mines, announced updated resource estimates based on the recent exploration and discoveries in the Rocky Mountains and other regions.[2] Kent's committee now calculates that Alaska contains some 276 tcf of undiscovered recoverable conventional natural gas, an amount that could fill current U.S. demand almost to the end of the century. If we add the committee's estimate for the lower 48 states, we have an estimated 820 tcf, more than a 40-year supply.

A new administration and changed attitude in Washington offer some promise that this resource will become increasingly important, if deliberate restrictions on its end-use are removed or mitigated. Untangling the complexities of the entire Natural Gas Policy Act is a topic for another column, however. Suffice it to say that natural gas policy has too long lay hidden under the shadow of other carbon-based energy sources.

Notes

1. Wolf Haefele, et al., *Energy in a Finite World: Paths to a Sustainable Future*, Report by the Energy Systems Group of the Int'l. Institute for Applied Systems Analysis, (Cambridge, Mass.: Ballinger, 1981).
2. Harry C. Kent, "The Outlook for Remaining U.S. Gas Reserves Based on Recent Exploration and Development Activity." Speech to the Eighth Energy Technology Conference, Washington, D.C., March 11, 1981.



DOE

One recent authoritative report estimates that the United States has enough untapped natural gas to fill current U.S. demand for more than 40 years.

Advanced Energy Budget In Holding Pattern; Worse to Come

None of the Department of Energy's advanced energy programs made it through the past months' budget-cutting process unscathed, but for the time being most managed to hold on to the majority of their projects.

The magnetic fusion program, one of the principal battlegrounds of this year's budget debate, maintained its fiscal 1981 level of funding. However, this leaves the final budget at least $50 million short of the amount mandated by the Magnetic Fusion Energy Engineering Act of 1980. The design work for the congressionally mandated Fusion Engineering Device (FED) is not upgraded or accelerated in the fiscal 1982 budget, nor has the Reagan administration formally decided to give the go-ahead for the FED, to have it on line by 1990 as scheduled. (See Fusion Report, p. 21 for details.)

In early July, the Senate-House authorization conference settled on a $473.5 million level for fiscal 1982. However, the House Appropriations Subcommittee on Energy and Water cut that figure to $447 million, ensuring that no new project starts or upgraded design work on the FED will take place. As of this writing, the appropriations committee on the Senate side has yet to act on the DOE's fiscal 1982 request for magnetic fusion. If the Senate appropriates more than the $447 million figure, then the appropriations bill will go to Senate-House conference

The Reagan administration has not decided to give the go-ahead for the FED.

MHD Lobby Formed

One of the advanced R&D programs cut to zero in the Reagan administration's budget was the magnetohydrodynamics (MHD) program for efficient energy conversion. In response, contractors and potential utility users of MHD technology banded together for the first time and launched a lobbying effort that succeeded in restoring $29 million, almost half the fiscal 1981 funding for the program.

The formation and activities of this users group was one of the main topics of discussion at the MHD conference held at the University of Tennessee's Space Institute June 15 to 17, the 19th Symposium on Engineering Aspects of MHD. In his address to the meeting, Dr. Heinz Pfeiffer of Pennsylvania Power and Light reported that more than a dozen utilities have joined the lobbying group, and he chastised the scientific and industry people involved in MHD development for not taking "the information and potential value of MHD to decision-makers" sooner.

Pfeiffer recommended that the advances in coal research coming out of the MHD program be brought to the attention of policymakers on a regular basis.

Breeder Program Back on Track

A similar industry mobilization took place last spring in response to the threatened shutdown of the Clinch River Breeder Reactor in Tennessee, the only U.S. demonstration fast breeder project. When the authorizing House Committee on Science and Technology voted to terminate the project in June, industry contractors solicited statements of support from groups such as Scientists and Engineers for Secure Energy. These were entered in the *Congressional Record* by the committee leadership along with the minority's probreeder position.

A Senate-House conference committee has now authorized $228 million for Clinch River in fiscal 1982, and the appropriations committees are expected to follow suit.

Prospects for FY 1983

By mid-September, the DOE and other federal agencies must submit their budget requests for fiscal year 1983. The prospects that the advanced energy programs will continue to squeak by without major cutbacks are not good, Capitol Hill sources report. With interest rates still at record high levels, and no letup in the budget-cutting fever in Washington, industry, the scientific community, and the public will have to maintain a high profile if the DOE's advanced R&D programs are to survive and go forward.

Remote Sensing: Is the U.S. Losing Its Lead?

Recent congressional hearings on the U.S. remote sensing program revealed not only that the United States has no plans to launch new remote sensing satellite systems after 1983, but that France is on track to surpass the U.S. lead in this area in 1984.

The hearings, held July 22 and 23 by the space subcommittees of the House Science and Technology and Senate Commerce Committees, were prompted by concern in Congress that the United States is falling behind other nations in this important area of space applications.

The United States pioneered Earth remote sensing in the 1960s with its meteorological satellites. These delicate devices have since gathered data on crop conditions, agricultural pests and diseases, snow cover in the win-

ter, spring water runoff, and many other aspects of land and sea conditions. The data have opened up enormous possibilities for agricultural management, storm and disaster forecasting, and minerals location.

A French Lead

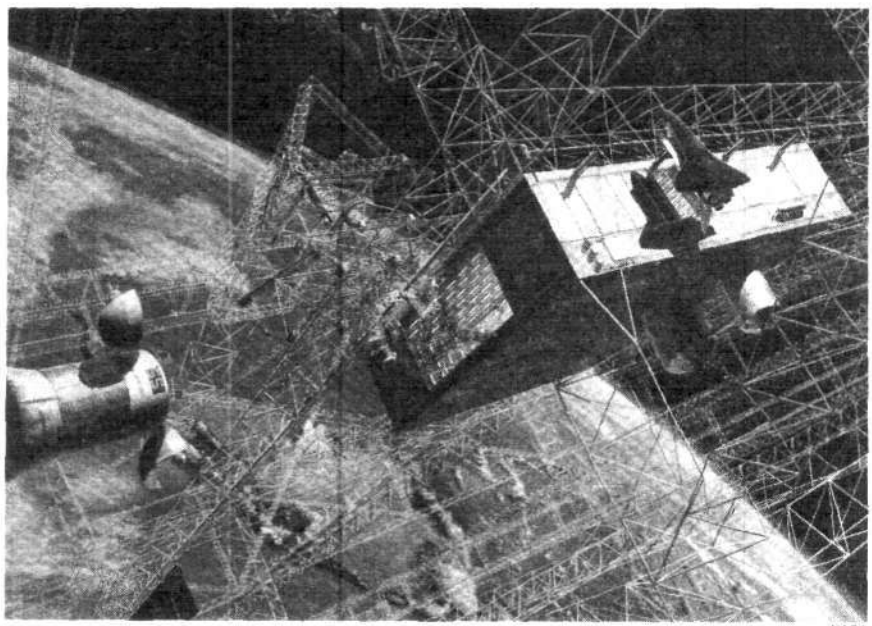
In his opening statement to the hearings, Sen. Harrison Schmitt (R-N.M.), the former Apollo astronaut and geologist who chairs the Senate Subcommittee on Science, Transportation, and Space, summarized the recent progress in remote sensing technology:

"The instruments carried by the American satellites of the Tiros and Nimbus series in the 1960s, which offered a ground resolution on the order of 1,000 meters, were the first to reveal the potential of space as a vantage point. Second-generation remote sensing instruments, with a resolution on the order of 100 meters, were developed during the 1970s for the Landsat series of satellites. . . . The 1980s will see the introduction of satellite-borne instruments with resolutions in the order of 10 meters, which will open up many new fields of application."

Schmitt then revealed that this quotation was taken from the introduction to the brochure for the *French* remote sensing system, called SPOT. The USA, Schmitt stated, has no development program to follow the Landsat D series of satellites, which will be operational in 1983. The 10-meter resolution satellites will not be launched by NASA but by the French!

Because of budget cuts, NASA's R&D program for remote sensing satellite technology has been eliminated, and there is now no doubt the French will be ahead of the United States by 1984, when the SPOT satellites are scheduled to be launched.

Both congressional subcommittees are considering alternatives to get industry to take over part of the operations of Landsat satellites, ground collection stations, and data processing facilities now funded by NASA, to free up NASA funds for advanced R&D work in remote sensing.



NASA

An artist's conception of construction in space.

NASA's Beggs: Space Station Is Next

At confirmation hearings June 17, incoming NASA Administrator James M. Beggs, a former General Dynamics Co. executive, identified a permanent space center as the most important next-step for the space program.

"It seems to me that the next major step is a space station because that will make a lot of other things possible in space in the future," he said.

The NASA confirmation hearings were held by the Senate Commerce Committee's Subcommittee on Science, Technology, and Space, chaired by former astronaut Sen. Harrison Schmitt (R-N.M.). Dr. Hans Mark, the new deputy director and former secretary of the Air Force, concurred with Beggs, stating, "I think the next step is development of a permanent presence in space."

The Space Shuttle's astronaut corps and space supporters in the House and Senate are already waging a lobbying effort for a space station, and NASA is now conducting preliminary design studies for the Space Operations Center.

The new NASA administrators were also asked their views on the future of NASA's space science program and the military use of space.

Beggs said he hoped the space science program could be rejuvenated, as "planetary exploration has been a great benefit to the country and a hallmark of the agency."

On the much debated military question that came up during the development of the Shuttle, Mark stated, "I support the space act which separates the civilian from military activities in space," though he added that separating the two functions is difficult when the same vehicle (the Shuttle) is to carry both kinds of payloads. Mark said he supports the proposal of Senator Goldwater for a fleet of 10 Shuttle orbiters, some of which would be dedicated to military uses.

Expand NASA's Mandate

Schmitt challenged the new NASA team to also think about expanding the space agency's mandate to deal with other transportation issues.

"Would you see adding a maritime, rail, and automotive R&D effort to the NASA charter?" Schmitt asked. Beggs replied that "this should be studied more in depth."

An Interview with Dr. Friedwardt Winterberg

Opening the Frontiers of Science

Dr. Friedwardt Winterberg, a pioneer in inertial-confinement fusion, was the featured speaker on a university tour sponsored by the Fusion Energy Forum of West Germany May 25 through June 5. Winterberg lectured on the importance of fusion for basic research and space exploration to students in Aachen, Bonn, Giessen, Karlsruhe, Kiel, Mainz, Munich, and Stuttgart.

Well known in Germany, Winterberg was educated at German universities and was a student of the great physicist Werner Heisenberg. His lectures generated lively discussion from the student audiences, especially on the subject of nuclear energy. While in Stuttgart, Winterberg was interviewed on a topical news program on prime time television on the future of fusion.

Winterberg, currrently a professor at the University of Nevada in Reno, is considered the father of impact fusion for his early work in thermonuclear ignition by hypervelocity impact. He received the 1979 Hermann Oberth gold medal of the Hermann Oberth-Wernher von Braun International Space Flight Foundation for his work on thermonuclear propulsion. Winterberg's book, The Physical Principles of Thermonuclear Explosive Devices, *was published by the FEF in August.*

This interview was conducted by Jonathan Tennenbaum, director of the Fusion Energy Forum.

* * *

Question: What do you see as the significance of fusion, and what are its prospects?

During my lecture tour here in West Germany, I have heard that some scientists have predicted that controlled fusion could not be achieved before the year 2050. I don't know who made this prediction, but I consider it completely wrong. I am rather certain that by the year 2000, fusion will have been meaningfully achieved in the sense that it will already be in use for the production of energy; it will also be used to solve other problems, problems that have nothing to do with the production of energy, but are of tremendous importance for basic research in general.

The moment controlled fusion is achieved, development can and will proceed with tremendous rapidity. And I believe we will achieve controlled fusion during this decade.

I am thinking of space travel. By using nuclear-powered rocket engines, it will be possible to transport gigantic payloads at greatly increased speeds throughout the solar system. I am also thinking of the application of fusion to particle accelerators in high-energy physics, by means of which it will be possible to achieve a deeper fundamental understanding of nature.

Question: Now that that Space Shuttle Columbia has had a successful *maiden voyage*, the possibility of putting men in orbit on a scheduled-flight basis lies open to us. How does this milestone contribute to the prospects for fusion-powered space travel?

The two developments have a very interesting and very close interrelationship. First of all, from now on we will be able to regularly put men in orbit with a device like the Space Shuttle; that is, a device with relatively low acceleration. But with the application of fusion power, we will be in a position to put very large payloads in orbit at an extremely low cost in comparison with the Space Shuttle.

Let's remember that it is very expensive to put payloads in orbit with the Space Shuttle, and probably will remain so. We are not just putting men in orbit; we want to establish whole industries there, and so equipment constitutes the largest part of the mass to be transported. Through the use of fusion, it should be possible to build magnetically driven cannon to achieve shots that reach very high speeds—perhaps 10 kilometers per second. These shots can pierce the atmosphere, and in this way can put large payloads in orbit at a very low cost—perhaps one thousandth of the cost by the Space Shuttle.

With these payloads in orbit, we can construct large spaceships with nuclear-powered rockets, which in turn can push out to Mars, to Jupiter,

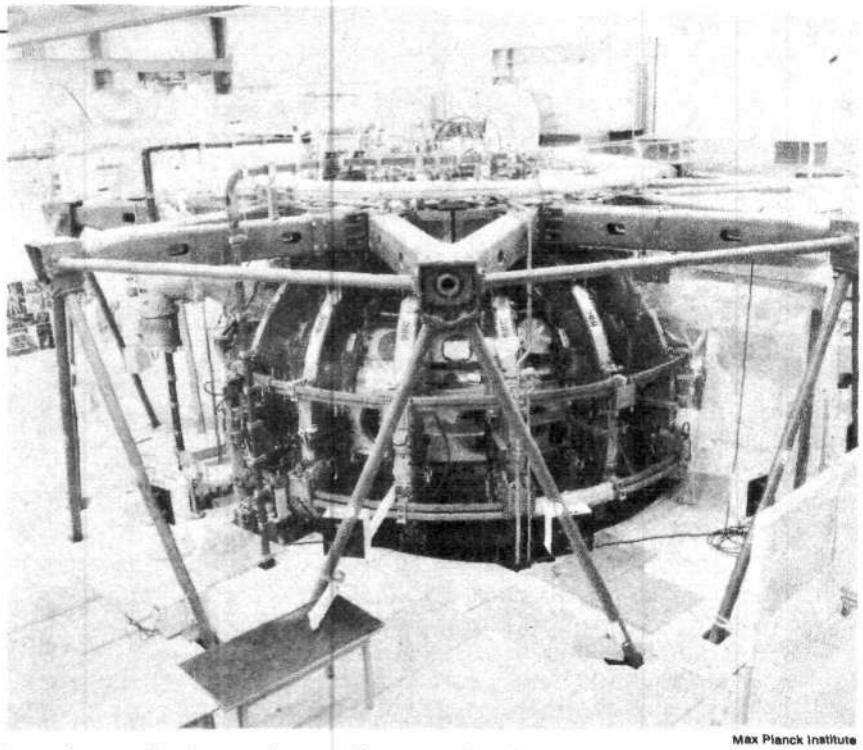
or even to the outer limit of the solar system to Pluto, and carry payloads of millions of tons. Then we could build whole observatories and scientific colonies on these planets or their moons.

Question: When can industrialization of the solar system begin, and how does this relate to the talk about limits to growth and the end of industrial society?

The large-scale industrialization of the solar system could begin perhaps by the middle of the next century, when fusion rockets will have been extensively developed and tested and observatories will exist on the planets or on the moons of the larger planets. As I picture it, this should be possible from the year 2050. This industrialization could then contribute on an unlimited scale raw materials that are gradually being exhausted or are becoming scarcer on Earth, putting them to use for further industrial development.

Question: Recently, the International Institute for Applied Systems Analysis (IIASA) in Vienna published a study titled "Energy in a Limited World," which claimed that fusion power can make no significant contribution to the world economy before the year 2030. What do you think of this viewpoint?

This study appears to be based on the principle of futurology, a pseudoscience that makes linear extrapolation into the future from known facts. Such linear extrapolations have proven to be wrong again and again. Of course, I too must engage in certain extrapolations in formulating my own forecast, and it may well be that I am still judging the matter much too pessimistically. Remember that in 1903, when the first airplane flew, almost nobody considered it possible that we might be walking on the Moon in less than the span of a man's lifetime. In fact, less than 30 years passed from the development of the first liquid-fuel rockets in the early 1940s to the first Moon landing.



Max Planck Institute

Spending cutbacks are hitting the Max Planck Institute for Plasma Physics in Garching and other West German laboratories. Pictured here, the Institute's Asdex tokamak, Europe's largest tokamak.

We are always strongly inclined to underestimate the tempo. Remember also that about 1920 the question was raised in the United States whether air passenger service was possible between New York and Chicago. At the time, the answer was that it would never be possible, because the Alleghanies stood in the way.

So I would like to stress that the moment controlled fusion is achieved, development can and will proceed with tremendous rapidity. And I believe we will achieve controlled fusion during this decade.

Question: You have yourself designed new technologies for use in inertial fusion. Isn't that an example of a development that could not have been foreseen by linear methods?

Yes, I think that's a very good example. Technologies were developed during the mid-1960s with which very powerful electron beams could be produced—beams of up to millions of amperes. At an earlier point, in the 1950s when fusion research began, these technologies were not yet known. Now another possibility has opened up much more recently in the concept of magnetic isolation, where not only electron beams but also ion beams of many millions of amperes can be produced.

With these intense ion beams we have new stimuli and new potentialities for achieving not only inertial fusion but also magnetic fusion. Here is the connection: In magnetic fusion, as attempted so far, essentially, gas discharges are induced. These discharges excite streams of electrons in the plasma, inducing a flow of electron plasma.

So now we have a technique by which we can produce ion beams of incredible strengths. Theoretical investigations show that a plasma becomes extremely stable when such ion beams are fired into a plasma instead of electron beams. This cannot come about through a gas discharge, which can only lead to electron beams, but with the help of magnetic isolation—that is, with a magnetically isolated diode—the desired ion beam can be produced. All

the problems that have provoked plasma physics until now and posed enormous difficulties, suddenly disappear into thin air.

Question: At the time, people said that the magnetically isolated diode (MID) couldn't possibly work.

When I first proposed this concept—that was 10 or 12 years ago—it was completely ignored. A few years later, a very prominent man explained that magnetic isolation belonged in more or less the same category as the perpetual motion machine. He declared in a letter published in the journal *Nature* that anybody who proposed such a thing should build a working model, just like the patent office official who required the same of inventors of perpetual motion machines. Since then, however, the prominent man has stated that this kind of perpetual motion machine really works, even though true perpetual motion does not.

Today MID is being used, for example, at Karlsruhe. They are also pursuing inertial fusion there, and indeed with ion beams generated by MIDs—albeit initially on a smaller scale than in the United States.

Question: That brings us to another theme. In the Federal Republic very little is being done in the field of inertial fusion. Do you think more should be done, and why has so little been done until now?

In the mid-1950s there was a debate over what course fusion research should take, organized and led by Professor von Weizsäcker's administration. At that time it was decided not to enter the field of inertial fusion, but to concentrate solely on magnetic fusion. The state of inertial confinement today thus reflects a decision taken very early, but which may yet be reversed, as we see in Karlsruhe.

Question: How in your opinion should research in this field be carried forward?

I would say that we should put tremendous emphasis on these new technologies, which as allied technologies for fusion lead to decisive new perspectives, as with the production of intense ion beams. In my opinion it will not be done simply with magnetic isolation as such.

What we need immediately are magnetically isolated diodes that can generate ion beams of extremely high quality. The beams produced by this means are not so far of the desired quality. So it has been not at all easy to focus on a tiny spot.

A laser beam is a beam of higher quality; sunlight or the beam of a flashlight represents only a poor quality by comparison, since unlike lasers it cannot be focused on a point. We must do research on the focusing of ion beams to extremely fine dimensions. If we succeed here, then we shall have completely new perspectives and unforeseen breakthroughs, which will make it much easier to produce fusion than heretofore imagined.

Question: In the Federal Republic, not only is there no increase in investment in fusion, but resources are being cut back, as for example at Garching. What do you think of this situation?

Basically, we should not recommend cutbacks, since that would mean dispensing with the know-how of this high-powered technology, and dispensing with the experts who have a wealth of knowledge about it. And in financing particular projects, great emphasis should be put on the latest technologies, as in the project underway at Karlsruhe. There must be a multitude of approaches underway—say, 10 to 100 times as many as now. Then the Federal Republic would achieve importance on a world scale in this area, much as the Federal Re-

Members of the Fusion Energy Forum organizing in Munich. "They are definitely contributing a great deal to the formulation of a positive energy policy."

public has achieved importance in the field of high-energy physics with the synchrotron electron accelerator in Hamburg.

Question: Recently in Bild der Wissenschaft [Image of Science, an anti-technology German magazine], the Social Democratic member of parliament Steger expressed the view that the Federal Republic should eventually put an end to fusion research—when, say, projects like JET [the Joint European Torus] failed to produce the desired results.

If we terminate this research now, it would be comparable to having ended aeronautical research on the eve of the invention of the airplane. Put yourself in 1900, when all the projects that had been tested until then had failed—for example, airplanes driven by steam engines. What if we had given up and said, it won't work, let's throw in the towel? The airplane would never have been developed, and people would have gone around saying, we can go no further. We would be living today as in the era before 1903.

So it would be a tremendous mistake, since there is no doubt that controlled fusion is possible in principle. No doubt whatever. It's not a question of whether one or another project achieves its goal, or even when it does. Aeronautics is a perfect example here. There was the Zeppelin, and there was the airplane. Both worked, and it may be that both inertial fusion and magnetic fusion will work, or also a third method that we are not yet working on today or that is not yet known to us. So it would be a mistake to say since the one won't work, the other won't work: "If the Zeppelin fails, forget about that airplane idea."

It would be not only sad, it would be stupid. Because there is no question but that fusion will work. We don't know whether all the experiments that are planned will click or whether just some of them will. But then, even when one experiment fails, you still have the expertise, and that is the most important investment. You have all the know-how, and it can be put to work on another project.

Question: At your lectures, the question was often raised whether we still need fission, since fusion is so promising.

We need fission in any case. The first fission reactor was brought into operation in 1942. With fusion we are still in the situation in which fission found itself *prior* to 1942. By contrast, fission now has decades of technological development behind it. This is conspicuous in the fact that we have available to us nuclear power plants producing electricity on a large scale. We cannot afford simply to wait until fusion reactors come on line. We need fission if only as an interim solution. If nuclear power plants are not built in the Federal Republic, and the nuclear energy program comes to a halt over the next 10 years, then this will lead, with inescapable certainty, to the economic collapse of the Federal Republic.

If we terminated fusion research now, it would be comparable to having ended aeronautical research on the eve of the invention of the airplane.

Question: What about the problem of waste disposal?

This is where lies are spread among the people. It is claimed that the problem of waste disposal has not been solved. In fact it is completely solved, in technical detail. But of course, if you don't build a waste disposal center, you can't deal with any wastes, any more than you can fly the airplane if you don't build an airport.

Question: Many people say we should rely more on solar energy. The IIASA report I mentioned says that solar energy will be more important than fusion over the next 50 years. What is your opinion?

By no means. That is completely insane. Solar energy is too inefficient. No amount of research can change that. No matter how much money is poured into solar energy research, in fact, no research can alter the limits of solar radiation. Then people will say we should build solar power plants on or near the Sun. Unfortunately, that cannot be done. Solar energy is like the emperor's new clothes—it isn't there. The best you can do with solar energy is to make warm water. And that is really all.

There are even people who propose to introduce solar power in Sweden. Now, since Sweden is often overcast, and is relatively close to the North Pole, it isn't clear to me how this is supposed to work. It would be a truly hopeless enterprise. The other argument, that the Third World has plenty of sun, is also wrong. Even under the most favorable conditions, solar energy is still very uneconomical. Solar energy is insanely expensive. Because it is so inefficient, we would need gigantic collector panels. If we wanted to supply the United States with solar power and used the most favorable region—the American Southwest—we would cover thousands of square kilometers just with collectors, not to mention what the outcome of a sandstorm would be.

Question: But we could also say that *fusion is a form of solar energy.*

Precisely. The Sun is actually a giant fusion reactor. If we want to collect solar energy at the Earth's surface, we can only do so in two dimensions, that is, by means of collector surfaces. Its incidence is very irregular, and apart from cloudiness, there is no sunshine at night, as everbody knows.

The inconstancy of sunlight makes it an even more uneconomical proposition—and substantially so. But with fusion, where we produce an artificial sun on Earth, we can collect the energy in three dimensions. The concentration of energy is therefore higher in the extreme. We won't need thousands of square kilometers, but can work with very small spaces. We have a highly concentrated energy source. The concentration of energy in fusion is much, much higher, millions of times greater than in chemical combustion.

Question: What impression do you have of the work of the Fusion Energy Forum from your recent tour?

First of all, I have been very impressed with its members. They are all very energetic and intelligent young people with a genuine interest in the common good. They are definitely contributing a great deal to the formulation of a positive energy policy in the interests of the Federal Republic. This they are doing through their education of the public on the truth about nuclear energy, fusion in particular.

Question: You have spoken before thousands of listeners here, especially in the universities. What do you think of university students in the Federal Republic?

The universities constitute a wide field, where through education many adherents can be won for an energy policy beneficial to all. I don't believe that all students here are environmentalist "greenies." That's just not true. Many students are committed to nuclear energy, and many are undecided because they hear all manner of propaganda, including bald-faced lies. Your campaign to spread the truth and to educate the students on fission and fusion is a contribution of tremendous importance. Given the positive results we see here now, I believe your campaign can succeed if you carry on with the approach you have used so far.

FEF Dossier Available

Environmentalists Handle Nuclear PR

In the course of investigating slanders of the FEF circulated to U.S. utility executives, the foundation discovered the equivalent of the fox being hired by the chickens to help design their coops; namely, a top environmentalist firm, Ogilvy & Mather International, now handles the public relations for the U.S. nuclear industry.

After further research, the FEF compiled and issued a dossier on Ogilvy & Mather, the advertising representative for leading one-worldist and environmentalist circles, and their buyout of the public relations firm of Underwood & Jordan. For many years Underwood & Jordan has been the key public relations voice of American electric utilities and nuclear power companies.

Ogilvy & Mather's May 1981 acquisition, one of the least publicized of the recent wave of "flight capital" takeovers of American companies by foreign and foreign-linked firms, is probably the most dangerous to the U.S. national security, the dossier says.

Among the clients represented by Ogilvy & Mather International are the World Wildlife Fund, Royal Dutch Shell, three British government institutions, and the Principality of Monaco—clients the FEF has documented to be leading opponents of industrial progress and the widespread implementation of nuclear energy.

"American utilities and energy companies are now being advised by the same firm that is the publicity brains behind the world environmentalist movement," the dossier states.

In fact, David Ogilvy, the former British espionage expert who founded the advertising firm, is one of the executive council members of the World Wildlife Fund and personally plans its publicity campaigns against high-technology energy production.

Ogilvy & Mather International also represents the Bronfman family-controlled Joseph E. Seagram & Sons of Canada, placing the advertising firm near the center of the recent wave of foreign takeover attempts of U.S. industry.

"Underwood & Jordan did not object to the takeover," the dossier continues, "which put Ogilvy & Mather International in public relations control of the Edison Electric Institute, the association of investor-owned utilities; of many individual utilities; of several nuclear firms; and of Americans for Energy Independence, among others.

"Many of the utilities affected have not even been informed of the takeover. However, electric power companies nationally have been receiving advice from New York and Washington-based 'analysts' to forget nuclear power as an option, on the grounds that energy consumption is dropping and nuclear power will never again be a justifiable capital investment. This directly defies current U.S. administration and congressional policy."

The dossier noted that this advice has been associated with slanders of the FEF, its 200,000-circulation *Fusion* magazine, and its contributing authors. In March, the Edison Electric Institute mailed out to all its members a package of materials slandering the FEF, which had already been judged libelous by the High Court of France (see *Fusion*, Aug. 1981, p. 58). In June, an Underwood & Jordan vice president advised an author against publishing in *Fusion* an article critical of the science budget cuts. This targeting of the FEF is now understood to be coordinated by Ogilvy & Mather International and its environmentalist clients.

Five hundred copies of the dossier were mailed out to utility executives, scientists and engineers at the national laboratories, government energy officials, and trade union leaders. Copies are available from the FEF. Please enclose a self-addressed, stamped envelope.

Houston Spaceweek Conf. Refutes 'Limits to Growth'

The world renowned astrophysicist Dr. Krafft Ehricke elaborated his theory of the "extraterrestrial imperative" as the answer to limits to growth ideology before an audience of 150 at the FEF's conference celebrating national Spaceweek in Houston July 8.

Ehricke, a pioneer in rocket and manned space flight development for more than 30 years, began his keynote address with a point by point refutation of the arguments of the *Global 2000 Report,* prepared by the Carter administration and still policy of the Haig State Department.

"Every single advance since photosynthesis in the negentropic development of this biosphere has, together with its benefits, created new problems to be solved," Ehricke asserted. "The antitechnology movements use the appearance of such problems to assert that there must be no more advance. But we must not be preoccupied with the problems, but with the solutions. If we allow ourselves to be stopped by the problems, we will become the weak link in the overall development of the biosphere. I don't want man to go down in infamy as the weak link!"

Ehricke located the necessity of man's conquest of space in the context of the principle of the continuing development of the universe and the biosphere of the Earth. He then outlined the three stages of the exploration and development of outer space opened up by the success of the Space Shuttle: space industrialization; space urbanization; and what he termed divergence, the effects on human evolution of living in space.

Putting Man into Space

Future astronaut Dr. Claude Nicollier, a Swiss astrophysicist from the European Space Agency who is training for the Space Lab mission, joined Ehricke on the program, along with Jim Hudson, a supervisor for Rockwell Industries, and Carol White, editor of *The Young Scientist.* The conference was greeted by a spokesman for Houston Mayor James McConn.

Nicollier gave a presentation on the work of the European Space Agency, which is preparing for a Shuttle flight in collaboration with NASA in 1983. This mission will carry the European-built Space Lab into space in the payload bay of the Shuttle for important in-orbit experiments.

Hudson introduced a NASA film on the first flight of the Space Shuttle Columbia with a discussion of the promise of the future flights of the reusable Shuttle, whose thrust, he reminded the audience, is 100 times greater than the first rocket that put an American into orbit in 1962.

The focus of Carol White's speech was the necessity of immediately reversing the cuts in NASA's budget, which threaten important programs; and she reported on the FEF's proposal for a NASA budget of $14 billion, more than double the present amount, but the equivalent spent on space by the United States at the peak of the NASA program in 1966.

The conference, which was attended by area FEF members, local officials, and a representative of Texas congressman Bill Archer's office, was covered in the *Houston Chronicle,* the *Houston Post,* and the ABC-TV affiliate.

The December issue of *Fusion* will feature an article by Ehricke on the extraterrestrial imperative, which will explore the physiological, aesthetic, and immunological changes in human evolutionary characteristics that will result from living in extraterrestrial environments.

Krafft Ehricke and Carol White at the FEF's Spaceweek conference in Houston.

Columbia Readied

Continued from page 50

will attempt to provide a scientific map for finding schools of fish, locating by color the concentrations of green chlorophyll, characteristic of algae. The distribution of algae will then be mapped with temperature in order to locate schools of fish.

This mapping will also provide data on ocean pollution that will be checked with data from ships and low-flying aircraft. The experiment will concentrate on the region near the Canary Islands, off the coast of Peru, and along the east coast of the United States off Cape Cod and Georgia.

—Marsha Freeman

European Panel Recommends Increased Fusion Effort

A high-level scientific review committee recommended to the European Community in early July that it "remain in the front line of fusion R&D [through] a steady continuation of the European Fusion Programme. . . . The main objective of the programme for the coming decades must be to prove the feasibility of fusion as an energy source and to search for optimum ways of fully exploiting its potential."

To accomplish these goals, the panel proposed a 30 percent funding increase in fusion R&D over the coming five years.

The 11-member committee included scientists from European universities and representatives from the nuclear, aerospace, and electrical industries. It was chaired by Professor K. H. Beckurts, a senior vice president of Siemens, A.G.

The committee report recommends that the Joint European Torus (JET) tokamak fusion device, now under construction in Britain at the Culham Laboratory, "push ahead as fast as possible" and that it be brought to full operation and be prepared for operation with the deuterium-tritium fuel that will be required in commercial reactors.

The JET is a tokamak approximately the size of the Princeton Tokamak Fusion Test Reactor, scheduled for a 1982 completion, and it is designed to reach energy breakeven, thus demonstrating the scientific feasibility of magnetic fusion. The JET program is now about two years behind the TFTR, and the European Community is expected to decide shortly to burn deuterium-tritium fuel in the reactor.

An International Effort

An important recommendation of the report is to "initiate a substantial and well-balanced program in fusion technology, mainly focused on the solution of the technological problems of NET [Next European Torus], making use of relevant experience in fission reactor technology."

In this recommendation, the panel is echoing the results of recent reviews of the U.S. and Japanese fusion programs, which concluded that fusion was ready to enter the engineering and technology development phase. The panel suggests that the EC "intensify activities on the conceptual design of a next step device . . . by setting up a NET study team," and that a "high-level Fusion Technology Steering Committee advising the [EC] Commission on the activities of the second stage" be created.

Increased international cooperation, particularly with the United States, will be crucial for the engineering phase, the panel suggests; in areas such as the magnetic mirror, where Europe has no program at all, it should be willing to send people and possibly hardware to the United States to increase its participation in the advanced U.S. program.

The panel recommends against beginning a fusion-fission hybrid development program, which would use the neutrons produced in the fusion process to breed fuel for conventional reactors, but it does suggest that the potential for such systems "be periodically reviewed." The panel also rec-

DOE Stalling on FED

Continued from page 21

ready to manage, plan, and oversee the fusion program's entire engineering effort, not just the Fusion Engineering Device, and that industry should take over the role of the CFE.

Other individual companies, in particular those aerospace companies with many years of experience in government-sponsored space and defense programs, expressed another view. The role of the CFE should not be "overly ambitious," said Dr. Donald Kummer, representing the fusion program of the McDonnell Douglas Astronautics Co. Its function should be "planning, programmatic, and technical administration in support of the Office of Fusion Energy" in the DOE, he said.

Kummer emphasized that the role of the CFE must be "clearly delineated. . . . When the boundary conditions for the CFE are not fixed, it is inevitable that the national laboratories, universities, or industry will find that their traditional roles are being infringed and they will protest."

Another aerospace representative, Pete Staudhammer of TRW, stressed that the engineering phase must be a partnership between the laboratories and industry, and he recounted TRW's experience in the late 1950's ballistic missile planning, in which industry provided the systems engineering and technological direction for the Department of Defense.

Staudhammer also warned that "the future of the magnetic fusion program may well be in jeopardy . . . because of lack of proper funding," a reference to the fact that the Reagan budget has given fusion $60 million less than the 1980 legislation for the 1982 fiscal year.

Dr. Harold Agnew, who has both industry and lab experience (as a former director of the Los Alamos National Scientific Laboratory and now as president of General Atomic Co.), then summarized what he called three prerequisites for the transfer of fusion technology to industry.

First, he said, there must be a strong national commitment to the engineering phase of fusion that does not change with each administration; second, strong industrial leadership must be available; and third, the knowledge concentrated in the laboratories must be accessible to industry as the fusion program moves into the engineering phase.

Finally, panel member Mike McCormack reminded the witnesses and other panel members that the FED will not be a commercial demonstration reactor but an engineering device, so the concern by some representatives, such as the AIF speaker, that utility end-users be involved in the FED, is premature.

—*Marsha Freeman*

ommends continuing the small European inertial fusion program.

To push the JET program forward and embark on an engineering phase, the report calls for a budget of about 1,500 million European Currency Units (about $1.5 billion) over the period from 1982 to 1986, compared to the 877.1 million ECU formerly projected for 1979 to 1983. Discounting inflation, this is approximately a 30 percent real increase over the five-year period.

The report also addresses the looming problem of a shortage in scientific manpower. "The average age of the staff working on fusion R&D in the Community is about 45 years," the report states. "In about 15 years time, when these staff retire, most of the know-how acquired in 30 to 40 years of R&D efforts will disappear rather suddenly, unless new staff is trained and introduced in the system in time to allow an adequate transfer of this know-how."

To counter the manpower shortage, the report recommends a European Fusion Research Fellowship program with 30 to 50 well-paid positions for young scientists and engineers.

Although the panel notes that "the route to commercial fusion will be long and costly and involve the solution of extremely difficult technical problems," it states that the U.S. Magnetic Fusion Energy Engineering Act of 1980 and the spring 1981 recommendations of a Japanese fusion review are built on a "worldwide consensus that the potential advantages of harnessing the energy source of the stars on earth are so enormous that they justify this very considerable effort."

Viewpoint

Continued from page 10

Congress provided legislative authority to require a substantial amount of new, precise, and sophisticated data, and established "uniform criteria" to be used in assessing pesticide safety. Congress apparently intended for all pesticides used in the United States to be evaluated according to a set of uniform criteria and equally stringent standards.

The EPA was delegated with the authority to implement the provisions of the FIFRA amendment, along with the basic safety requirements that already existed under the Miller amendment. Passed in 1954, the Miller amendment to the Federal Food, Drug, and Cosmetic Act requires the establishment of tolerances for pesticide chemicals in or on raw agricultural commodities, either as residues remaining on food products after harvest, or those chemicals that might be intentionally added after harvest to fresh or processed commodities.

The EPA was also delegated the Delaney amendment passed in 1958. This amendment further provided that "no additive shall be deemed to be safe if it is found to induce cancer in man or animal."

The constant pressure on the EPA from various groups, and Congress as well, coupled with the strict requirements for pesticide registration contained in the various federal laws, is probably responsible for most of these problems.

I believe that pesticide registration procedures should adequately and realistically assess risk versus benefit, and minimize unnecessary testing, costs, and time delays.

I suspect the agency may have responded by overreacting to some claims or charges by antipesticide groups that were unfounded or overstated. However, the federal laws are written in such a way that the EPA may not have much choice in its manner of response. We in Mississippi have experienced some of the problems first hand in the loss of Mirex fire ant bait, 2,4,5-T, DDT, and Silvex for forestry uses, to name a few.

I should add that the EPA has been responsive to our requests for exemptions to allow the use of unregistered pesticides in emergency control programs utilizing the synthetic pyrethroids and other new pesticides for control of cotton bollworm and tobacco budworm on cotton. We have also experienced the conditional registration benefits, which speed up registration of pesticides. However, with two years' loss of a control program while fire ants multiplied in the 230 million infested acres and spread to millions more, and with the new material costing 10 times as much, this kind of cooperation can, and will, kill us sooner or later.

In my judgment the first step needed to bring order out of chaos is "defanging" the Delaney amendment of 1958 and allowing the Environmental Protection Agency to exercise judgment in weighing costs and benefits. Once this dam is broken, the other restrictions should gradually give way to a sensible public policy.

Jim Buck Ross is the commissioner of the Mississippi Department of Agriculture and Commerce.

Iraqi Reactor

Continued from page 49

and other obstacles through a miracle of ingenuity and foreign assistance, there is still the matter of the safeguards, the report stated. Iraq operates its nuclear facilities under the auspices of the International Atomic Energy Agency, which requires that there be foreign observers either in the facilities or with access to them at all times. The IAEA surveillance includes intensive chemical assays, on-site radiation detection equipment, time-lapse photograhy, and seals, whose explicit purpose is to guard against the diversion of nuclear materials for bomb production.

The FEF report also found that the possibility of Iraq's constructing a plutonium bomb from the small quantities of U-238 present in the fuel is remote. The extraction of weapons-grade plutonium requires sophisticated isotope separation techniques, which Iraq does not possess.

As for the common argument that Iraq has so much oil, it could not possibly need nuclear as an energy source, this reasoning ignores the fact that Iraq has the most ambitious industrial development program of any Mideast nation, and has plans to use nuclear as its principal energy source after its oil reserves are used up in industrialization.

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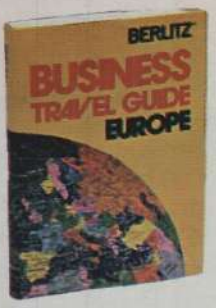

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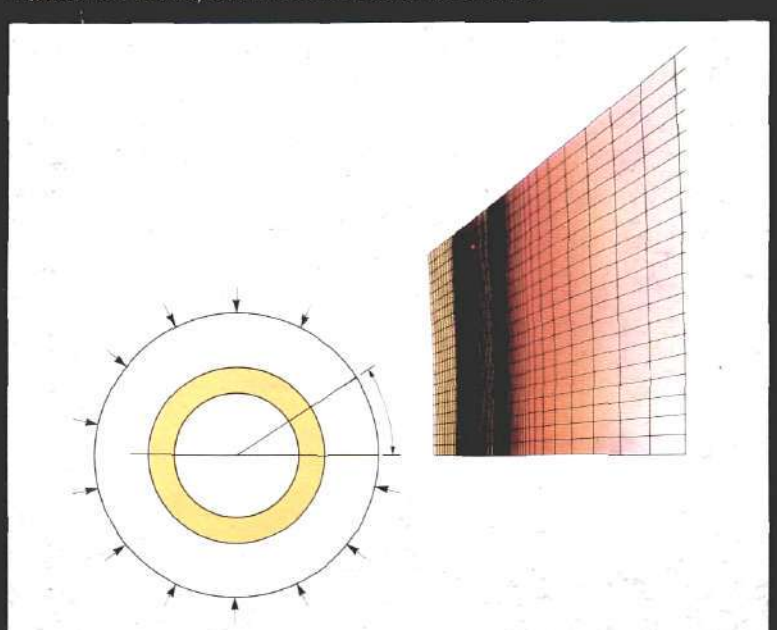
The Riemannian Tradition

The hydrodynamic method of Bernhard Riemann, particularly his 1859 paper on shock waves, has been an essential – and often secret – ingredient in the development of thermonuclear fusion energy, supersonic flight, and the hydrogen bomb. This issue of *Fusion* looks at Riemann's influence in each of these areas.

- **Steven Bardwell and Uwe Parpart discuss the impasse in inertial confinement fusion research and present a proposal for breaking this impasse using Riemann's concept of shock waves.**
- ***Fusion* interviews Adolf Busemann, one of the most outstanding proponents of the Riemannian tradition in this century. A giant in aerodynamics, Busemann has also made major contributions to magnetic and inertial fusion.**
- **Charles B. Stevens reviews the *Progressive* case, the government's attempt to block publication of an article on the H-bomb. As he shows, what the government wanted to classify was not the bomb, but Riemann's theoretical work.**

Above: *Participants at the 1935 European aerodynamics conference at Volta, Italy, a milestone in the development of supersonic flight. Adolf Busemann is fourth from left, third row. Theodor von Karman (white coat) is at his left in the second row; Ludwig Prandtl is fifth from left, first row.*
Below left: *Computer simulation of two shock waves propagating through a pellet containing deuterium-tritium fusion fuel.* *See page 29.*
Below right: *The November 1979* Progressive *article. As* Fusion *has documented, the so-called secrets that the government wanted to classify have been in the open literature since 1859.*

The cover: The front cover photograph, showing shock wave formation around a test model of the space shuttle in a wind tunnel, is courtesy of Ames Research Center, NASA; cover design is by Virginia Baier.



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