The DOE's Buchsbaum Report: Fusion by 2000!—page 48

FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION

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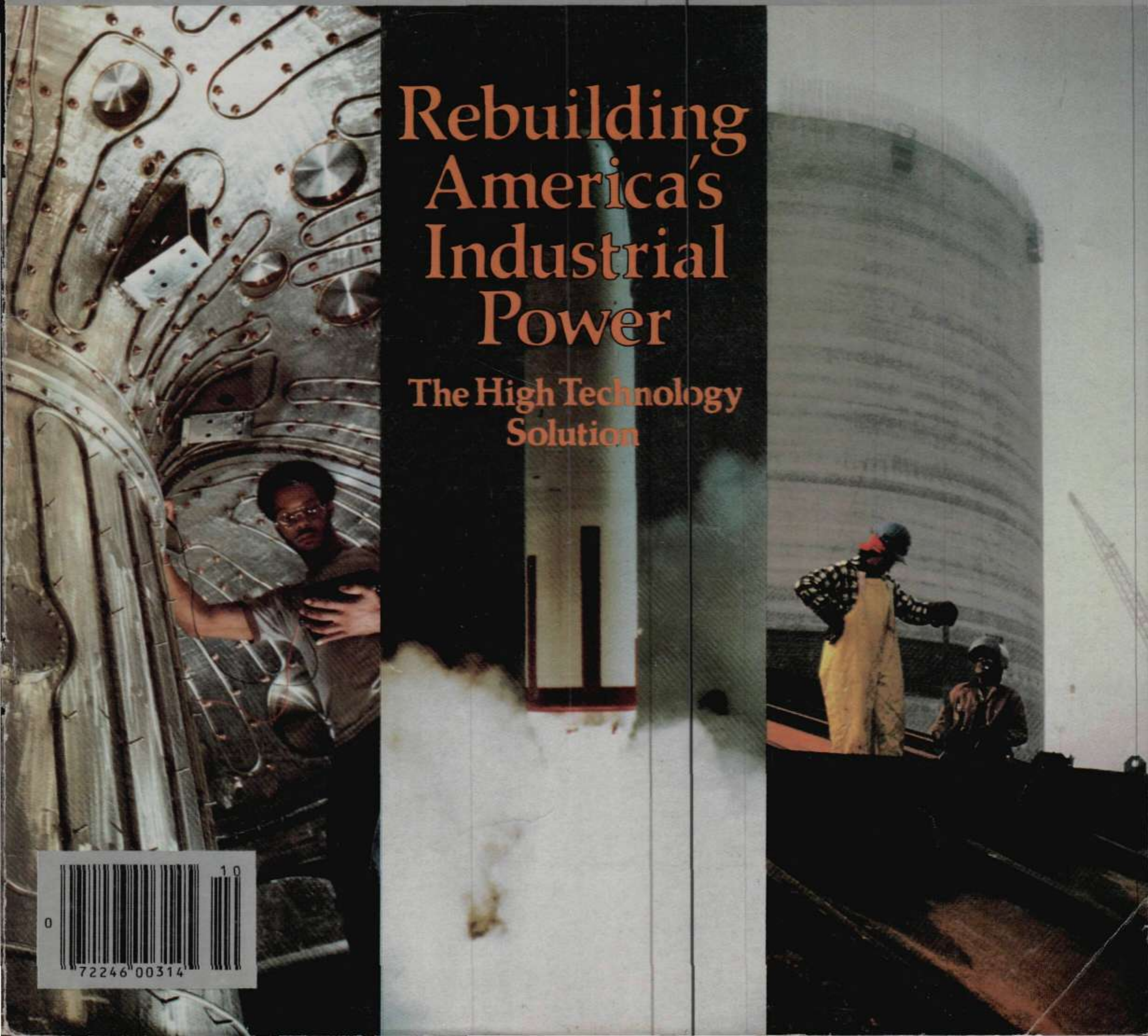

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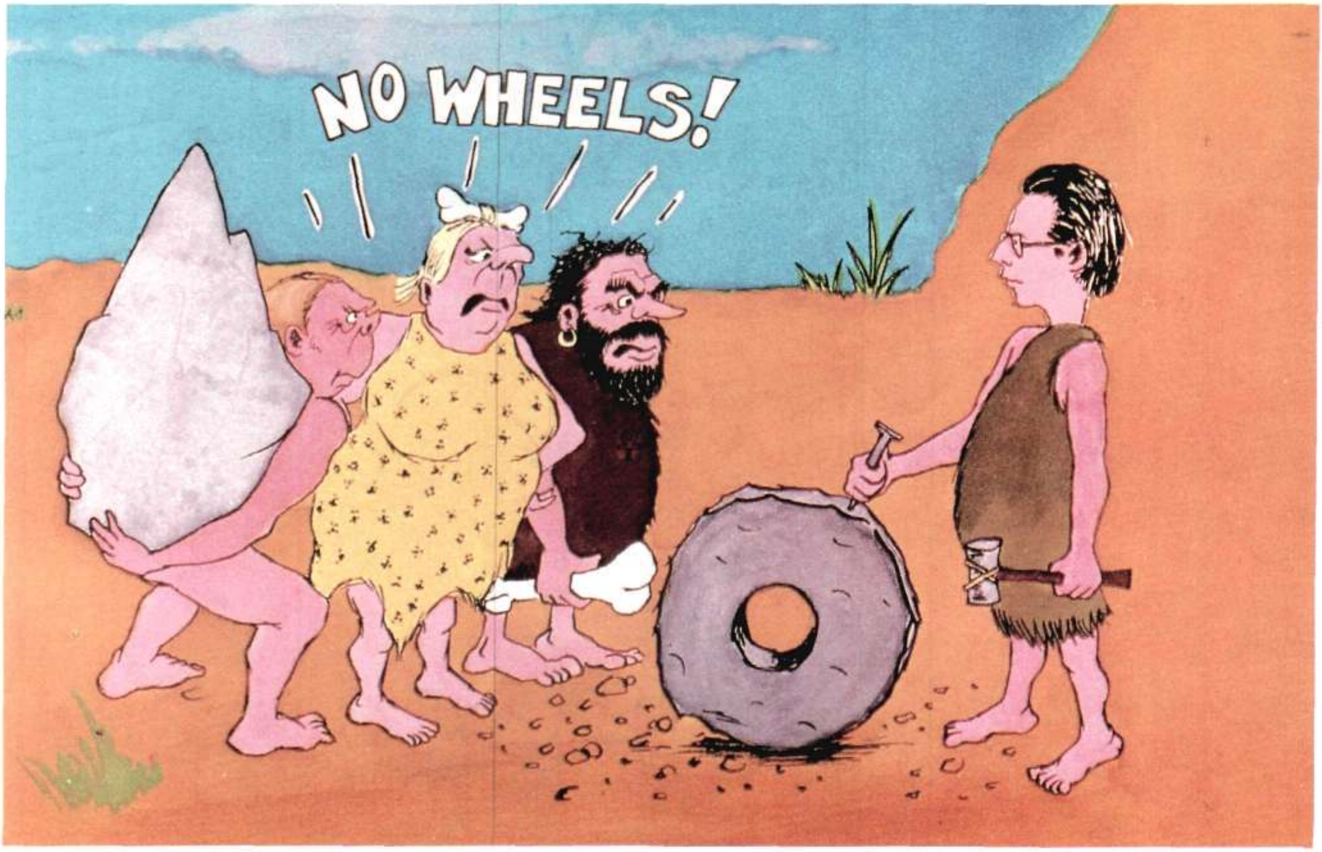

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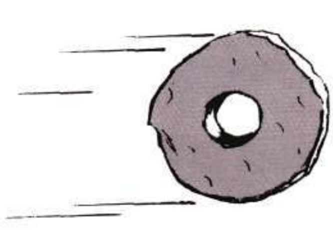

FUSION

MAGAZINE OF THE FUSION ENERGY FOUNDATION

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

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

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Special Report:
The Great Reindustrialization Debate

The Technological Frontiers

India: Paradigm for Development

America's Opportunity

News

Departments

Editorial

Fusion: The Keystone of Reindustrialization

With this special issue on "The Great Reindustrialization Debate," *Fusion* signals its intention to play a major role in shaping policies in this vital area. Fortunately, those of us committed to a high-technology, export-oriented policy have been provided with a most valuable piece of ammunition—the report of the Department of Energy's fusion review panel, headed by Dr. Solomon Buchsbaum of Bell Laboratories.

The Buchsbaum report, reprinted in full in this issue, is the most important validation ever presented of the fusion program and of the viability of moving fusion into its engineering development phase. Its main conclusion is that although a broad-based fusion research program should be maintained, there should also be an immediate push for a project that tests engineering feasibility, funded through doubling the fusion budget to $1 billion annually.

These findings stand by themselves as the basis for the United States to immediately implement Congressman Mike McCormack's legislative mandate for an Apollo-style effort to build a demonstration fusion reactor by the end of the century. But there is also a larger implication. A national commitment to develop fusion power and its related chemical and processing technologies also properly sets the parameters for reindustrialization policy as well.

First, there should be no more talk of the discredited concept of "scarce resources." Second, it is equally obvious that to lay the basis for a fusion economy, there must be full development of fission technologies, from mass production of floating plants, nuplexes, and advanced breeder reactors to high-temperature reactors and their chemical applications. Third, we can take a much harder look at the mix of energy sources and technologies (and their underlying political and economic assumptions) that will provide us with the bridge to the fusion era.

If the criteria are low price, high efficiency, and productivity (that is, maximum energy flux density) and if the policy is to produce hydrogen in the minimum possible time via nuclear- and plasma-based processes, then technological and economic strategies other than those now being pursued are clearly called for.

The West Europeans and Japanese, for example, have demonstrated the viability of oil-for-technology deals. The Soviets are making use of the magnetohydrodynamic method of fossil energy conversion to electricity. The West Germans use nuclear power to gasify coal.

The point is that we are not slaves to the blind forces of either nature or politics. We determine the laws governing both. We still have the option of pursuing policies of international development and cooperation within which our unique scientific and technological capabilities will guarantee us economic strength and strategic security.

We have selected the articles in this special issue to illustrate and highlight the vast possibilities that are still open to us if we have the moral fiber to set a great purpose for our nation. In the United States, as in this issue of *Fusion*, the role of the fusion program is at the center of the great reindustrialization debate.

The Lightning Rod

My dear friends,

Returning from a brief trip to market some months ago, I was astonished to find a young man and woman engaged in a heated argument on my doorstep. So violent was their quarrel, in fact, that they did not even notice my presence.

"Here now!" I exclaimed, "what has set you two at each other? I am a peaceable man and don't care for such disturbances on the portals of my hearth."

Whereupon both parties turned to see who had accosted them, and the girl seized my arm and batted an impressive set of eyelashes at me in a fashion altogether flattering to a gentleman of my advanced years, almost causing me to drop my groceries. Fortunately her companion, a tall, well-muscled fellow with an army-surplus knapsack on his back, came to my rescue with a helping hand.

"Why, you must be Dr. Franklin," the youthful temptress cooed.

She was dressed in the simple, unpretentious fashion of today's youth: a t-shirt and diamond-studded, designer bluejeans.

"I'm Ephemera Love-Ins, with a hyphen," she continued. "I came to discuss our future together—our global future, that is."

"Delighted," I replied, bowing with all the gallantry I could muster. "Is it Miss or Mrs.?"

"Ms., of course," she replied with a touch of hauteur, withdrawing her hand.

"Anyway, when I got here this disgusting peddler told me he was here first, and wouldn't go away no matter what. It's people like him who are overcrowding this planet, and . . ."

At this juncture her companion intervened, grabbing my hand and pumping it up and down several times with a grip that could have crushed granite.

"Bill Dupp," he introduced himself. "I'm with Beartraps, Unlimited. If you could spare just a few minutes . . ."

"Haven't I seen you before?" I asked. "Didn't you used to play . . ."

"Quarterback," he nodded happily.

"Well, we can't conduct business here in the street," I declared. "Why don't you both come in?"

As soon as we were indoors, my two guests immediately began a new quarrel over who would command my attention. When I suggested we apply the ancient principle of "ladies first," Ephemera insisted the floor be given over to Bill.

"Ben, I'm a simple man and my message is simple," he began. "This country is in trouble. We've got to have more beartraps. Beartraps are what made this country great."

"Beartraps are nasty!" Ephemera broke in. "They're male-dominating, expensive, and pollute the environment. They probably cause cancer."

She certainly had a lovely tan.

Apparently oblivious, Bill resumed: "Ben, did you ever hear the saying 'Build a better beartrap, and the world will beat a path to your door?' Well, I don't have to tell you, the world is pretty down on us these days because we're just not putting out beartraps the way we used to."

"That's nonsense," Ephemera interrupted again. "The world doesn't like us because we're always producing ugly, awful machines like beartraps, instead of sunning ourselves on the beach the way Nature intended. Beartraps are imperialist."

Undaunted, Bill plowed on. "The bears are getting bigger and greedier all the time. I'd like to put a beartrap in every house on this block, Ben, but I just haven't got 'em," he said, as he reached for his knapsack.

"Why, just look at this old sample they gave me," he complained, dragging out a well-rusted hunk of metal. "I'm ashamed to show it to you."

"Bill, I agree with you," I said. "A bear in a quiet residential neighbor-

Continued on page 4

Calendar

September

30-Oct. 2
Fuel Cycles for the '80s
American Nuclear Society
Gatlinburg, Tenn.

October

5-8
Workshop on Power Plant Security
American Nuclear Society
Oakbrook, Ill.

5-7
2nd Annual North American Meeting
International Association of Energy Economists
Washington, D.C.

6-8
Int'l Conf. on Materials for Nuclear Steam Generation
American Nuclear Society
St. Petersburg, Fla.

7-9
24th Conf. on Analytical Chemistry in Energy Technology
Department of Energy
Gatlinburg, Tenn.

13-16
3rd World Energy Engineering Congress
Alliance to Save Energy
Atlanta, Ga.

14-17
4th ANS Topical Meeting on Technology of Controlled Nuclear Fusion
American Nuclear Society
King of Prussia, Penn.

20-24
Int'l Conf. on Current Nuclear Power Plant Safety Issues
IAEA
Stockholm

22-23
Uranium Industry Seminar
Department of Energy
Grand Junction, Colo.

The Lightning Rod

Continued from page 3

hood like this one could be quite a problem. But to tell you the truth, I think we've got other problems too.

"I'd like to hear what Ephemera has to say about our global future. You know, when I was at the butcher's today, I had to pay a stiff price for my dinner, and it seemed to me the meat wasn't as good as it has been. Living on a government pension as I do, it isn't easy, and there are a lot of other hungry people—not to mention the bears."

"We've all just got to conserve," said Ephemera sweetly, glancing at me with some disapproval. "You look as if you could lose a little weight anyway." I felt our friendship cooling.

Bill refused to be distracted. "If we don't do something about the bears," he said, "you might not be around to enjoy your dinner soon."

"I see your point," I told him. "But let me ask you a question. Don't you think our beartrap problem has something to do with our steel problem? I read somewhere recently that our steel factories are only operating at 60 percent of capacity, and plants are closing down all over the place. Now how are we going to make good steel beartraps without steel?"

I noticed that at the word "steel," Ephemera turned white. But Bill looked at me thoughtfully. I was beginning to feel a certain fondness for the boy. Although somewhat obsessed with bears, it was clear he understood what I was talking about.

At this point a remarkable change came over Ephemera.

"Bill, honey," she murmured, and walked over and sat down in his lap. "The only important thing is catching bears, isn't it?" (I could see he found it more than a little unsettling, especially when she began to run her fingers through his hair.)

"Yes, ma'am," he said.

"Well, what if we could build a cheap, safe, natural sort of beartrap that wouldn't cause pollution or hurt the nice bears? Wouldn't that be good for everybody?"

"I guess so," said Bill.

"And then the bears wouldn't get mad at us if they got caught, but would just pass away peacefully. . . ."

"Mmm," said Bill, whose eyes were beginning to glaze over.

"I'm not sure this is going to work," I said to no one in particular, for by that time they were drifting out my door on a cloud.

At last report, they were still together. Ephemera is running a macrobiotic health food store, and Bill has a little workshop in the basement where he turns out handtooled leather beartraps—it's right next to a Chinese laundry.

Apparently they still quarrel frequently, and I'm not sure Bill is really happy. But his friends say he is very proud of their young son, and Bill tells everyone that someday, when the boy grows up, he's going to be the President's National Security Advisor.

Yr. obt. svt.,

Benj. Franklin

Letters

Evolution: A Transcendent View

To the Editor:

The aim of this letter is to express my admiration for the scientific paper of Carol Cleary published in *Fusion*, March 1980.

The title, "Evolution: A Riemannian Approach to Biology," rapidly gives to the reader the fundamental structure of the scientific biological model presented by the author: The inside space of living matter cannot be explained within the limits imposed by Euclid's geometry. A more extensive and unlimited geometry is needed in which the biological phenomena may reach successively higher and higher order domains. In these domains negato-entropic organization increases to such a degree that biological species became capable of transforming the surrounding medium, that is, the biosphere.

When Riemannian geometry is considered a fundamental part of scientific models in biology, a new light illuminates the investigator helping to solve the "question of evolution." The errors and fallacies of the Darwinian view are easily grasped: "Survival of the fittest" is only a wrong model.

The theory that evolution proceeds by random small biochemical changes in the gene's coding for a structural or enzymatic protein-point is also a scientific model that does not agree with the facts. Point mutations were found to occur at an equal rate in placental mammals and in lower vertebrate species. On the other hand, changes in the number of chromosomal arms occur five times more frequently and increases in chromosomal number seven times more frequently in placental mammals than in lower vertebrates.

Continued on page 6

Letters

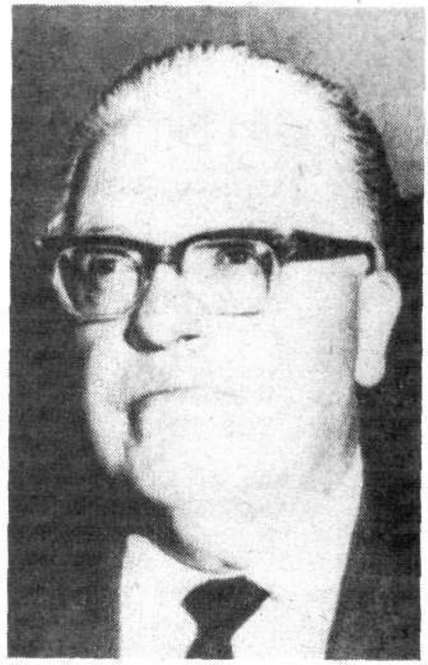
Continued from page 5

Ecological opportunities for evolution are fundamental, and in this respect Cleary says: "Rapid evolution of the sort that could account for the mainline fish-to-amphibian-to-reptile-to-mammal vertebrate development is thus not related to random variations created by point mutations in genes. It is related to higher-ordered rearrangements in chromosomal structure apparently caused in placental mammals by advances in social structuring of the species under favorable ecological conditions (Wilson 1975, Bush 1977)."

Cleary's article is still more transcendent; it is Platonic in essence. It defends the progressive order that can be reached by biological organization improving the surrounding medium, and it implies the defense of all negato-entropic mechanisms. This means also that the highest organization of the universe from which reason is derived has the potency to be a creator within the same universe. God, the supreme Creator, loves man so much that He has given him this pristine gift—that of creation.

Dr. Demetrio Sodi Pallares
Mexico City

Dr. Sodi Pallares is former chief of the department of electrocardiography at the Institute of Cardiology in Mexico City and former president of Mexico's National Academy of Medicine. His article on the "Negato-Entropic Therapeutic Action of Insulin in Cardiac and Other Cases" appeared in the July 1979 Fusion.



Demetrio Sodi Pallares

The 'Education Gap'

To the Editor:

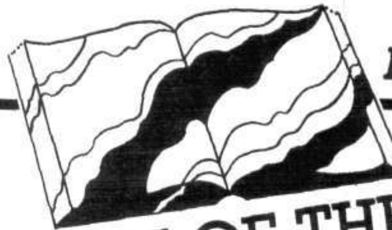
Professor Wirszup's study of Soviet precollege science curricula, a boxed insert in Ms. Gilbertson's August 1980 special report, "Something's Rotten in U.S. Education," reminds me of studies done in the post-Sputnik 1950s, to prove the existence of an "education gap." While the professor's study appears alarming, like the earlier ones it seems to look only at the names of courses.

In the 1950s, these names were inflated for propaganda purposes. I recall that a simple shop course in sheet-metal construction was called "metallurgy"; while foreigners who visited an English class were unable to sustain a grammatical conversation with the class's best students. (It seems that they were being given high grades so that their instructors would look good. A perennial problem in the field of Soviet Quality Assurance.)

I do not recall other examples, but the point was clear: Establishing a demanding curriculum does not guarantee a high level of education. Also required are (1) apt students (which eliminates most general populations, especially including that of the Soviet Union, which is still largely rural and Asian); and (2) objective enforcement of objective standards (which any bureaucracy will eventually defeat, let alone the Soviet one).

Over 20 years ago, we cried about an "education gap" on the basis of such studies as this one. It turned out to be a propaganda hoax. They want us to be taken in by their propaganda, so that the strong will lose heart and

Continued on page 85



News Briefs

Charles Cantus

Rep. Mike McCormack: "Five hundred nuclear plants by the year 2000."

TSONGAS ANTINUCLEAR OUTBURST ENDANGERS FUSION BILL

Members of the fusion community were stunned when Senator Paul Tsongas announced at the hearings on his fusion bill July 28 that he had proposed the bill as "an alternative to the Clinch River Breeder Reactor." According to Washington sources, the future of the bill, SR 2926, is uncertain, largely because of the unpredictability of the antinuclear Tsongas. Testifying at the hearings before the Research and Development Subcommittee of the Senate Energy Committee were Edward Frieman, director of the Department of Energy's Office of Energy Research; Dr. Stephen Dean of Fusion Power Associates; and Dr. Zalman Shapiro, head of the Westinghouse fusion program, who was representing the Atomic Industrial Forum.

In a second outburst, the junior senator from Massachusetts interrupted the hearings, just before Shapiro testified, with a diatribe against the pronuclear Fusion Energy Foundation, demanding that industry representatives disassociate themselves from the FEF. Tsongas also tried to pressure the fusion spokesmen to state that if we had fusion by the year 2000 the nation would not need the nuclear breeder.

Fusion supporters had hoped that the Tsongas bill would provide a basis for negotiation with the House fusion bill sponsored by Rep. Mike McCormack, but many are now wary of Tsongas's approach. In a syndicated newspaper article on *Fusion* that appeared in the Contra Costa (Calif.) *Times* a week before the hearings, Tsongas is quoted as saying: "I was aghast at the stuff that's in that magazine. . . . I saw their magazine and I almost considered withdrawing my bill."

McCORMACK CALLS FOR 500 NUCLEAR PLANTS BY 2000

Representative Mike McCormack, a Washington Democrat, told a July 21 symposium on "Nuclear Power Prospects, Problems, and People" that the United States should build 400 to 500 nuclear plants and develop breeder and reprocessing technologies by the year 2000. The Washington, D.C. forum, sponsored by the industry-supported National Energy Resource Organization, included presentations by several legislators and scientists.

McCormack said that "the professional counterculture antinuclear environmentalists" were impeding the U.S. nuclear program. The Department of Energy has not published any public documents on nuclear energy, McCormack said, and the one they have in progress is being held up by counterculture advocates within the DOE. McCormack also said that Congress should rewrite the National Environmental Protection Act and the Clean Air Act "so that they do what they were intended to do and are not used as a weapon to prevent almost anything from getting built in this country."

A full report on the forum will appear in the November Fusion.

HOUSE RESTORES NUCLEAR LABORATORIES CUTS

The U.S. House of Representatives voted up an amendment June 24 restoring $107.4 million for fusion, fission, high-energy physics, and solar energy work at the national laboratories. Rep. Don Fuqua, a Florida Democrat who chairs the House Science and Technology Committee, sponsored the amendment. Stating on the floor of the House that this is the first time in 18 years he has advocated restoration of a spending cut, he declared, "I plead with my colleagues" to avert the shutdown of laboratories that would be forced by a planned dismissal of 1500 R&D personnel. Specifically citing Brookhaven, Fermi, and Oak Ridge laboratories, Fuqua stressed the need for maintenance, "and I am not speaking of maintenance as it relates to leaky roofs or leaky faucets, but maintenance on equipment that they utilize in carrying out this basic research." The 1981 fiscal year funding amendment, which Fuqua termed "half a loaf," passed 254 to 151.

COMMISSION ON MEDIA HITS PRESS FOR TMI LIES

In a news conference at the Pennsylvania State Capitol building in Harrisburg July 18, the recently formed Independent Commission to Investigate Media Corruption and Unfairness reported its findings on the role of the media during the Three Mile Island incident. There was a deliberate policy to keep qualified scientific personnel away from the news media at TMI, said commission member Ira Seybold, a nuclear radiation and plant safety expert. Seybold presented the 25 reporters in attendance with the commission's report on who controlled the press behind the scenes—the White House, the National Security Council, the Justice Department, the governor's office, and the Federal Emergency Management Agency. Two CBS-TV affiliates and the *Philadelphia Inquirer* reported on the commission's findings.

UNIVERSITY FUSION ASSOCIATION LAUNCHED

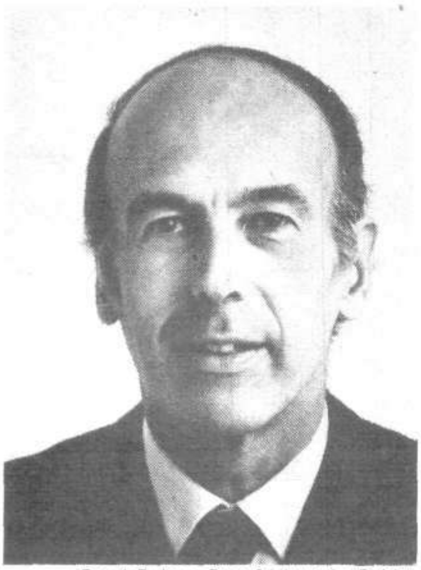
Academic-based scientists around the United States formed a University Fusion Association to promote the continued participation of university research groups in the fusion program and "to enhance the broad-based support for fusion, both in plasma physics and engineering, through contacts with various segments of our society."

The association had more than 100 individual members on July 1 and elected an executive committee that includes F.F. Chen, UCLA; H.R. Griem, University of Maryland; R.N. Sudan, Cornell; J.L. Shohet, University of Wisconsin; H. Grad, New York University; R.A. Gross, Columbia University; G.H. Miley, University of Illinois; F.L. Rone, University of Washington; B. Coppi, MIT; K.W. Gentle, University of Texas; N. Hershkowitz, University of Iowa; and A. Simon, University of Rochester.

Interested university fusion personnel should contact an executive committee member or Joyce Oliver, 308 Upson Hall, Cornell University, Ithaca, N.Y. 14853, (607) 256-1000, ext. 4275.

FRANCO-GERMAN SUMMIT STRESSES JOINT DEFENSE

French President Valéry Giscard d'Estaing and West German Chancellor Helmut Schmidt concluded a five-day summit meeting in Bonn July 11 with a joint press conference at which, for the first time, a leader of the Federal Republic publicly praised France's independent *force de frappe* military apparatus as a capability for the defense of Europe. Schmidt stated that he welcomes recent French breakthroughs on the neutron bomb as a contribution to modernizing the French deterrent. The complementarity of the French and West German economies was also stressed in the summit's final communiqué. The conservative French daily *Le Figaro* commented editorially that Giscard and Schmidt envisage "a joint common security based on the French nuclear force and German classical conventional military capability."



French Embassy Press & Information Division

Giscard: An umbrella for France's allies

U.S. FIRM CHARGED WITH MILITARY TRANSFERS TO CHINA

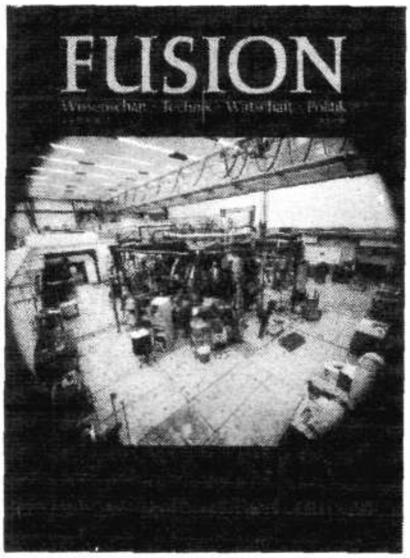
Potomac International, a Washington-based firm, is involved in transferring military technology, including missile technology, to the People's Republic of China, according to Capitol Hill sources. U.S. Defense Secretary Harold Brown has reportedly approved the clandestine conduit to China of information required for producing "enhanced radiation warheads," or neutron bombs, and technology required to build solid-fuel missile delivery systems that could reach the western United States.

Potomac International is headed by Richard V. Allen, a senior advisor to Ronald Reagan who helped Henry Kissinger develop the Nixon administration's "China initiative" in 1972. He is widely considered to be first in line as Reagan's national security advisor should the California Republican be elected president.

SOVIETS BUILDING WORLD'S FIRST NUPLEX

The Soviet Union is constructing the world's first nuplex, an industrial complex centered around a high-temperature nuclear reactor, according to the July 5 issue of the French weekly *L'Express.* The plan is to build 1,000-megawatt high-temperature nuclear reactors connected to steelmaking or chemical factories to supply industrial process heat. The Soviets reportedly estimate that such a 1,000-MW plant could supply the energy for two chemical plants producing 1 million tons of ammonia for fertilizer, or one steel plant with a 2 million ton per year capacity. The nuplex design not only makes use of the "waste" heat from the nuclear power generation process, but also eliminates the need for separate fossil-fuel-based industrial heat and electric power supply. The Soviets have announced that a demonstration nuplex is under construction, but did not disclose where it is being built.

The Fusion Energy Foundation has proposed nuplexes as the centerpieces for industrializing the Third World.



The first German-language Fusion, *July 1980*

PROMARIJUANA MEDICAL EXPERTS REVERSE GEARS

Leading medical experts who formerly called marijuana a harmless recreational drug are now warning of the drug's medical dangers. Dr. Robert L. DuPont, the former director of the National Institute of Mental Health who had lobbied for legalization of the drug, recently told a nationwide television audience that he has changed his mind because "we now know a lot more about the health hazards of marijuana and how really dangerous it is." A recent Institute report to Congress criticizes the pot lobby's attempts to compare the medical dangers of marijuana to those of tobacco and alcohol. Such comparisons "falsely minimize the hazards of marijuana," the report says.

FUSION PUBLISHES IN GERMAN

The first issue of a German-language *Fusion* magazine appeared in July, published by the Fusion Energy Forum (FEF) based in Wiesbaden, West Germany. Printed in a run of 10,000, *Fusion* features the history of tokamaks and a report on the Asdex experiment at the Institute for Plasma Physics in Garching, Europe's largest fusion facility. Editor Hans Bandmann reports that the new bimonthly magazine is expected to grow quickly. Subscriptions are 24 deutschemarks for six issues (4.80 DM per single issue) and can be ordered from the FEF, Postfach 2448, 62 Wiesbaden, West Germany.

FUSION GOES 'CLASSIFIED'

Fusion is pleased to announce a new classified advertising section that includes small display ads. Started in response to requests from readers and advertisers, the display section will include the announcement of new products and materials, new companies, seminars, conferences and trade shows, and publications. For more information on the classified ad section call Patricia Van Thof, (212) 265-3749.

LOUSEWORT LAURELS TO U.S. GEOLOGICAL SURVEY

The Lousewort Laurels this month go to the U.S. Geological Survey for its contract to Stanford Research Institute International to organize "Project Earthquake Watch" modeled on the Chinese method of earthquake prediction. According to a report in *Science News* June 14, the project involves 1,250 human volunteers who observe the behavior of certain animals, looking for changes that the Chinese claim indicate the imminence of an earthquake. Such behavioral changes include snakes crawling out of hibernation, dogs running in circles, and rats swarming in the streets in daylight.

The results seem appropriate to the technology. In the year since Stanford's 1,250 observers have been on line, six earthquakes of magnitudes of 5 or greater on the Richter scale have struck California, but only two touched on the fringes of the animal-watching network. And according to Stanford, the predictive accuracy in these two cases was "inconclusive."

Viewpoint

Getting Serious About Nuclear Energy

by Rep. Clarence Brown

It is not overly dramatic to say that the nuclear option is today facing its most severe test. Battles are being waged against nuclear power before administrative agencies, in the courts, in the halls of Congress, in our states and cities, and even in the streets.

Nuclear power in this post-Three Mile Island period has become an easy symbol on which to focus the public's fear of the unknown. Despite fatal DC-10 crashes, evacuations forced by the derailment of trains transporting deadly chlorine gas, acid rain and increased carbon dioxide in the atmosphere as a result of more coal burning, and more than 50,000 deaths a year on our nation's highways, nuclear power has been the target in a war of extinction waged by self-appointed protectors of the public.

The weapons in that war have been harassment and red tape—frequently changing and increasingly stringent regulations, many of which are not needed to ensure safety.

Since the 1960s the time required to bring a nuclear plant on line has doubled. In fact, it now takes twice as long to license and build a nuclear plant in the United States as it takes European countries and the Japanese to build plants using the same technology.

As a result of long licensing times, changing regulations and the accompanying construction delays, and uncertainty about the federal government's intentions for the future of nuclear power, many utilities have canceled plans for nuclear expansion. Over the past several years, cancellations of existing orders for nuclear plants have exceeded new orders. In fact, since 1978 no new reactor units have been ordered. Consequently, projections of nuclear-generating capacity by the year 2000 have fallen steadily from a 1972 forecast of 1,200 gigawatts to the present forecast of approximately 300 gigawatts.

Although it is clear that nuclear energy is facing severe problems, there is also cause for optimism. Shortly after the Three Mile Island accident, there were several attempts to kill nuclear power through congressional action. These efforts sought to overburden the licensing process and thus make nuclear power so unattractive to utilities that they would abandon their nuclear plans. It didn't work.

In the House of Representatives in June 1979, Congressman Jim Weaver (D-Ore.) offered an amendment to the Nuclear Regulatory Commission Appropriations bill that would have prohibited the issuance of any new operating license to a plant that would be located in a state without an approved emergency response plan. Fortunately, the Weaver amendment was defeated on a 147 to 235 House vote.

Another amendment offered in the House by Congressman Ed Markey (D-Mass.) would have imposed a six-month moratorium on the issuance of new construction permits. This amendment to the NRC authorization bill fell by an even wider margin—135 to 254.

So as the votes in Congress demonstrate, there is unlikely to be any vote to kill future nuclear expansion. There continues to be strong congressional support for a breeder program and there appears to be a greater willingness to forge ahead to resolve some of the spent-fuel-storage and waste-disposal problems confronting the nuclear industry.

It is abundantly clear to me that we must forge ahead with nuclear development. It is pure stupidity to reject this most important contributor to our energy future. I am sure that the Democrats will realize this when the voters react to their antinuclear platform this fall.

No Other Alternative

The fact is that in the intermediate and long term, we have no other alternative than to proceed rapidly with nuclear development. Our other alternatives—to rely more on oil and gas—are totally unrealistic and are more likely to lead us into war than almost any other thing that I can think of. Of course, conservation, solar, and other renewable energy resources are part of an answer; but so is nuclear energy.

Those who maintain that a full commitment to conservation and renewable energy resources will wean us from our dependence upon foreign oil and allow us never to build another nuclear plant are deluding themselves. We simply have to be realistic about our energy future. In my view, the Japanese and Europeans are approaching the problem more realistically than are we.

In my talks with the Japanese, who have had a uniquely horrible experience with nuclear energy,

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Buchsbaum Report Is Well Received

The evaluation by the fusion community, the Office of Management and Budget, and the leadership of the Department of Energy fusion program is that the report of the Fusion Advisory Panel headed by Dr. Solomon Buchsbaum of Bell Laboratories will bolster attempts to increase the funding and national commitment to the magnetic fusion program.

The panel, assembled by request of Dr. Edward Frieman, the director of energy research of the DOE, will have its draft report considered by the DOE's Energy Research Advisory Board (ERAB) Aug. 18. Buchsbaum chairs the full ERAB.

The Buchsbaum report, released June 23, has received little coverage in the nation's press. However, in an article on the front page of the June 24 *Washington Post*, Tom O'Toole reported that the Buchsbaum recommendations "are likely to have a deep impact on the White House, the Department of Energy, and the Congress, in part because the panel consists of some of the nation's most renowned scientists."

This impact is already being felt. Congressman McCormack was able to point to the distinguished panel's conclusions in his successful attempt to add money to the fusion budget's fiscal year 1981 appropriation.

Support for Senate Bill

Also, the report will be used to support Senator Paul Tsongas's fusion bill, introduced into the Senate July 2. The bill, SR 2926, was submitted with six cosponsors, including Senators Church (D-Id.), Sasser (D-Tenn.), Baker (R-Tenn.), Williams (D-N.J.), Bradley (D-N.J.), and Domenici (R-N.M.).

Although the Senate bill does not specify the required budget increases for magnetic fusion either for fiscal year 1981 or overall, as McCormack's House fusion bill does, it calls for demonstrating fusion reactor engineering feasibility in the early 1990s and commercial feasibility by the year 2005.

According to Mitch Tyson, energy aide to Senator Tsongas, the senator hopes to hold hearings in the beginning of August, between the congressional recesses. If there is no strong opposition within the Senate Energy Committee, Tyson estimates that mark-up for the bill could take place as early as September.

One of the important aspects of the Tsongas bill is that although less than perfect, it adds seriousness to McCormack's fight for his fusion bill in the House. As a McCormack staff member commented, it puts something on the table around which to hold "negotiations."

Likewise, the Buchsbaum report itself opens the door for the DOE to reverse its delayed schedule for making a decision on building a next-step engineering device, a delay that sets back the entire fusion program.

The Buchsbaum report also gives the Office of Management and Budget some back-up in supporting the program plan of the DOE fusion office to accelerate the fusion timetable.

Buchsbaum Comments on Report

Fusion asked Dr. Solomon Buchsbaum to comment on the report of the DOE Fusion Advisory Panel he headed. Here are excerpts from his remarks.

The fusion program is ready for the next phase, which is engineering experimentation and analysis. In a nutshell, the panel's report called for steering the fusion program on its natural path of evolution. Until now the program has focused on the physics questions.

I was very impressed by the way the panel went about its work. Each of the panel members devoted a lot of time and attention to this effort. The panel jelled very quickly and was able to come up with its recommendations unanimously.

The full Energy Research Advisory Board might modify the report. Hopefully, it will not throw it out, but it will be used by the Department of Energy.

Industry's Role

The panel members all agreed that the next step cannot take place without industry. The program needs a deep and long-term involvement of industry. Everyone agreed with that.

The panel was favorably impressed with the international cooperation in the program, with the INTOR [the tokamak of the International Atomic Energy Agency] design work and the exchange of knowledge between countries. The U.S.-Japan cooperation is particularly attractive.

The panel is helping to steer the program on its technical path. We are pleased to have been of help. Fusion is a long-term program, needing several more decades to achieve a commercially viable fusion reactor.

Fusion Budget Flip-Flops in Congress

Caught between the administration mandate for budget cuts and the political mandate to beef up the U.S. magnetic fusion program, fusion funding has been added and subtracted more than once in the congressional budgeting process.

In a late session July 2, just before the congressional recess for the July 4 holiday, the House passed a supplemental budget request for add-ons for some programs and at the same time approved recisions for nearly every Department of Energy program. Reportedly, the fiscal year 1981 fusion program was cut by $5 million.

In addition, as *Fusion* goes to press, the House has passed an amendment by Congressman George Miller, a California Democrat, that will cut 2 percent across the board from all DOE programs. Sources on Capitol Hill report that the decisions have not been made as to how this will affect each individual program.

The Senate has not completed its part of the budget process. With the Congress in abbreviated summer session because of the party presidential conventions, Senate deliberations will be cutting the Oct. 1 fiscal year 1981 deadline close.

Up and Down History

At the beginning of May the Energy and Water Subcommittee of the House Appropriations Committee had marked up the fiscal year 1981 magnetic fusion budget at about $366 million—$30 million less than that requested by the Department of Energy and $60 million less than the amount authorized by the Science and Technology Committee of the House.

When the full Appropriations Committee marked up the bill to go to the full House floor, it left the subcommittee's recommendation untouched. A letter from presidential science advisor Frank Press asking the committee to restore funding to the DOE's request level of $396 million seemed to have no effect.

On June 24, when the Appropriations Committee bill went to the House floor, Congressman Don Fuqua (D-Fla.), chairman of the Science and Technology Committee, offered an amendment to increase the fiscal year 1981 magnetic fusion budget by more than $20 million to bring the total back up to $394.1 million. The full House voted up the increase by 254 to 151.

This overwhelming vote of confidence for fusion budget expansion was bolstered by Congressman Mike McCormack's reference during the floor discussion to the Buchsbaum fusion review panel report released the previous day, which had concluded that commercial demonstration of fusion can be accomplished before the turn of the century.

Carter Signs Synfuels Compromise

On June 30 President Carter signed into law his long-awaited synthetic fuels bill. The Energy Security Act had finally been approved by a Senate-House conference committee June 16, after more than a year of debate and rewrite. Three days before, however, the House unexpectedly sent back to committee the legislation intended to clear the way for the ambitious coal synthetics program by creating the Emergency Mobilization Board.

The synfuel compromise allocates $20 billion from now until 1987 to design and construct 10 plants to convert coal to liquid fuels. Each plant, producing 50,000 barrels per day of oil equivalent, is projected to cost more than $1.5 billion. The program will be overseen by a Synthetic Fuels Corporation, not the Department of Energy, and is to be reviewed in 1987.

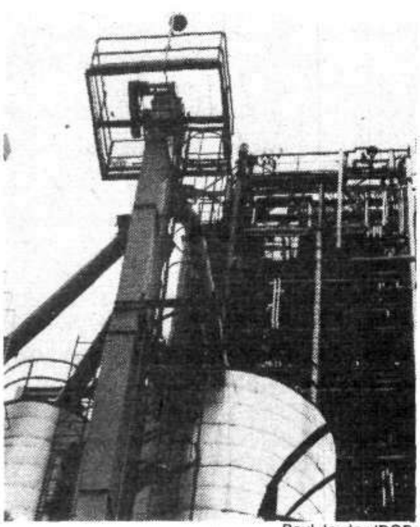
If at that time the program is judged economically and technically sound, an additional $68 billion may be authorized to give the United States a synfuel production capacity of 2 million barrels per day of oil equivalent by 1992. The $20 billion appropriation also includes $6.5 billion for a solar energy bank, financial incentives to the Defense Department to purchase the fuels, and money for alcohol fuels production by the Agriculture and Energy Departments.

Current estimates on the cost of these synthetic fuels are at least $45 (and more likely $90) per barrel of oil equivalent.

At the same time, under the gun of the "balance the budget" mania on the Hill, the Senate passed legislation June 23 providing $4 billion to help utilities convert oil-burning capacity to coal. The House has already passed a similar piece of legislation, and both versions authorize considerably less than the president's request of $10 billion.

The dramatic 232 to 131 defeat of the Energy Mobilization Board was a product of the combined forces of conservatives who felt that the board would have the mandate to trample on states' rights, liberals who feared environmental regulations would be tossed out the window, and others who just wanted to embarrass President Carter.

For an evaluation of synfuels, see "Inappropriate Technologies," Fusion, Sept. 1980, p. 71.



Paul Jordan/DOE

The DOE's High-Btu Gasification Pilot Plant near Chicago

Forecasting The Economy Away

The DOE modeling and analysis division went through one of its frequent exercises of "updating" its forecasts of energy and electricity growth for the United States last February. Along with previous exercises, the update provided data for the World Coal Study released in late May by the Massachusetts Institute of Technology. The MIT study projects U.S. coal production and consumption to the turn of the century, as well as overall economic growth.

The figures developed by the DOE and used by the World Coal Study estimate that U.S. GNP growth will slow to 2.8 percent per year from 1980 to the year 2000, that annual overall energy growth will be about 2.2 percent, and that electricity use will grow between 3.8 and 4 percent. Such energy and electric growth rates are little more than half the rates of growth during previous periods of relative economic prosperity.

The DOE projected that U.S. industry would continue to replace capital stock with more energy-efficient equipment, and that higher prices would "decouple" energy growth from overall economic growth.

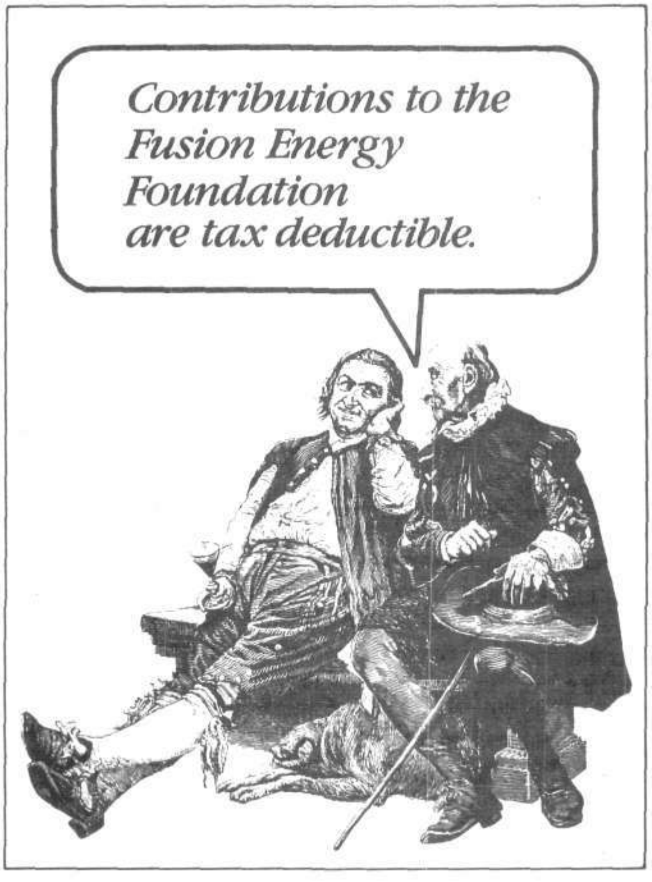
Now the DOE's most recent energy and economic projections have changed all this for the worse, assuming that the current "recession" will continue at least for the next year or two. According to Dr. John Stanley-Miller, who heads the modeling and analysis division of the DOE, his staff has just completed preliminary new projections that are not yet official, but are not likely to change.

Growth Rates Down

The new projections, Stanley-Miller said, are that "electrical growth rates to 1990 will be more on the order of 3.4 percent, not 3.8 to 4 percent. The industrial use of coal will also be more conservative than we estimated," he said, because as a result of the economic recession, companies are not buying new coal-burning boilers to replace their old oil burners. "Environmental constraints will also make coal more expensive than we had projected."

The release of the World Coal Study and the acceptance of its premises in the Venice summit communiqué of the leading OECD nations were heralded as a great push forward for world coal consumption. Stanley-Miller points out, however, that the DOE's projections of U.S. coal use "are lower than they used to be."

Indeed, in 1977 when President Carter made the "moral equivalent of war" speech announcing his energy program, his goal was the doubling of coal production to 1.2 billion tons per year by 1985. The DOE now considers it optimistic for U.S. production to reach 1.1 billion tons per year by 1990!



Viewpoint

Continued from page 11

they have indicated that they will proceed as quickly as possible in putting more nuclear plants on line. In addition, they have told me that they will not hesitate to go to anyone, including the Russians, who is willing to supply their nuclear fuel needs.

Unless we get serious about our commitment to nuclear energy, we will soon find that we are no longer leaders in nuclear technology. The loss of leadership in this area will have staggering implications.

Because of President Carter's 1977 decision to ban commercial reprocessing of spent nuclear fuel, his reduced emphasis on the Portsmouth, Ohio centrifuge enrichment project, and his opposition to the breeder reactor, we are rapidly losing our place as a leader in nuclear technology. The Europeans are reprocessing, they are enriching uranium, and they are vitrifying nuclear wastes. The facts speak for themselves.

In light of our domestic needs and the international imperatives, we must lay the groundwork for a major nuclear program on the domestic front. This program will include away-from-reactor storage facilities for spent fuel; the commercial reprocessing of spent fuel; permanent repositories for nuclear waste; the development and use of breeder reactors; a sharp reduction in the time it takes to license new reactors, consistent with safety; the rapid development and use of gas centrifuge enrichment facilities; and the development of nuclear fusion.

To implement this program in Congress, we will need to do some selective pruning of the legislative and executive branches. The result will be healthy growth next spring.

Clarence Brown, known as "Mr. Energy," has represented Ohio's seventh congressional district since 1965 and is the ranking Republican on the Energy and Power Subcommittee of the Interstate and Foreign Commerce Committee.

National

Economist Challenges Zero Growth In Science

In the June 27 issue of *Science* magazine, economist Julian L. Simon of the University of Illinois-Urbana takes on the lies and false assumptions widely publicized as fact by the U.S. media, the zero-growth movement, and such agencies as the United Nations and the U.S. Agency for International Development (AID).

Titled "Resources, Population, Environment: An Oversupply of Bad News," Simon's article documents the positive effects of increased population on societal well-being that result from the uniquely human quality of mind. "People bring not only mouths and hands into the world but also heads and brains. The source of improvements in productivity is the human mind, and the human mind is seldom found apart from the human body."

Simon takes apart the argument that "the instant a calf is born, per capita income and wealth go up, but the instant a child is born, per capita income and wealth go down," or as Malthus put it, that an increase in population "increases the number of people before the means of subsistence are increased [and the] food therefore which before supported eleven millions, must now be divided among eleven millions and a half." He counters that the important variable to look at is the "additional person's contributions to increased knowledge and technical progress."

Malthusian Econometrics

Modern econometric models accept the Malthusian perspective, and from this static equilibrium viewpoint do not allow sufficient time to account for people's development and subsequent positive effects upon society's increasing productivity, Simon writes. "But more important are an

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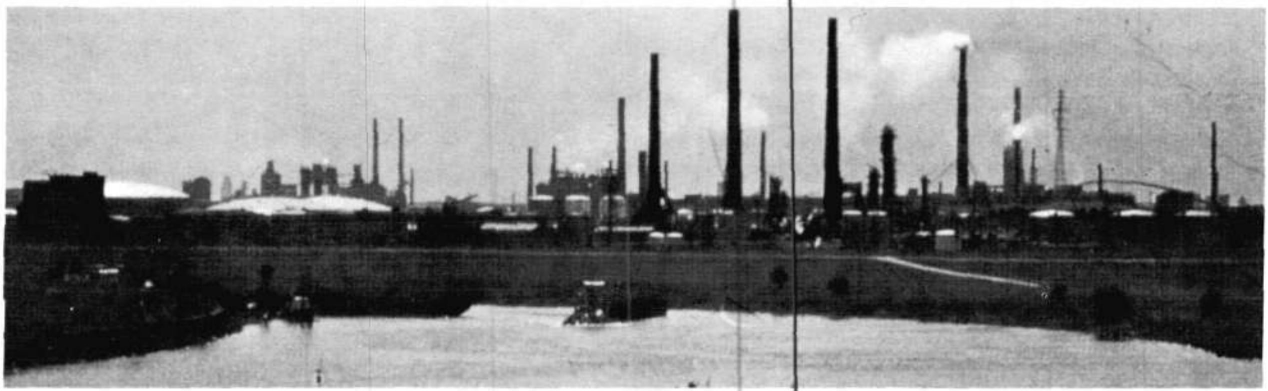
United Nations

Small, nonmechanized farms are the IMF and World Bank's policy for the Third World. Here, Ethiopian tribesmen tending a cotton field.

Special Report



United Nations

The Great Reindustrialization Debate

Recovering World Industrial Leadership:

Is it possible to do the right thing for the wrong reason? I think not, although on occasion it may look like that in the short run, and arguably some good may come from disorderly motion in the right direction—if only the arrest of further regress and the opportunity for the intervention of reason.

I am prompted to make this summary comment after reading through an impressive stack of articles, documents, memoranda, and discussion papers on the topic of the reindustrialization of the United States issued in recent months by a large variety of government and private institutions and published by as many journals. *One common motive runs through all* of them: the Soviet threat. Secondary motives for retooling mentioned in some cases are the German-Japanese threat to U.S. export positions and the possibility of an oil cutoff from the Middle East.

However, I feel compelled to conclude that if it were not for such inconvenient external threats, these same institutions and authors would find little wrong with the self-imposed moral and physical decay of U.S. society. Was it the Soviets who forced us to embrace the idiocies of the "postindustrial society," the ideology of "zero growth," and the virtually unopposed, widespread sale of mind-altering drugs to our school children? Did the Soviets invent the mind-destroying rock and disco music; are they behind the commercial-television-induced idiot passivity of much of our population, or the introduction of the New Math in our schools, which virtually assures the future scientific illiteracy of a whole generation? Finally, did the Soviets force upon us the decay of our steel industry, the cessation of investment in high-technology industries, the creation of an incompetent volunteer army, or the election of a president who made it his business to all but destroy our nuclear industry and several other advanced energy R&D projects, thus increasing the risk of nuclear war by increased dependency on foreign oil and the temptation to secure supplies by military force?

An honest observer will have to answer "no" to all of these questions. If the United States today is economically and militarily weak-kneed, intellectually flabby, and morally feeble, this is so not because we have been left behind by astonishing Soviet—or, for that matter, German and Japanese—breakthroughs and accomplishments in science, education, and military and civilian industrial production. It is so because we ourselves, and those whom we foolishly continue to allow to mislead us, have done an expert job at wrecking our scientific and industrial infrastructure, permitting a moral imbecile like Zbigniew Brzezinski or the Club of Rome's Aurelio Peccei, latterday followers of Thomas Malthus (original zero-growther and sworn enemy of the American Republic), to set the tone of the debate on our future rather than recovering for our guidance the ideas of Benjamin Franklin and the other founding fathers of this nation.

Table 1
ANNUAL RATE OF PRODUCTIVITY INCREASE 1965-1978

United States	1.9%
Canada	4.1%
Japan	8.1%
France	5.7%
West Germany	5.4%
Italy	5.7%
United Kingdom	2.9%

Source: U.S. Department of Labor, Bureau of Labor Statistics.

U.S. productivity, the key parameter for economic health, has increased at a much slower rate than in the rest of the industrial nations.

There is little doubt in my mind that the only regret Brzezinski and others of his persuasion—apostles of the "technetronic age" and the "postindustrial society"[1]—have about the present state of affairs in the United States and worldwide is that so far they have been unable to persuade, cajole, or blackmail the Soviet Union, West Germany, France, and Japan into going along with their vision of the brave, new, postindustrial world. Currently, from their perspective, an unfortunate but unavoidable tactical adjustment is necessary. They must restore, at least superficially, certain elements of America's industrial and military might, so as not to lose the world strategic initiative entirely to a French-German-Soviet détente alignment for the purpose of cooperation in the industrial development of the Third World.

Such an approach to "reindustrialization" as a temporary technical and political expedient cannot succeed either in the broader economic sense or in the accomplishment of seemingly narrower objectives like the rebuilding of U.S. military power. Overall profitability of investment in industrial capacity—ignoring economies of scale, which is justifiable for sufficiently large capital volumes—is directly proportional to the increase in productivity resulting from the investment and this, in turn, is a monotonic function of the degree of technological innovation embodied in the new capacity.

No attempted "quick fix" for the economy through expansion "in width"—that is, within the present technology base—could sufficiently conform to the necessary profitability criterion to definitively pull the economy out of the hole. In fact, as Dr. Steven Bardwell shows in an accompanying article, if linear, "in-width"

The High Technology Path

by Uwe Parpart

expansion of economic activity should be undertaken for the principal purpose of production of military hardware, it would absorb potentially productive output into nonproductive consumption and increase the drag and burden on the productive sector of the economy: A shortlived flash recovery would in short order be followed by even deeper collapse.

We have demonstrated both theoretically and empirically that the root cause for the enduring malaise and lack of crisis-resiliency of the U.S. economy is the 25-year cancerous—and since 1968 even more accelerated—growth of the economy's service sector in relation to goods-producing manufacturing and farming sectors (Figure 1).[2]

The increasingly rapid downturn in capital formation that accompanied this shift—the United States now reinvests less than 10 percent of GNP compared to West Germany's 15 percent and Japan's 20 percent—led not only to a slowdown in productivity growth in manufacturing, but also, for the first time in 1979, to net productivity losses (Table 1). Since 1965, the United States has averaged only a 1.9 percent annual rate of increase compared to West Germany's 5.4 percent and Japan's 8.1 percent.

The U.S. economy has actually become more labor intensive and less energy intensive since at least 1976. Thus, as we have shown previously, considered as a thermodynamic machine, the economy is losing its capacity to produce the "free energy" crucial to cushion external shocks and to power future expansion.[3]

Social theorists such as Herman Kahn, Zbigniew Brzezinski, or Daniel Bell (author of *The Coming of Post-Industrial Society*, 1973) may proclaim these economic facts signals of the transition to their technetronic or postindustrial age. (According to Bell the postindustrial society is "based on services," "a game between persons" as opposed to "a game against nature," "what counts is not energy, but information," not "the quantity of goods as marking a standard living, [but] the quality of life as measured by services and amenities.")

More aptly they are characterized as the quite unmistakable signs of the rot and destruction of U.S. industrial capacity. And Brzezinski may try to convince the gullible that "America, having left the industrial phase, is today entering a distinct historical era, a different one from that of Western Europe and Japan" and that "this is prompting subtle and still undefinable changes in the American psyche, providing the psychocultural underpinnings for the more evident political disagreements between the two sides of the Atlantic."[4] But the facts rather more simply are that the Europeans disagree with a Brzezinski-dominated U.S. government policy of deliberately wrecking one's own economy, only to then turn around

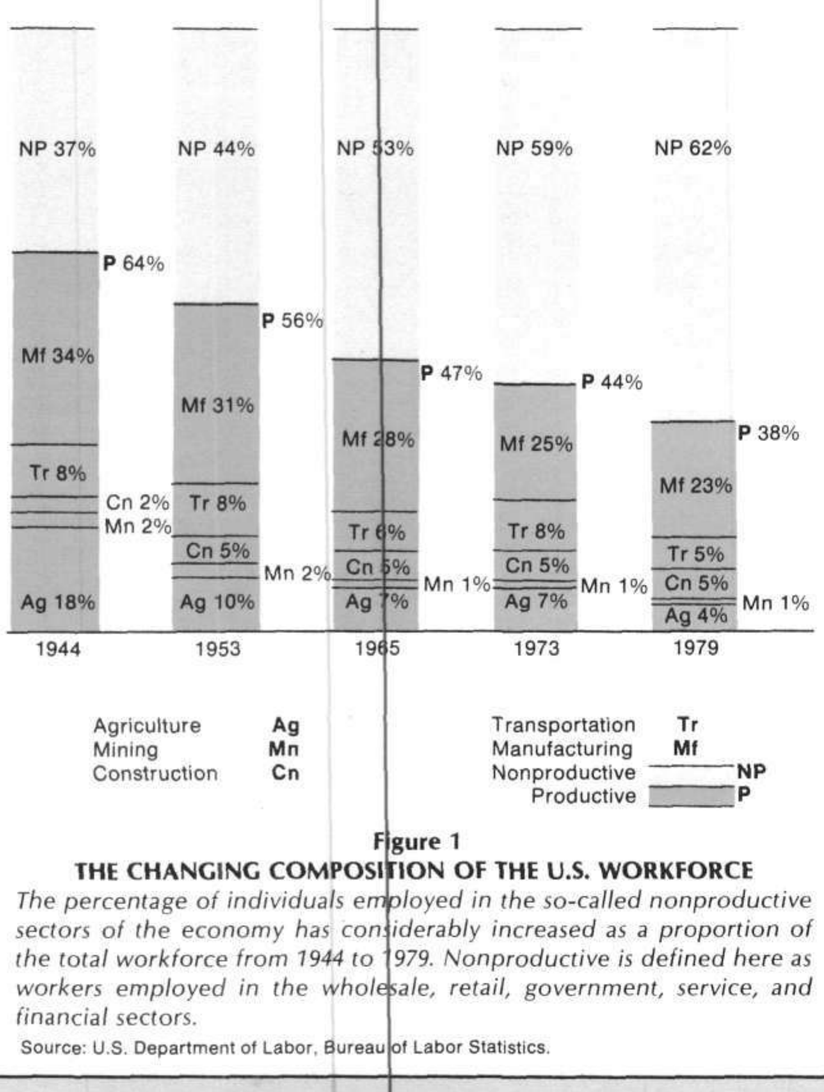


Figure 1
THE CHANGING COMPOSITION OF THE U.S. WORKFORCE
The percentage of individuals employed in the so-called nonproductive sectors of the economy has considerably increased as a proportion of the total workforce from 1944 to 1979. Nonproductive is defined here as workers employed in the wholesale, retail, government, service, and financial sectors.

Source: U.S. Department of Labor, Bureau of Labor Statistics.

and, from a position of weakness, aggressively push the world toward thermonuclear extinction.

To sum up the argument to this point: Since the 1950s, and increasingly since the mid- to late-1960s, U.S. capital stocks have been renewed at insufficient rates and have become increasingly obsolete. As a result, productivity growth has declined dramatically and during the last 15 years has averaged less than one-third the West European rate (not including Britain) or the even higher Japanese productivity increases; U.S. educational standards and performance have collapsed, declining by more than 20 percent since the early 1960s; and U.S. scientific and engineering manpower in R&D has decreased at an alarming rate.

The most recent (January-June 1980) collapse of U.S. industrial output, reflected in the exponential decline of the industrial production index further highlights the fundamental weakness of the U.S. economy (Figure 2).

These facts speak for themselves and should alone provide ample motivation for full-scale efforts to restore U.S. industrial and educational excellence without enlisting a Soviet threat that may or may not exist in the form portrayed but is causally unrelated to the U.S. problem at hand. It should be clear as well that only a reconstruction effort "in depth," attacking the root causes of the decay of U.S. industrial and moral strength will have a reasonable chance for success. It is precisely because such an "in depth" effort is needed that enlistment of an external threat to motivate reconstruction is such a dangerous and potentially self-defeating political game.

Those U.S. scientists, engineers, and industrial leaders whose past performance and present effort permit no doubt about their genuine concern for America's future must be warned that making short-term tactical alliances to ward off a Soviet threat or Middle East oil cutoff with the architects, apostles, and, until recently, the most ardent practitioners of zero-growth, postindustrialization, and the drug-rock counterculture—be that Brzezinski or the Navy's Elmo Zumwalt—contains the grave danger of blinding oneself or looking the other way when it comes to doing battle with precisely those political forces and ideological orientations that caused America's weakness in the first place.

It is the ultimate proof of loss of integrity and of the internal destruction of the nation if we no longer possess the intellectual vision and moral fortitude to set our own strategic goals, to do what is right for that and no other reason, rather than being prodded time and again into incompetent responses by an external foe.

Strategic Goals and Economic Principles of Reindustrialization

If American political and scientific leaders today looked at the world through the eyes of their one-time revolutionary leaders Franklin, Washington, and Hamilton rather than through the distorting spectacles of the ideological standard bearers of the empire these revolutionary leaders set out to utterly destroy—I want to single out in particular Adam Smith, Thomas Malthus, Jeremy Bentham, and the apparent adversary of the latter, Edmund Burke—then they would have no difficulty in discerning the strategic frontiers to be conquered over the next two or three decades and the initiatives to be taken to focus American efforts and restore a purpose to the nation. Before us lies the vast task and opportunity of collaboration with the nations of the Third World to lay the firm foundations and, in many cases, actually to assure their attainment of modern industrial nation status during the next quarter-century.

This is the proper arena for competition with the Soviet Union—not pursuing military confrontation over areas representing dwindling raw material resources, but bringing to bear the most powerful weapons we are able to field—our scientific and technical ingenuity and the political legacy of the American Revolution—to help create sister republics throughout the world sustained through commitment to and joint pursuit of moral and economic progress.

The second frontier is the one we already touched during the high points of the NASA-directed Apollo program, but from which we have since retreated: space exploration

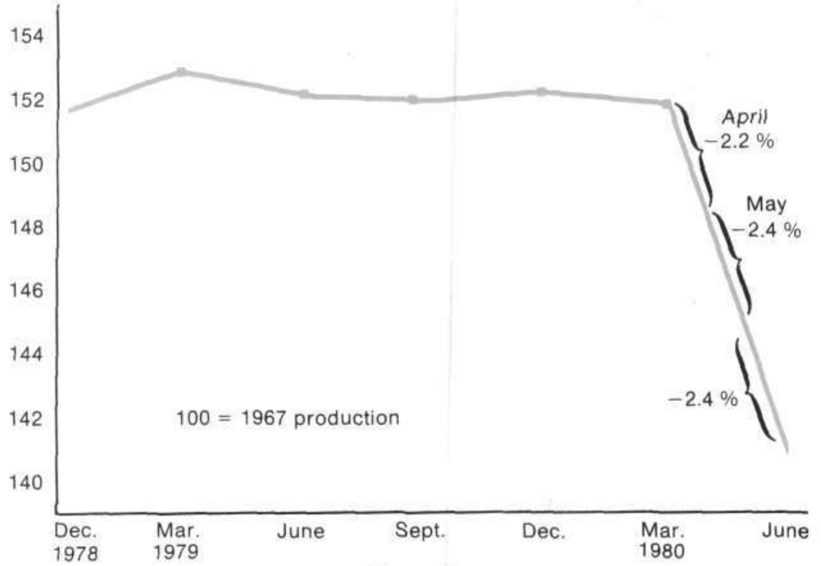


Figure 2
INDEX OF U.S. INDUSTRIAL PRODUCTION

U.S. industrial production has taken a dramatic exponential downturn in the first half of 1980, which if it continues at this rate would average as much as a 25 percent drop this year.

Source: U.S. Federal Reserve Board

and the development of long-distance manned space travel for the longer-term purpose of space colonization.

Setting for ourselves these in fact rather obvious strategic goals and *rallying the population in their support* will ensure that the projected process of reindustrialization proceeds, guided by a point of perspective that induces the proper constraints and boundary conditions, preventing long-term distortions. At the same time, it provides to the population the incentives and new sense of purpose that will go a long way toward definitively defeating ideologies related to no-growth.

The Energy Equation

Ultimately, strategic miscalculations as well as major strategic setbacks can always be traced back to flawed epistemology or lack of epistemological rigor. Energy policy in the 1970s is a most important case in point, and unless the lessons of what went wrong in that period are fully comprehended and assimilated by policymakers, even well-intentioned development strategies for the 1980s will fail miserably.

Before 1973-74, energy policy in explicit terms hardly existed; at most, energy was thought of as one among a large number of factors entering into the economic growth equation. It was one of the very few positive byproducts of the 1973-74 oil crisis that the all-pervasive and determining role of energy in the economic process became widely recognized. There, however, the matter stopped and intellectual sloppiness took over, born at least in part of compromise with an outright capitulation to "postindustrial" and "limits to growth" Newthink.

The result is the revolutionary idea of "decoupling"—the notion that, since energy prices have increased dramatically in the second half of the 1970s, the well-being of an economy actually depends on the implementation of successful conservation policies. Furthermore, decoupling holds that conservation need not impair long-term economic growth since it has been empirically demonstrated that in the past few years the ratio between the percentage of economic and energy growth rates in the advanced sector countries has dropped from near 1 to about .75.

Consequently, the June 22-23, 1980 OECD summit in Venice, although *dominated* by the generally sound policy perspectives of the Giscard-Schmidt Franco-German leadership, adopted the energy policy principle of achieving a .6 ratio of energy to economic growth. It was also noted that since 1975, the United States had achieved increases (albeit small) in output per manhour with decreasing energy per manhour.

There is, of course, nothing mysterious about all this: The "decoupling" that has occurred in the advanced sector in the past several years is almost entirely the result of the already noted shift from productive (goods-producing) to nonproductive (service-oriented) employment categories. This has carried with it a collapse of productivity and, through burdening the productive sector with ever-increasing unabsorbable overhead expenses, has produced historically unparalleled inflation rates. To the extent that a measure of decoupling has occurred in manufacturing itself, it has been demonstrated to be the result of shifts in the internal composition of industrial output; that is, of shifts into lines of products utilizing more labor-intensive, less productive manufacturing methods.[5]

"The root cause for the enduring malaise and lack of crisis resiliency of the U.S. economy is the 25-year cancerous growth of the economy's service sector in relation to goods-producing manufacturing and farming sectors."

Legitimate forms of decoupling—legitimate from the standpoint of maintaining certain minimal rates of productivity increase—can be achieved only through the introduction of innovative production technologies that may indeed realize certain savings in total energy expended *as a side-effect* of operating at much increased *energy flux densities.*

In the broadest sense, higher flux densities translate into improved utilization of available energy, hence into improvement of the free energy/total energy ratio—freeing up energy for the negentropic expansion of a nonequilibrium system.

Recently developed aluminum production technologies, for example, utilize much higher currents in the electrolytic cells, simultaneously reducing the total energy per ton of aluminum produced. Similarly, higher energy flux densities—units of energy flowing per unit time and spatial cross section—in agriculture have significantly lowered the energy input required to produce a ton of grain through greater fertilizer use per time and hectare.

One crucial presupposition of going to higher energy flux densities (which directly correlate with increased productivity) is that the quality of energy available for industrial production is also improved. This flux density-productivity link is quantifiable in a set of partial derivatives that depend, fundamentally, on the "quality" of energy:

- rate of change of output with respect to change in *electrical* energy (holding labor, capital, and raw materials input constant);
- rate of change of productivity with respect to changes in total energy (holding all else constant); and
- rate of change of electrical energy with respect to change in capital investment (holding all other inputs constant).

Historically, the requirement of improved energy quality is illustrated by the increasing amount of electricity as a portion of total energy consumed. Of two equal amounts of energy in the form of electricity and process heat, it is the former that is much more versatile and of much higher quality, determined by a higher degree of organization. High-quality, low-entropy energy output, however, in turn requires higher energy flux densities in the energy production device itself.

This closes the circle for the discussion of the proper conception of the relationship between energy and economic growth: The crucial determinant of economic growth—comparable in thermodynamic terms to the efficiency-determining temperature of the process—is productivity. Such productivity is to be measured by the ratio of reinvestable profit to capital and labor costs; productivity growth is the direct correlate of increases in energy flux density, which presupposes higher flux density energy production methods.[6]

Decoupling proposals are at best irrelevant to this problem cycle, but in the manner posed at present they will undoubtedly lead to the adoption of energy policies that will maximize the short-term economic damage resulting from productivity losses and the longer-term damage resulting from the installation of a mix of energy technologies that are least supportive of high-flux raw materials processing, manufacturing, and agricultural production methods.

Stated differently, because they favor low-flux systems, decoupling efforts end up leading to energy waste by forcing up energy input per unit output. Furthermore, they make it more and more difficult to reverse such follies by saddling us with energy systems incapable of delivering the proper energy mix for optimal production technologies, thus increasingly foreclosing profitable investment in the most productive high-technology areas.

Conversely, having clarified some essential causal links between energy and economic growth, we are now able to give a positive characterization of the reindustrialization problem as follows: We have defined the strategic goals—Third World development and expanded exploration of the solar system. Realization of these goals requires determination of an optimal trajectory—a "least action" path—taking our present condition as a starting point and advancing under the equivalent constraints of maximizing productivity and utilization of high energy flux methods.

Growing availability of increasingly versatile, low-entropy energy is the pervasive condition that must be satisfied for smooth travel on such a trajectory. Rapid development of high flux tolerating materials is another essential condition.

Before proceeding to a sharper delineation of an optimum path in the form of an outline policy proposal for industry, we must briefly take up an issue epistemologically closely related to decoupling—rationalization.

The same 15-year period from 1965 to 1980 in U.S. economic history that was characterized by extremely low average productivity increases also saw a great preponderance in industry of "rationalizing" instead of "expansionary" innovations (rationalizing meaning "labor saving" without concomitant increases in production).

Clearly, such forms of rationalization do not have a positive impact on global productivity, but simply represent yet another variant of the displacement of productive by nonproductive labor in the economy as a whole. "Information replacing goods," "shift toward the information society," and so forth are the slogans certain analysts have coined to describe the phenomenon. But much as in the case of decoupling, rationalization without basic productive technology innovation at best comes to nought and usually camouflages actual losses in productivity as a result of lack of capital investment.

"Overall profitability of investment in industrial capacity is directly proportional to the increase in productivity resulting from the investment and this, in turn, is a monotonic function of the degrees of technological innovation embodied in the new capacity."

Rationalization—the equivalent of energy saving—cannot stand alone, propping up a decaying infrastructure. As the West German and Japanese examples demonstrate, it can play its proper role only in an environment shaped and determined by adequate investment in basic innovations in production technology (see Table 2).

A Policy for U.S. Industry

A special issue of *Business Week*, dated June 30, 1980, takes up the topic of the "Reindustrialization of America," and under the headings "A New Social Contract" and "A Policy for Industry" presents a set of major policy recommendations. The substance of the new social contract—inspired, as *Business Week* notes, by the philosophy of Rousseau, the 18th century's foremost "back to nature" anti-industrial spokesman!—is to be the creation of "a new sense of teamwork."

The principal industrial production and development goals are in the areas of information and data-processing, microelectronics (chips, and so forth), solar energy, biotechnology (genetic engineering), coal and synthetic fuels, and, finally, the more traditional aerospace sector. Steel, petrochemicals and plastics, and to some extent the auto sector are *Business Week's* candidates for pruning; machining and machine tools are regarded as growth sectors, if only to support growth in other areas.

Coupled with certain tax and credit proposals, this motley list is presented as a long-term industrial development strategy. I have referred to it here at some length only because it does combine some of the better features of programs put forward by other institutions and individuals (including certain legislation in Congress), and because it is at the same time so utterly devoid of any leading or integrating concept and methodology.

The strategic goals and methodological principles I have discussed in the preceding section give rise to the following outline policy proposal, which should be compared to the *Business Week* recommendations.

The guiding concept of these proposals is the pursuit of the strategic goals of Third World development and space exploration and development along the maximum productivity, high energy flux density path. This is further specified as follows:

1. Fusion Energy Development

The commercial development of controlled thermonuclear reactions is the principal energy development goal for the remainder of this century. Its success will allow the most effective complementarity of currently existing nuclear energy technologies from the standpoint of the fuel cycle, waste disposal, and so forth.

Fusion energy conforms most immediately to the requirement of the creation of extremely versatile, low-entropy energy sources. In the most highly developed form, fusion technology will permit direct energy conversion, allowing us ultimately to dispense with most moving parts in energy production. The extremely rich, low-entropy fusion energy spectrum, finally, will become the basis of entirely new materials-processing and industrial-production methods.

The "low-entropy," "far from equilibrium" physics required in the exploration of the fusion process simultaneously represents the most promising overall orientation for theoretical physics progress.

The term *far from equilibrium* is borrowed from nonequilibrium thermodynamics and chosen here in keeping with the thermodynamic nomenclature throughout to refer to processes we have elsewhere described in the framework of Riemannian nonlinear dynamics. These are, characteristically, directed multistage processes, different stages representing qualitatively different internal dynamics and modes of interaction, connected by singular phenomena such as shock waves, and so forth.

A most promising new concept for inertial confinement fusion illustrating this type of process has recently been proposed by Friedwardt Winterberg of the Desert Research Center in Nevada.[7] Noting that for beam drivers (lasers, particle beams) intended to ignite the fusion process, their energy density ϵ and energy flux density ϕ are related by the equation

$$\epsilon = \phi/v$$

where v is the average particle velocity, Winterberg proposed that instead of directly delivering laser-generated photons to the target, it would be advantageous to start the process with a large kinetic energy of modest velocity but large mass—as in the case of a hypervelocity macroscopic projectile. This energy is then converted into photons by shock heating of a high-atomic-weight (high-A) gas. In turn, through confinement in an opaque-walled cavity, the photons are converted into blackbody radiation. It is finally this radiation of energy flux density $\phi = (c/4)\epsilon$ (where c is the speed of light) that is used for target compression and heating. Thus, by forcing an initial kinetic implosion energy to undergo multistage conversion, we have transformed a given energy of density ϵ into an extremely large energy flux density ϕ. Since the required implosion velocity of the cavity containing the high-A gas is comparatively small, this method requires much less power to drive the fusion process than that required by direct pellet implosion.

In addition to the crucial role of scientific epistemology, funding is a key issue in fusion development. In spite of largely inadequate funding—less than $1.5 billion in total over the past 10 years—the U.S. magnetic fusion program has made astonishing progress, traversing in less than a decade the enormous distance from small-scale laboratory experiments to the assurance of proof of scientific feasibility and the initiation of engineering power reactors.

It is a still largely unnoticed success story that already in its broad implications outstrips the significance of the Apollo project. Along with information processing technology, it also represents the only high-technology area in which the United States has maintained a substantial lead over all other competing nations.

2. Biological Sciences

The role of fusion in energy and industrial production will be played by genetic engineering in agricultural, medical, and pharmaceutical applications. Significantly, the study of "far from equilibrium" systems in plasma physics and thermodynamics has given important new impulses to theoretical biology.

3. Space Exploration

Technologically, the future of space exploration will become intimately linked to fusion energy development.

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Table 2
INDUSTRIAL INNOVATIONS IN THE U.S. ACCORDING TO SAMPLING BY EXPERTS

Period	Type of Innovation: Expansionary	Rationalizing
1952-1954	29	36
1955-1959	8	33
1960-1964	18	44
1965-1969	12	55
1970-1973	17	70
1952-1973	**84**	**238**

Source: NSF Science Indicators Report.

The table shows how U.S. industry has invested in gimmicky labor-saving measures (rationalizing) at the expense of technological innovations. Similar figures for West German industry indicate that in the same time period an expansionary type of investment generally dominated.

The LaRouche-Riemann Model:

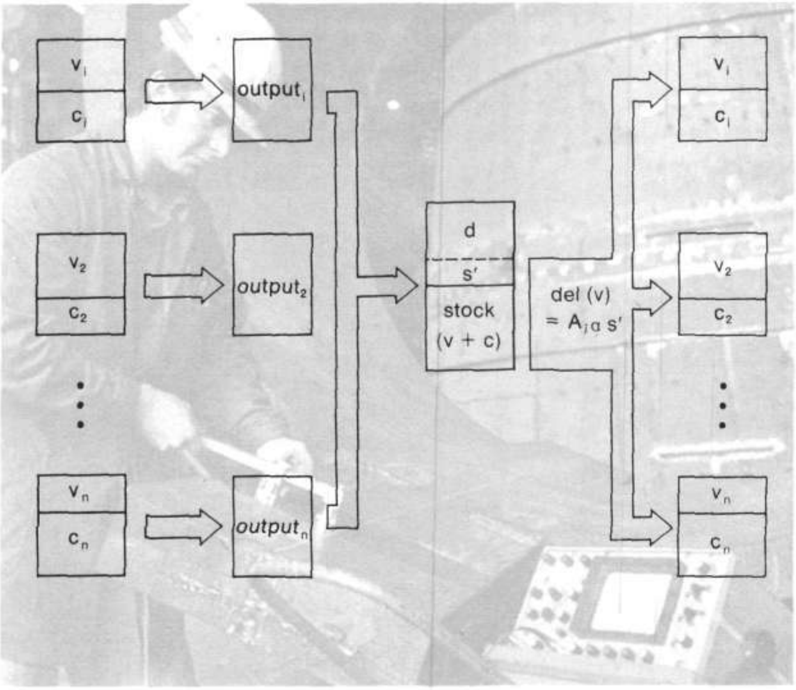


Figure 1
FLOW CHART OF SECOND-GENERATION LAROUCHE-RIEMANN MODEL

The model begins with the inputs to a cycle of economic production divided into the tangible goods necessary for reproduction of the productive workforce (labeled v_i, for the tangibles consumed by the productive workforce in the i-th sector) and the tangible goods required for the reproduction of plant, equipment, and raw materials (labeled c_i). These inputs are consumed in the production process, resulting in output from each sector.

Each sector produces surplus ("value added") in proportion to the productivity of that sector; causally, the employment of productive labor creates profits. The model then pools the output from each sector and divides the total output into three categories: first, the stocks necessary for an exactly equilibrium reproduction of the labor force and capital goods of the economy (this will equal the sum of the v_i and c_i of the next cycle of production); second, the surplus invested in the expansion of v and c in the next cycle (this reinvestment goes either to an expansion in scale or quality of the economic process); and third, the other "overhead" expenditures (labeled d) out of which are met the stock of tangibles both necessary (health, education, some services, some parts of government, and so forth) and unnecessary. The successful reproduction of an economy depends on the relative size of the productive compared to the nonproductive expenditures. On this basis, the model defines a "free-energy ratio," $s'/(c+v)$. If this ratio is increasing at an increasing rate, then the economy is progressing.

A look back at the two decades of economic history since 1960 shows one of the most dramatic changes in the structure of the world economy in the 400 years of modern capitalism: the U.S. economy, once the overwhelmingly dominant economy in the world, has become a second-tier industrial power. The West Germans have more exports, *in absolute amount,* than the United States; the West Germans produce *almost twice as many* machine tools as the United States; the West Germans and Japanese lead U.S. industry in capital investment and level of implemented technology in almost every industry; the living standards of West German industrial workers in key industries like steel are *higher* than those of their U.S. counterparts.

Although this state of affairs is not irreversible, it is indicative of a fundamental sickness in the American economy—a systemic disease whose symptoms and etiology have escaped the mainstream of current economists and policymakers. The misdiagnoses are familiar; to take some examples: "Imported oil"; yet the Europeans and Japanese import more than 90 percent of their oil, while the United States imports about half that percentage. Or "energy waste"; yet the energy efficiency of the U.S. economy has nominally *increased* since 1973, and the U.S. economy has gotten worse. Or "cheap foreign labor"; yet West German steel workers are better paid than Americans.

The Fusion Energy Foundation, in collaboration with the weekly *Executive Intelligence Review,* has undertaken a detailed study of the American economy using the LaRouche-Riemann econometric model (see Figures 1 and 2). The preliminary conclusions from this study provide a striking view of the current state of the U.S. economy and the policies necessary for an American recovery.

First, the American economy over

℞ for a Healthy Economy

by Dr. Steven Bardwell

the last 20 years has suffered from acute underinvestment. A comparison between the West German and U.S. economies performed with the LaRouche-Riemann model shows, for example, that an economy investing at the accelerated rates of the West German economy can weather a disturbance like the 1973 oil price rise with relatively few ill effects. (See *Fusion*, Sept. 1980, p. 73.) The U.S. economy totally lacks that resiliency.

Second, the most important parameter reflecting this lack of investment is the secular decline in U.S. industrial productivity. Using the model, a more sophisticated measure of productivity has been developed that shows that this decline in productivity—more than any other parameter—measures the failure of an economy. It is the long-term decline of productivity of key sectors of the economy like steel and the utilities (through attacks on nuclear energy) that has made the growing overhead burden of financial speculation, government debt, and transfer payments unbearable. The result has been double-digit inflation.

Third, the U.S. economy is now at the point of a catastrophic collapse; and this collapse is inevitable unless an emergency reindustrialization program is implemented. Without a drastic, long-term mobilization of the country's manpower, capital, and brainpower, our economy will collapse. (For more details on the Riemannian analysis of the threat to the U.S. economy of "thermodynamic death," see *Fusion*, Aug. 1980, p.57.)

The Riemannian Litmus Test

Using the model, we have found that the litmus test for any reindustrialization program is its effect on *productivity*. Since the LaRouche-Riemann model is based on the fundamental causal relations among productivity, capital investment, and technological progress, the model shows unequivocally that nothing can

Continued on page 80

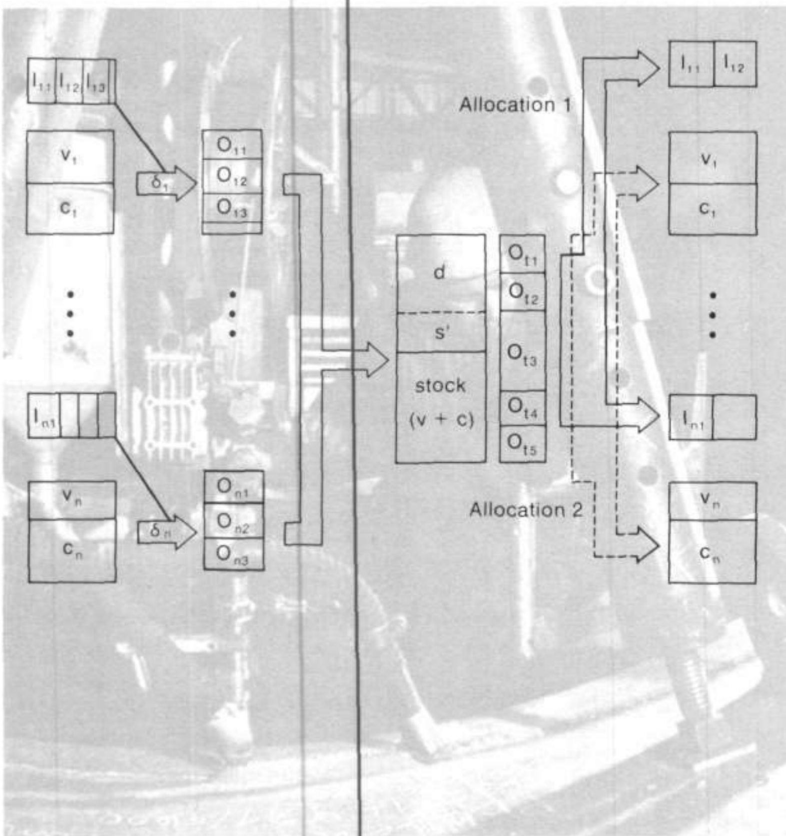


Figure 2
FLOW CHART OF THE THIRD-GENERATION LAROUCHE-RIEMANN MODEL

A real economy functions on two levels simultaneously, only one of which is treated by the model shown in Figure 1. In addition to the flows of tangibles tracked in the second-generation model, the economy's reproduction depends on the material composition of these flows. Thus, a certain mix of labor, capital, energy, and new technologies implies reproduction in the next cycle at a certain productivity. In the third-generation model, this composition is taken into account by a productivity measure that functionally depends on the input-output vectors for that sector. This allows the modeler to determine the productivity of a given sector by varying the inputs to that sector (its energy intensivity, for example).

Once the production cycle is completed, two allocations must be made. The first of these replicates the financial allocation of reinvestment to each sector parallel to that in the first chart. In addition, the surplus product must be allocated in its material form. This latter allocation is especially critical in bottleneck areas like machine tools where a small shift of investments from one sector to another can greatly affect the overall productivity.

Major Energy and Reindustrialization

A number of major studies of reindustrialization and energy policy have appeared in the past few months. This grid, prepared by Vin Berg, summarizes some of the more prominent reports and meetings. The reader is urged to compare these statements of the problems and solutions with the Fusion Energy Foundation perspective.

Title
World Coal Study

Date
May 1980

Sponsors
AMAX, ARCO, MIT, Mellon Foundation, Rockefeller Foundation, British Petroleum, Cambridge University Engineering Department, Warburg Foundation, World Wildlife Fund, Bechtel Corp., Friedrich Krupp GmbH

Focus
Energy needs/coal

Statement of Problem
Reliance on oil and natural gas must be phased out, but nuclear power will probably fall short of even current, scaled-down projections, and solar and other renewables can make only partial contributions in the OECD nations; yet, current OECD coal output would fall 50 to 66 percent short of projected new energy needs in the year 2000, assuming only 2.5 to 3 percent economic growth rates per year.

Recommendations
Energy must be "decoupled" from economic growth, reducing the ratio to 0.6 by 1990. Governments must ease environmental restrictions, streamline regulations to shorten lead-time on new facilities, and conclude multilateral agreements to achieve a threefold increase in coal output and expedite exports from coal-rich to coal-poor OECD nations.

Title
Declaration of the Heads of State

Date
June 23, 1980

Sponsor

Organization for Economic Cooperation and Development (Venice summit, June 22-23, 1980)

Focus
Energy needs

Statement of Problem
Large increases in the OPEC price of oil have retarded growth and produced higher inflation rates and a threat of severe recession and unemployment in the industrialized nations.

Recommendations
The existing link between economic growth and consumption of oil and other forms of energy must be broken, requiring the doubling of production and use of coal and the increase of nuclear power use in the medium term, and requiring a substantial increase in synthetic fuels, solar energy, and other renewable sources over the longer term. Overall, by 1990, this will reduce oil demand from 53 percent to 40 percent of total OECD energy demand and reduce total energy demand in relation to economic growth to a ratio of 0.6.

Title
Economic Development

Date
September 1980 single-issue edition of *Scientific American*

Sponsor
Scientific American

Focus
Third World development

Statement of Problem
The population explosion and poverty in the developing nations are not caused by fertility rates but by the lack of scientific industrial revolution, which will stabilize population.

Recommendations
"Group of 77" demands for a "new international economic order" defined in the United Nations should be accepted; the UN model shows that Third World development will stabilize population globally at 8 to 12 billion by the year 2000; any such predictable population can enjoy the elimination of want through existing technology and physical resources. The developed countries should undertake the systematic transfer of scientific-industrial technology to the poor nations, focusing on the world's 10 major underdeveloped river valleys (e.g., Indus, Ganges, and Brahmaputra), bringing these under cultivation by 20th-century technologies. Energy is the crucial factor—in the form of fertilizers, pesticides, and mechanization in agriculture, in mineral resources extraction, and in industry, transport, and communication. Nuclear energy is the crucial energy technology for Third World development.

Note: This is a summary of the general thrust of a number of individual articles in the issue.

Proposals

Title
Revitalizing the U.S. Economy

Date
June 30, 1980 single-issue edition of *Business Week*

Sponsors
Business Week/McGraw Hill

Focus
Reindustrialization of the United States

Statement of Problem
Large parts of the U.S. economy are too inefficient to compete in world markets, because the leading categories of old basic industries are obsolete in relation to West Germany and Japan, in particular; innovation and R&D have lagged behind America's competitors.

Recommendations
Old basic industries should not necessarily be modernized; *competition with other* nations must be the criterion for selecting which industries and product lines should be encouraged and which allowed to vanish. A new "social contract" that takes precedence over the aspirations of poor, minorities, and environmentalists must be accompanied by government tax, budget, and credit policies tailored to encourage those competitive industries in which "information takes the place of goods" (e.g., microelectronics); energy resources must be similarly tailored, emphasizing coal, solar, and other renewable forms.

Title
Research Revitalization Act of 1980 (HR 6632)

Date
February 26, 1980

Sponsor
Rep. Charles Vanik (D-Oh.)

Focus
Technological innovation

Statement of Problem
American manufacturers have suffered a decline in domestic productivity and become noncompetitive on world markets, particularly in relation to Europe and Japan, because America has lagged behind in high-technology initiatives that are essential to the export marketplaces.

Recommendations
Government must provide tax credits and incentives for the formation of reserve funds for research and development by corporations; the goal should be to maximize production of new technology per dollar of tax resources lost and to focus research on the university campuses under private corporations' sponsorship. This program would be a substitute for the military R&D and space programs in efficiently creating new technologies.

Title
Colloquium on Contingency Planning for an Energy Emergency

Date
June 24, 1980

Sponsor
Hoover Institution on War, Revolution, and Peace; Stanford University; Scientists and Engineers for Secure Energy

Focus
Energy needs/oil supply cutoff

Statement of Problem
Sudden cutoff of oil from the Persian Gulf as a result of political destabilization or war would immediately transform American lifestyles, reducing oil supplies by 35 percent, GNP by 15 to 25 percent, auto use by 50 percent, and other transport by 30 percent; it would force abandonment of hard-to-heat residential and commercial buildings, curtail recreational and cultural activities, and accelerate relocation of populations to warmer climates; U.S. defense capabilities would be in severe peril.

Recommendations
To reduce vulnerability, high-level policy organization as in World War II must be applied to increase domestic coal and nuclear sources, as well as gas, shale oil, and biomass; oil and gas price decontrol must be accelerated to force real conservation; environmental restrictions should be amended or specially administered to expedite these measures; nuclear and coal installations must be brought up to full capacity, while plants now under construction or awaiting licensing should be completed on an accelerated schedule.

Note: A statement issued from the colloquium was signed by individuals; and various points of view were aired, favoring different emphases.

Title
Suppose the Oil Stops

Date
June 1980, Lawrence Livermore *Energy and Technology Review*

Sponsor
Lawrence Livermore National Laboratory, Energy and Resource Planning Group

Focus
Energy needs/oil cutoff

Statement of Problem
A total Middle East oil cutoff could send the price over $100 per barrel and have extreme political and economic effects comparable to those of World War II, with the United States losing—per International Energy Agency sharing agreements—36 to 40 percent while allies lose 74 to 83 percent of oil supplies.

Recommendations
Short, medium, and long-range measures to reduce vulnerability must involve "changing the energy menu" of the United States. In the short term, transport including auto use and commercial and residential heating must be curtailed by as much as 50 to 60 percent. Medium term (5 to 10 years) measures include electric car and electric/gasoline hybrid cars, and synthetic fuel development. The only realistic long-term (10 to 20 years) alternatives are coal and nuclear power, which should include fast breeder development; coal and nuclear power are necessary, despite controversy, and even without an oil cutoff, because oil must be phased out.

Materials Processing with the

In the next 20 years we will need new technologies for raw materials extraction and processing as well as for energy production. The economy of the 21st century will depend upon the development of these technologies to redefine the world resource base and open up new horizons for producing and using materials.

Fusion energy and plasma techniques coupled with fusion power reactors will play a vital role in this materials and chemical processing. This more general application of fusion and related plasma science, which will literally generate new resources, is a direct result of the higher organization of matter and energy in a fusion plasma; the fusion plasma energy is a lot more than just heat.

Traditionally, the energy from the combustion of fossil fuels, mainly heat, has been used for raw materials extraction, reduction, and processing. In 1968, two scientists, William C. Gough and Bernard J. Eastlund, proposed harnessing the unique properties of the ultrahigh-temperature fusion plasma to meet the energy, materials, and fuel needs of the next millennium.

In a report prepared for the Atomic Energy Commission in 1969,[1] Gough and Eastlund stated that their concepts "evolved from the strong belief . . . that controlled fusion should not be viewed solely as another means of providing heat to generate electricity via the conventional steam turbine cycle. Rather controlled fusion should be investigated as a new *prime energy source* with potential inherent advantages uniquely suited for direct conversion of energy into forms useful for society."

Conventional methods to produce energy generate heat either by the combustion of fossil fuels or by the splitting of uranium atoms in a nuclear reactor. Fusion, the fusing of isotopes of hydrogen at a temperature of tens of millions of degrees, produces not only heat, but also a full array of electromagnetic radiation, charged particles, and neutral particles at high energy levels, as well as electric power by conventional or advanced conversion methods.

It is the unique by-products of the fusion process that can be used to reduce metal ores, for chemical processes, and bulk materials separation. Unlike the fusion energy of the sun, controlled fusion plants on earth can be "tuned" to produce more or less of various by-product particles and radiation depending upon what is required.

Gough and Eastlund's concept, called the fusion torch,[2] includes two major uses for the unique properties of the fusion plasma. First, the ultrahigh-temperature plasma produced in the fusion reaction can be used to reduce *any* material into its basic elements. Second, the energy in this ultrahigh-temperature plasma can be used to produce a full field of electromagnetic radiation that will permit chemical processing to be carried out in a working fluid.

Materials Reduction

The fusion torch is created by transferring the plasma from the region where it is generated in the fusion reactor, through a connecting region that isolates it from the plasma source, to an interaction region. There the high-temperature plasma is ready for torch applications. Any solid material—scooped-up sections of the earth's crust, oxidized ores already mined, or solid urban waste—can be fed into the interaction region.

The high thermal conductivity and large energy flux of the fusion torch plasma produce a shock vaporization (propagation of shock waves) that ionizes the solid. Lower-temperature plasmas created by shock tubes or electric arcs cannot produce the shock waves that propagate in this ultrahigh-temperature plasma, and when lower-temperature plasmas come in contact with solid materials, it merely cools the plasma.

Once the fusion torch ionizes the solid material and breaks it down into its constituent elements, a separation technique must be used to recover the elements. A number of separation techniques have been proposed and tried experimentally, including electromagnetic separation, which first separates the electrons in the plasma from the plasma itself and then separates the ions of differing mass.

Quenching, or quick cooling of the plasma, will produce the simplest molecules and prevent different atoms from recombining, such as in the reduction of ferrous oxide into iron and oxygen. Quenching is accomplished by injecting a cooler gas, flowing the plasma over a cold surface, or expanding the plasma flow.

If the temperature and density of the plasma are held constant in a set of conditions favorable to the recombination of a desired type of material, this selective recombination will allow the accumulation of the desired materials on the walls of the torch.

Other methods of separation, including charge exchange, plasma centrifuges, plasma accelerators, and curved magnetic field flow, have also been investigated.

The importance of this direct plasma application to meet the economic development requirements of the 21st century is obvious. Gough and Eastlund estimate that by the year 2000, an all-electric city of 10 million people would need an electrical capacity of about 140 gigawatts (GW). If 10 GW of this total were used in the fusion torch, municipal solid waste alone could generate 27,000 tons of materials to be recycled for use. Low-grade ore bodies that are not economically exploitable by conventional methods would become attractive and, eventually, with fusion power commercial and widely available, whole sections of the earth's crust could be processed to extract the important raw materials.

Although it is doubtful that large-

Fusion Torch

by Marsha Freeman

scale materials reduction with a fusion plasma can become significant before fusion reactors are commercial, the use of the electromagnetic and particle energy from present energy-consuming plasmas and energy-producing fusion plasmas in the future is under development now.

Chemical Processing

Ultraviolet (UV) radiation is already used commercially for sterilization and photolysis. By injecting trace amounts of impurities, possibly aluminum, into selected materials, the radiation field of the fusion plasma in a torch could be "tuned" to produce high levels of UV radiation. The UV can be transmitted from the plasma through a window and absorbed by the working fluid.

UV radiation is used commercially now for sterilizing high-cost foodstuffs like milk, but if produced more cheaply through fusion it could be applied to the desalination of water, the processing of urban sewage, the conversion to electricity through fuel cells, and for many kinds of plasma chemistry.

UV photons could be used for the photodissociation of water into hydrogen and oxygen. It has been estimated that hydrogen production using a water vapor cell with UV radiation could be produced at prices comparable to proposed nuclear-based processes, and at less than current cost of electrolysis. This process would mirror the continual UV dissociation of water that takes place in the upper atmosphere through rays of sunlight.

Synthetic Fuels

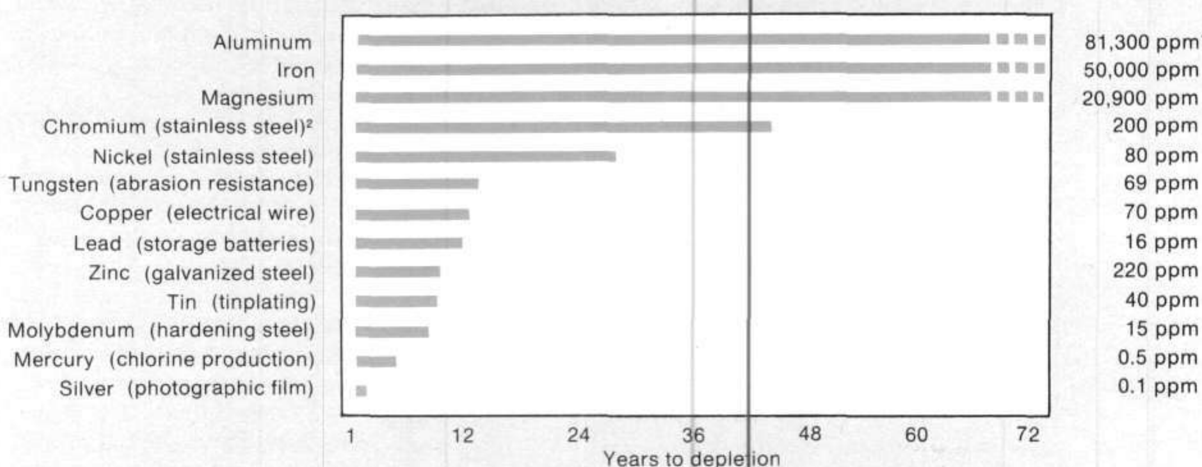
During the mid-1970s fusion scientists focused attention on the production of synthetic fuels from fusion energy. A series of reports and a workshop sponsored by the Electric Power Research Institute (EPRI) beginning in 1976 brought together teams of scientists and engineers in fusion and related fields to evaluate future research paths for nonelectric uses of fusion power.[3]

Nearly every excitative radiation created in the fusion process can be used to produce synthetic fuels. These include microwaves for plasma chemistry to mix carbon dioxide and hydrogen to produce methane; the use of UV and soft X-rays for photochemistry to dissociate water to produce hydrogen; the use of the high-energy *neutrons for radiolysis, similar to X-ray* processes; and the use of the charged particles in a torch to dissociate water or recombine carbon fuels.

KMS Fusion has proposed using laser fusion systems for the production of hydrogen through radiolysis. A team of researchers at Brookhaven National Laboratory has designed an entire synfuel production flow train using water, coal, and carbon dioxide as the raw materials. Rather than burning vast amounts of coal, fusion could provide up to 40 percent of the energy required for gasification or liquefaction techniques; and as coal

Continued on page 30

DEPLETION OF RESERVES OF COMMERCIAL GRADE ORES FOR WORLD POPULATION AT U.S. LIVING STANDARD



Present reserves of ores required for industrial production and high living standards will run out if we succeed in raising the entire world's population to U.S. living standards, unless the fusion torch is developed.

1. Abundance in earth's crust, in parts per million (ppm).
2. Process for which ore is required.

Fusion Torch

Continued from page 29

becomes more expensive or is not available in certain areas, it could be replaced by extracting carbon dioxide from the air or the ocean.

Using a combination of the heat and electricity produced from fusion has been suggested in high-temperature electrolysis designs to produce hydrogen from water, as have thermochemical cycles. All of these ideas are important to pursue experimentally.

Some in the fusion community view the fusion torch and other materials applications of fusion as "overkill," believing that conventional processing techniques could use the same energy more efficiently. But this skepticism is based on a lack of scientific research on the utilization of the special properties and efficiencies of hot plasmas for the indicated purposes. The point is that these applications of fusion plasma have yet to be experimentally scoped out.

In their 1969 report, Gough and Eastlund conclude that "the vision is there, its attainment does not appear to be blocked by nature. Its achievement will depend on the will and the desire of men to see that it is brought about." Good experimental work on plasma applications to metals processing and synfuel production has already been carried out by Bethlehem Steel, Avco Everett Research Lab, and other corporations.[4] A well-funded, centrally directed fusion applications program would assure the raw materials and energy needs of the next century.

Notes

1. B.J. Eastlund and W.C. Gough, "The Fusion Torch: Closing the Cycle from Use to Reuse," Division of Research, U.S. Atomic Energy Commission, May 15, 1969.
2. B.J. Eastlund and W.C. Gough, "The Fusion Torch: Energy, Wastes, and the Fusion Torch," Division of Research, U.S. Atomic Energy Commission, April 27, 1971.
3. Electric Power Research Institute, "Workshop on Synthetic Fuels from Fusion," April 1977, EPRI ER-439-SR. Electric Power Research Institute, "Enhanced Energy Utilization from a Controlled Thermonuclear Fusion Reactor," September 1976, EPRI ER-248.
4. The Mitre Corporation, "Applications of High Temperature Plasmas," June 1979, MTR-79W00166.

Using Fusion for

In a mid-1970s presentation to the New York Academy of Sciences, Edward Teller predicted that inertial confinement laser fusion would become the "internal combustion engine" of the 21st century. This was no overstatement—inertial confinement fusion has the inherent potentials for its energy output (extremely high density and quality, low entropy) to make it the ideal propulsion unit for the full range of terrestrial and extraterrestrial applications that will be needed as the benefits of high-technology civilization are extended to the entire earth's population and, eventually, throughout the galaxy.

Although investigations into laser fusion for propulsion applications have been quite limited, sufficient work has been done to provide the outlines of what these fusion systems will look like. Dr. Friedwardt Winterberg was one of the first scientists to determine the unique capabilities inertial fusion offered for powering space ships,[1] and NASA carried out a number of programs in the 1960s to research the prospective applications of fusion energy and related plasma-based technologies to space travel.[2] More recent studies carried out by the Laser Program Systems Studies Division of Lawrence Livermore Laboratory (LLL) surveyed the full range of potentially using inertial fusion reactors as propulsion units for aircraft, sea vessels, and space ships.[3] This was a followup to the initial work of R. Hyde, L. Wood, and J. Nuckolls of the LLL Laser Program, completed in the early 1970s.[4]

Fusion Motive Power

Generally speaking, the same qualities that make fusion energy such an attractive energy source for direct electrical power production and alternative applications such as the fusion torch and fission-fuel breeder also make fusion an excellent power source for moving vehicles:

- Small fuel input. Fusion reactions convert several percent of the mass of the reactants into high-quality energy.
- Extremely high energy densities. Inertial fusion microexplosions, for example, have power densities trillions of times greater than those of conventional fuels.
- High-quality (low-entropy) energy output. The energy produced by fusion reactions can thus be used with high efficiency to generate the motive force for propulsion. Since the velocities of fusion reaction products approach 10^7 m/sec, they could be used as a very effective rocket exhaust. In turbine drive shafts for aircraft and marine ships, the high temperatures intrinsic to the fusion process allow more efficient conversion of the thermal fusion energy into mechanical motion.
- Low biological hazard. The biological hazard potential of the radioactive by-products from a fusion reactor is uniquely low. For example, a 1 million kW-thermal fission reactor produces about 10^{10} curies of very dangerous, volatile fission products.[3] But the total radiation produced by a fusion reactor of similar output (1.5 million kW-hr) is several orders of magnitude smaller and is of uniquely low-level biological hazard activity. It includes the 10^6 curies of radiation associated with the radioactive tritium fusion fuel and the 10^7 curies of radionuclides resulting from neutron-induced reactions within the reactor structure itself—a nonvolatile, localized hazard.

Given the advantages of a fusion-powered propulsion system, what are the practical considerations? A fusion power system must be designed for minimum specific volume and mass if it is to be competitive with other systems. The fusion reactor must therefore operate with a large energy flux on the wall of the fusion reaction chamber, which is called "wall loading." Wall loadings up to 10 MW/m^2 are envisioned as being necessary to

Propulsion

by Charles B. Stevens

give the fusion reactor an energy density comparable to nuclear fission.

Inertial fusion will generally be superior to magnetic fusion for propulsion technology since its specific volume and mass can be easily reduced by increasing the pulse repetition rate and the first wall loading. A summary of the performance characteristics of advanced propulsion systems for several applications is given in the table.

Marine Applications

To date, 250 shipboard nuclear-fission propulsion systems have been built worldwide. Although most of these are on military ships or submarines, 5 nuclear systems are being used to power civilian ships. As the *LLL report*[3] *points out*, as fossil fuels become scarcer and more expensive, "nuclear-power propulsion systems will become more and more attractive . . . and less environmentally sensitive countries might pursue such alternatives vigorously."

Use of inertial fusion for marine propulsion offers the lowest technical risk. The marine requirements listed in the table appear to be well within projected efficiencies and scaling laws for laser fusion power systems. The more spacious and mass-tolerant shipboard environments permit use of a helium-cooled, graphite-moderated version of a laser reactor operating on a closed Brayton cycle. This reactor system would be radioactively cleaner than other designs, and use of helium would allow high-temperature operation with higher thermal efficiencies.

One particularly attractive marine application that has been designed is a 400,000-ton displacement, semisubmerged oil tanker that would require a propulsion unit in the range of 125,000 shaft horsepower, several times the size of existing supertankers. Another future concept for fusion application would be a high-speed, cargo-tanker submarine with speeds in excess of 25 to 30 knots.[5]

The application of fusion propulsion units to aircraft is more speculative because a laser fusion power plant is not able to compete with chemical or nuclear-fission systems on a specific mass or volume basis, based on current design projections. Nevertheless, development of very large, 5,000-ton aircraft around the turn of the century may make fusion propulsion quite attractive.

Since payloads above 2,500 tons allow servicing to be carried out inflight, such a plane would only need to land for major overhaul. This continuously flying transport would virtually eliminate time lost in takeoff

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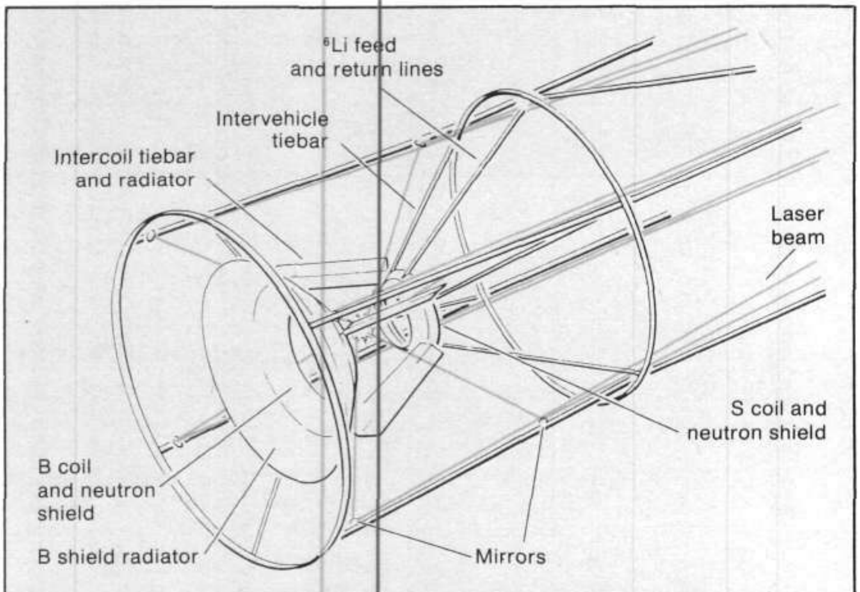
SUMMARY OF PROPULSION SYSTEM CHARACTERISTICS

Application	Technical risk	Power	Specific mass (kg/kW)	Specific volume (m^3/MW)
Marine				
Navy	moderate	90 MW[1]	30	80
Commercial	low	90 MW[1]	90	200
Airborne	high	360 MW	0.4	0.6
Space	highest	130 GW	0.05	not critical

1. Shaft power.



EXTRATERRESTRIAL LASER-POWERED SPACECRAFT

Laser-induced microexplosions in the reactor chamber (open to space vacuum) produce charged plasma debris that is directed by the magnetic mirror system through the larger mirror-loss cones out the rear of the spacecraft. The payload can be protected from radiation and will provide a living environment for the explorers or miners and cargo space.

Propulsion

Continued from page 31

and landing and, with vertical takeoff feeder aircraft, permit the location of passenger and cargo terminals close to city centers. A fusion propulsion unit would also eliminate in-flight transfer of large quantities of fuel.

Although these earth applications of fusion energy for propulsion appear potentially practical, it is actually in the realm of space travel that fusion stands out uniquely. Weight considerations are most important for space travel, and fusion reactions use the most weight-efficient fuel. But the key parameter for space travel is that of specific impulse, the impulse per unit weight:

$$ma(\Delta t/mg) = \Delta v/g = \text{unit of time}$$

(that is, specific impulse is measured in seconds). The higher the specific impulse, the more efficient is the power source.

Chemical rockets have maximum specific impulses of less than 450 sec, and fission systems less than 2,000 sec. But because of the high velocity of its reaction products, 10^7 m/sec, fusion systems have a potential specific impulse of 1 million sec. (Fusion-based space vehicles will make direct use of the high-velocity fusion products rather than use an intermediate thermal cycle, as is necessary in terrestrial propulsion systems.)

The basic idea in fusion-propelled space travel is to use laser-induced fusion microexplosions as the rocket thrust. The design in the figure illustrates this principle. Fusion microexplosions are generated with a laser beam in open space (an ideal reactor chamber because a virtual vacuum prevails).

The target is designed to generate high-energy charged particles, which are directed along an imposed magnetic field out the end of the thrust chamber. Virtually none of the energy is lost through this redirecting process. Radiation and heat generated by the neutrons and the plasma radiation intersecting the thrust chamber are also radiated out into space with the shield radiators. The result is that the exhaust from the fusion microexplosions is efficiently directed out the rear of the thrust chamber at extremely high velocities of 10^7 m/sec: a very small mass of fusion exhaust generates a large forward thrust.

A fusion-based spacecraft was designed by LLL for two types of mission: a 24-hour roundtrip lunar shuttle and a solar system transport. Economic exploitation of planetary and asteroidal resources would be feasible with this ship because of the relatively short durations for roundtrips and the large payloads possible.

With the development of larger fusion rockets in the next century, interstellar travel will become feasible, each trip taking several decades to reach the nearest stars and return.

Notes

1. *Fusion*, Nov. 1979, p. 41.
2. NASA SP-226, "Plasmas and Magnetic Fields in Propulsion and Power Research," Oct. 16, 1969.
3. J. Maniscalco *et al.*, "Civilian Applications of Laser Fusion," LLL report UCRL-52349, Aug. 14, 1978.
4. R. Hyde, L. Wood, and J. Nuckolls, "Propulsion Applications of Laser-Induced Fusion Microexplosions," *Proc. First Topical Meeting on the Technology of Controlled Nuclear Fusion*, I, 159 (San Diego, Calif., 1974). Also "Propects for Rocket Propulsion With Laser-Induced Fusion Microexplosions," AIAA/SAE 8th Joint Propulsion Specialist Conference Paper 72-1063 (New Orleans, La., Nov. 1972).
5. "Semi-Submerged Tanker for Arctic Waters," *Naval Architect*, May 1975.

Industrial Leadership

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Long-range space travel will have to rely upon fusion-based propulsion systems. Materials development is the other principal area of converging technological concerns.

Astrophysics defines the major field of theoretical overlap between space and fusion research. The high-density fusion experiment provides the most immediate access to the study of processes in distant stars. Solar system space exploration during the next two decades will give way by the end of the century to initial investigations of the conditions for space colonization.

It is an easy matter to calculate that with fusion propulsion we will be able to attain speeds of about 1/10 the speed of light. Traveling at that speed starting early in the next century, going to the next fixed star, staying for 1,000 years, then moving on to two farther stars, and so on, it can be shown that in a matter of only 1 million years human intelligence could readily spread through the entirety of our galaxy.

4. Microelectronics and Computer Development

A detailed assessment of the development potential of the computer and microelectronics category was presented in *Fusion*'s special issue on "The Frontiers of Computer Science in the 1980s," July 1980. Fusion development and space exploration are further elaborated in accompanying articles in this issue; and the biological sciences—with special emphasis on agriculture—will be explored in the November issue of *Fusion*.

This outlined breakdown of the high-technology, high energy flux industrial development path into four major categories requires a twofold interpretation:

First, it represents the principal recommended areas for large-scale U.S. private and public (governmental) R&D commitments, leading to an immediate doubling of existing efforts in the coming fiscal year, and at least a further doubling in each of the fiscal years 1983 and 1985. The full restoration of U.S. R&D potential represents the most urgent policy task and becomes the sound basis for all other efforts.

Second, these categories represent the necessary outline orientation for the development of U.S. industrial infrastructure and areas of concentrated future capital formation. While investment volume there will initially be small compared to traditional areas, industry must be guided in all traditional investment undertakings

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An Interview With FEF Research Director Parpart

Science In India

Editor's Note: Uwe Parpart, director of research for the Fusion Energy Foundation, toured India for three weeks this spring, discussing with scientists and government officials the 40-year industrial development program for India proposed by the FEF and briefing scientific groups on fusion energy. In this section, Fusion's special correspondent in India, Paul Zykofsky, interviews Parpart on his impressions of Indian science and scientists and summarizes the Parpart tour.

"There is a very rich scientific tradition that Indian scientists today quite consciously draw upon." At left, ruins of the 1724 Jantar Mantar astronomical observatory in New Delhi.
Shostal

Carlos de Hoyos

FEF research director Uwe Parpart: "This tour was one of the most encouraging things I have done in recent years."

Question: I understand that your lectures on fusion development were very well received. Where did you speak and what do you see as the future for fusion as an energy source in India?

I gave several lectures on fusion at different places; for example, one at the research and development center at the Bharat Heavy Electrical Corporation in Hyderabad, a second one at the Bhabha Atomic Research Center in Bombay, and another at the Indian National Science Academy in New Delhi. In each case I went through where fusion development stands at this point in the United States and the Soviet Union. I discussed fusion development within the more general context of energy policy—basically from the standpoint that the kind of fusion progress we have seen in the past five to ten years justifies the expectation that fusion could begin to be commercialized in the 1990s.

I stressed that this certainly goes a long way toward opening up the kinds of energy policies that remove the restrictions imposed on energy development by people who argue that there are absolute "limits to growth." Of course, if these restrictions are removed, then anything can happen, and the more general restrictions on economic development put forward by the Club of Rome will be seen not to hold.

This has very important implications for India and for Third World nations. It means that they can begin to look forward to economic development and the achievement of a modern industrial economy—and at least be well on their way toward that by the turn of the century.

Two days before I left India, Homi Sethna, the head of the Indian Atomic Energy Commission, gave an interview to the *Times of India* in which he indicated that aside from a scaling-up of the present plans for conventional nuclear energy, the Indian AEC had also mandated the formation of two working groups to take steps toward the development of some sort of rudimentary fusion program in India, specifically including laser fusion.

At present India does not have a coherent, well-defined program. Of course, there are plasma physics programs in the larger universities and ongoing plasma physics research at the research institutes, but there is no coherently defined program. I had recommended that such a program be set up pulling together researchers in the field in one location, and that a group undertaking fusion research possibly move toward acquiring a few small machines for initial studies. Perhaps the Sethna interview is an indication of motion in this direction.

I also stressed that it was Homi Bhabha who in 1956 said at the first Geneva Atoms for Peace Conference that in 25 years mankind should be able to prove to itself that fusion could be commercially applied. Bhabha's prediction was certainly by far the most accurate anyone had made at that point.

Question: You knew a great deal about India's scientific capabilities before your tour since you had helped develop the 40-year program. What were some of the things you had not anticipated?

First of all, in the area of energy research, I learned very early on in discussions that India is now absolutely, entirely self-sufficient in terms of its ability to construct nuclear plants. It's no longer the case that any parts of these plants have to be manufactured outside of India. In all the technologies that are necessary—reactor vessel fabrication, for example—the Indians now have all the machine tool setups and so on. This was just accomplished within the last year or so. India has two completed nuclear plants and several research facilities, plus a 1,500-MW fast breeder test reactor and two nuclear plants under construction.

This of course is especially significant in light of the fact that the United States and other countries refused after 1974 to cooperate with India in the further development of its civilian nuclear energy program.

I was also impressed to learn that there is a reasonably well-developed collaborative program with France on the development of the fast breeder reactor as well as a well-developed program in collaboration with the So-

United Nations

In the early 1950s, Nehru's policy was very much geared toward the proliferation of scientific research institutions as a necessary element of overall development. Here a woman assembles electronic equipment at the Electronics Division of the Bhabha Atomic Research Center.

viet Union on magnetohydrodynamics for coal combustion.

In addition, I had the occasion to discuss with scientists and people in government the development of the thorium fuel cycle for nuclear energy. India has tremendous reserves of thorium and there is a certain amount of controversy about its viability at this point, including the time frame in which it could be implemented. I indicated that there should be no questions about the scientific feasibility of developing a thorium program and that the question of technological implementation, as in all these cases, depends upon pulling together a program that actually has a mission orientation to accomplish its goal within a reasonably short period of time.

All of these things, when one sees them close up, are quite impressive. One of the more dismaying things, however, is that collaboration between scientists in India and the United States seems at a very, very low level. At the same time, it's very clear that with minimal U.S. inputs not just on the research side, but in more education-oriented research in Indian universities, tremendous accomplishments could be made very rapidly. For example, I was at the physics department at the University of Delhi, which is very theory-oriented, not simply because the department likes it that way but because it's very difficult to acquire and put together the apparatus to build up an experimental physics program. The Fusion Energy Foundation intends to promote some collaboration, especially in the area of physics, between Indian universities and university departments where we have contacts here in the United States.

Question: What was the reaction to the U.S. government's possible decision to withdraw shipments of enriched uranium for the Tarapur nuclear plant?

I think the reaction of the Indians is that they are extremely disappointed but they obviously are not going to be deterred from developing their nuclear program. A U.S. refusal to supply fuel will be a slowing down factor to some extent. It is also one of those situations in which the back-and-forth on "nonproliferation" is interpreted by the Indians as part of a deliberate policy. They are disappointed and disgusted. It's clear that this is another one of those instances in which the United States, for the flimsiest of reasons, has pursued a policy that is extremely detrimental not just to the government of India but to the best interests of the United States. One of the things that will inevitably happen is that India will look toward the Soviet Union and toward other countries to supply the relevant fuel; they'll just go somewhere else.

Question: What is the general view in the scientific community today toward economic development?

I think one thing to point out is that most scientists in India were beginning to feel that they were unwanted and unneeded after Indira Gandhi lost power. There was a very heavy emphasis under the Janata government and the Charan Singh government that followed it on what they called ruralism and so-called appropriate technologies, better wooden picks and shovels and things like that, but no significant development. India's scientists certainly were given the sense that they were not part of the direction in which the country was going. That translated into two things: first, an unfortunate cynical attitude on the part of these scientists about what can be accomplished, a kind of retrenchment that meant compromise on their part with a lot of foolish ideas; second, it meant that a lot of scientists and professionals left the country and went elsewhere. This has begun to be turned around by the new Gandhi government, although I stressed with many in government with whom I spoke that it is very necessary to give these scientists and engineers a very direct challenge to return to the fold, so to speak, and to pitch in to help in putting the country's economy back together.

I think the new government is very much interested in this and has shown every evidence of doing so, but the climate had been poisoned and can't be turned around overnight. I think they are now well on their way to turning the situation around.

There is specific evidence to this effect. There was an announcement just a few weeks ago by the energy minister, that the entire energy grid of the country will be put under national guidance, and now the first steps are being taken toward creating an actual national grid. Also, the first phase of an ambitious water development program is being mandated for implementation. So I think you have many signs that things are now moving in the right direction.

The need to make rapid progress, especially in the energy field, is very, very obvious. In every large city in the period before the monsoon, on any given day there were several hours in which at least parts of the city were without electricity. There is a lot of load-shedding and tremendous problems, so it is obviously necessary to turn that around.

There is another area I want to stress briefly, that of applied research: During the last 10 years or so, India has become self-sufficient in grain production—at least at present levels of consumption (which remain inadequate compared to our own standards). In particular, this was accomplished by a combination of water development, applied research, and agricultural science, especially in areas like the Punjab, West Bengal, and so forth. This has been accomplished slowly over the past 10 years. There was something of a slideback in the period of the Janata government, but actually right now the situation is moving forward. However, the quality of nutrition still lags far behind. For a phase of further progress in this direction there will have to be a situation in which industrial development, nutritional standards, and so forth, rapidly advance in tandem.

Question: What about budget constraints on Indian scientific research?

Clearly, for a country that exists under circumstances where most of the population still lives in miserable and very-hard-to-imagine circumstances for most of us, it is very difficult to make the decision to allocate resources to basic research. However, it is absolutely clear and well understood by people throughout government and in other walks of life that this is really where India's future lies, so that tremendous sacrifices have been made.

One major problem is the necessity for large-scale military expenditures, a necessity imposed upon India by the fact that China attacked India in 1962 and Chinese troops still occupy Indian territory in the northeast and northwest of the country. Second, the unfortunate so-called U.S. tilt toward Pakistan in the 1970s also created circumstances bringing into question India's security vis-à-vis Pakistan. This means that large amounts of money that should go to research and development are diverted for necessary military expenditures.

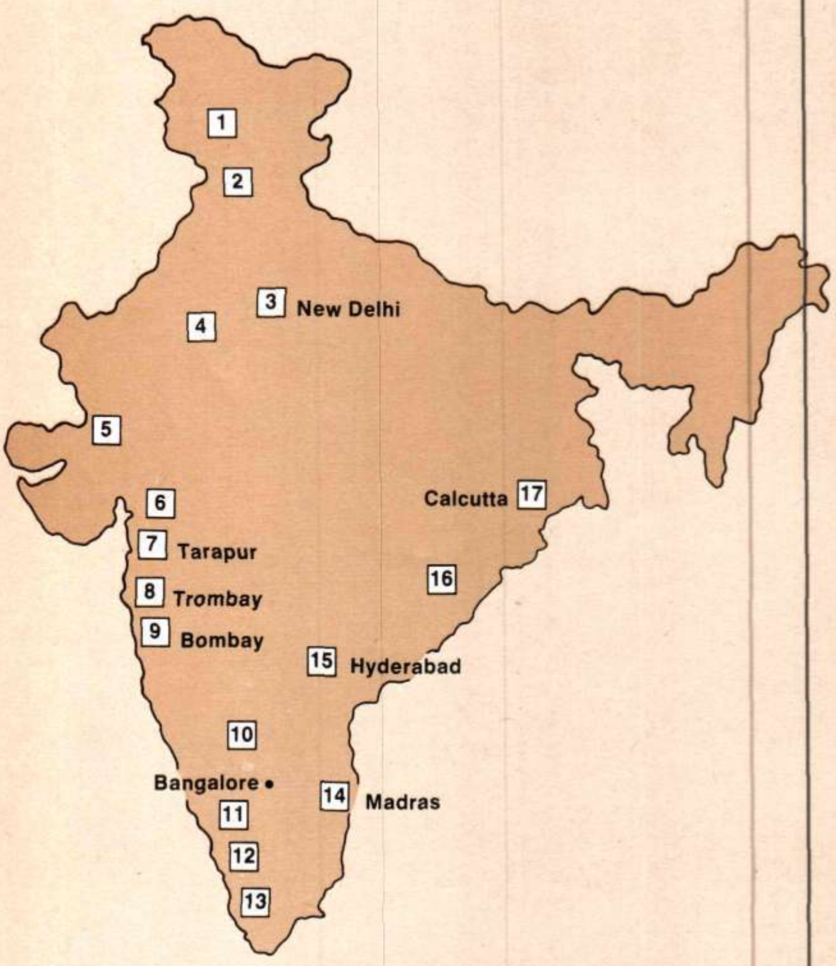
Question: In the May 1980 cover story on India, *Fusion* **stressed that the country has the highest number of scientists and engineers in the world after the United States and the Soviet Union. What is your firsthand impression of the scientific tradition that created this situation?**

One of the most interesting things is that when one goes to any of the Indian research institutes, there is inevitably a plaque saying "This establishment was inaugurated by Nehru on such-and-such a date." It is very obvious that in the early 1950s Nehru's policy was very much geared toward the proliferation of these scientific institutions as a necessary element of overall development. It was this phase of very rapid development of research and educational institutions that has carried India's development from that point on.

One of the things I realized is just how closely tied are the Indian determination to accomplish certain things and the establishment of a scientific elite and scientific institutions, whether in basic research or in more applied research fields such as reactor technology.

There are certain areas in which Indian science has excelled in the past, in physics, and especially in astrophysics, but also in mathematics and the mathematical sciences generally. These areas have an important tradition in India quite apart from the British influence and training. There are several thousand years of extraordinary accomplishments and commitments in India toward progress in what we would call the natural sciences and mathematics. Several significant inventions in geometry and arithmetic that determined the course of the development of the mathematical sciences had their origin in India and were passed along by the Greeks and the Arabs to Western Europe and later on to the United States. I have begun at least some preliminary work on tracing this in more detail. There are some books published in India on this subject, but they are somewhat sketchy.

To give you one example of the Indian tradition: the so-called Pythagorean theorem, if it was in fact first written down by Pythagoras, would have fallen in the sixth century. There is direct evidence, however, that the



INDIA'S NUCLEAR INDUSTRY

Dr. Homi Bhabha, the father of India's nuclear program, set out in the 1940s to make India's scientific manpower equal to the world's best. The network of India's research and nuclear facilities shown here is testimony to Bhabha's extraordinary vision.

1. High altitude research center
2. Heavy water plant
3. Atomic Minerals Division
4. Nuclear power station
   Heavy water plant
5. Physical research laboratory
6. Heavy water plant
7. Nuclear power station
8. Power reactor fuel reprocessing unit
   Bhabha Atomic Research Center
9. Tata Institute of Fundamental Research,
   Tata Memorial Center
10. Seismic station
11. Rare earth plant
12. Mineral sands
13. Heavy water plant
14. Reactor research center
    Nuclear power station
15. Electronics Corporation
16. Uranium Corporation
17. Saha Institute of Nuclear Physics
    Variable energy cyclotron

theorem and its full implications were known in India some 400 to 500 years before that.

It is also significant that the number zero was an Indian invention. The concept of zero plays an important role in the number system and also has what you might call a broader metaphysical significance in that it references a transfinite point of perspective on the number system involved. This was extremely crucial in the development of modern number theory.

It should be stressed that there is a very rich scientific tradition that Indian scientists today quite consciously draw upon. This was very consciously put into the foreground by the people around Nehru and others.

On the question of whether there is a particular "Indian" science, this question came up during my talk at the Indian National Science Academy. My response was that I really didn't think one could be a scientist unless one believed in the universality of science, and that that universality has to be the most explicit concern of any scientist.

It's interesting in this respect to see that in India today Islam does not play the kind of role that it tends to play in Iran, but actually it has had in the past a kind of secularizing influence that attenuates some of the most backward, cultish aspects of Hinduism. Muslim scientists in India tend to be very open and very much concerned with the universality of science, with the tradition of the great Arab scientists like Ibn Sina. So I don't see at all a rejection of the humanist scientific tradition as is widespread in Iran and unfortunately gaining influence in other Arab nations. In fact, it would be admirable if scientists in the advanced sector would show as much resilience as the Indian scientists have to the kind of antiscience philosophy prevalent in Iran and among the environmentalist propagandists in the West.

Question: Does the scientific establishment have a view toward building up scientific capabilities in other parts of the Third World?

Traditionally India has always had good relationships with the Arab nations and also with East Africa. And one of its most interesting exports, apart from the brain-drain question, is that Indian scientists and engineers, in fact, have begun to play a significant role in the economic development of other developing-sector nations. That's very important and useful.

Question: What is the overall outlook for the future in terms of the 40-year plan you discussed?

I found a great deal of excitement about the program that we had proposed. There was a lot of discussion, and we will be publishing the responses to the ideas that we developed with our collaborators in India.

Let me just say one thing about the scientists at Osmania University in Hyderabad. I spoke there before a group of economists from their economics department. This group had in the past worked on a model for the economic development of India, essentially involving shifting as much investment as is feasible to heavy industry development and the necessary support systems for rapid agricultural and industrial development. We had an excellent discussion over that, comparing their own ideas with ours.

It was very clear to me that it is not just in the natural sciences that the Indian tradition in science is alive and well, but in the field of economics and economic planning and development as well, which is a very encouraging thing.

On the other hand, I want to repeat what I mentioned before, that there is an explicit challenge to the Indian scientist once again to become much more directly involved in putting the economy back together.

I learned a great deal in India. We never regarded the 40-year program we put forward as being complete or sufficiently detailed. We wanted to set certain benchmarks and establish an overall methodology for development. Therefore, the suggestions for the program from Indian scientists were not really in the form of saying that this or that piece really won't work, but rather that some things could be done better and faster or that other things might have to be modified. Mainly what I learned was a great deal more about how to do this sort of rapid development project in detail. We will be publishing many of these commentaries from Indian scientists and planners in the magazine in the coming months, such as the piece on water development by R. Rama Rao in this issue.

FEF's Parpart Tours India

by Paul Zykofsky

Fusion Energy Foundation director of research Uwe Parpart spent the end of May and beginning of June on a tour of some of India's scientific and academic centers, delivering lectures and meeting with scientists, engineers, economists, planners, industrialists, and government officials. The purpose of the informal tour was to discuss the 40-year Program for the Industrial Development of India developed collaboratively by the FEF and the weekly magazine *Executive Intelligence Review*.

The India program was summarized in the May 1980 issue of *Fusion* and published as a special report by the *Review*.

The three-week tour, including stops in four of India's major cities, was "a major success," according to Parpart. "It has been one of the most encouraging things I have done in recent years," he told an audience of scientists at the Indian National Science Academy in New Delhi at the conclusion of his visit.

The tour opened with a three-day visit to Hyderabad. Despite its resemblance to an overgrown village—with its narrow streets in the old Muslim section of the city crowded with cycle rickshaws, bicycles, three-wheel scooters, and bullock carts—Hyderabad is India's fourth largest city with a population of more than two million. During his tour Parpart visited some of the city's advanced technology industries. More than 200 scientists and technicians attended his lectures on the status of international research in fusion energy at the Nuclear Fuel Complex and the R&D Division of the state-sector Bharat Heavy Electrical corporation.

A smaller meeting to discuss the

Uwe Parpart

A fishing village in Bombay, framed by the modern skyline of India's leading industrial city.

Riemannian economic analysis method codeveloped by the FEF was held at the economics department of the leading Osmania University, and Parpart also spoke to scientists and technicians working on coal combustion technology at the Regional Research Laboratory, one of the many laboratories set up throughout the country during Nehru's rule to build up India's domestic R&D capabilities. During his visit to Hyderabad, Parpart also met with a leading Indian biologist at the Center for Cellular and Molecular Biology, with an energy policy expert at the Administrative Staff College, and with the chairman of the State Electricity Board.

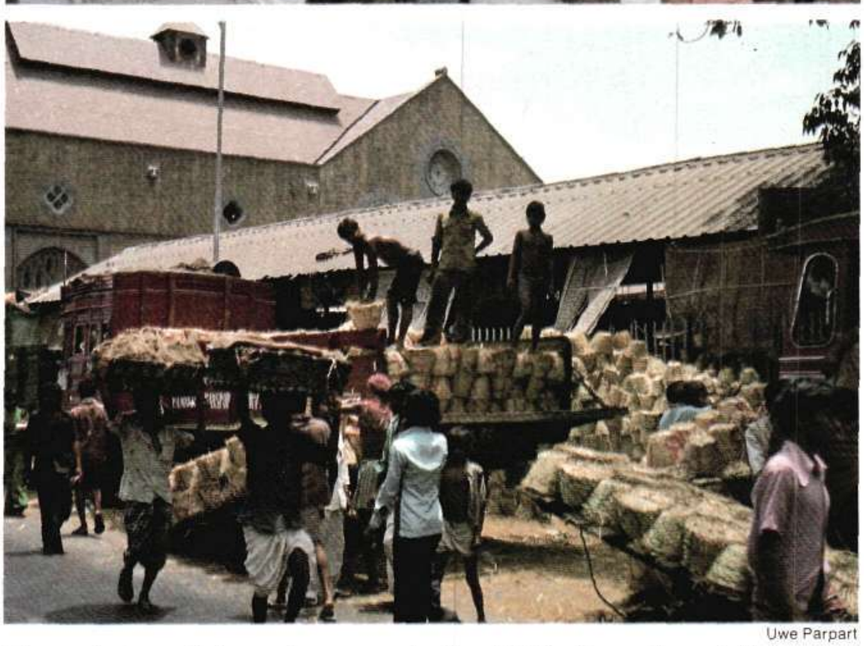
The next stop was Bangalore—a modern city that is the center of India's aerospace industry. Hindustan Aeronautics, which manufactures aircraft ranging from small, single-engine planes to Mig-21 fighters, is located there, as is the headquarters of the Indian Space Research Organization (ISRO).

In Bangalore, aside from a meeting with a top scientist at the ISRO and with the state planning secretary, Parpart spent most of his time meeting scientists at the sprawling campus of the Indian Institute of Science (IIS), where he delivered a lecture to 50 students and professors on "The Necessity of Nuclear Energy for Third World Development." The IIS, founded by the enterprising industrialist family of Bombay, the Tata family, has the largest concentration of leading Indian scientists in the country. It is here that world-renowned Indian physicist and Nobel laureate C.V. Raman, discoverer of the "Raman effect" in atomic physics, and other leading scientists worked.

The last stop of the tour before returning to New Delhi was Bombay, by far India's most cosmopolitan city, with the nation's largest concentration of industry. The highlight of Parpart's stay in Bombay was a five-hour visit to the Bhabha Atomic Research Center (BARC) in nearby Trombay where he delivered a lecture on "Fusion Energy: How Soon?" to more than 500 scientists and technicians.

The Bhabha Tradition

The establishment of BARC in 1954 was the result of leading Indian scientist Dr. Homi Bhabha's efforts to build up a nuclear energy program in India on a par with those of the developed nations. Today BARC employs 11,000 people, including 3,000 scientists and engineers, and is one of the largest and best equipped research centers in the world doing work in a wide range of disciplines.



Uwe Parpart

Above: A view of the main mosque in the old Muslim section of Hyderabad, looking out from the famous Char Minar, an example of Medieval Muslim architecture. Below: The fruit market in Bombay, known for its mangoes.

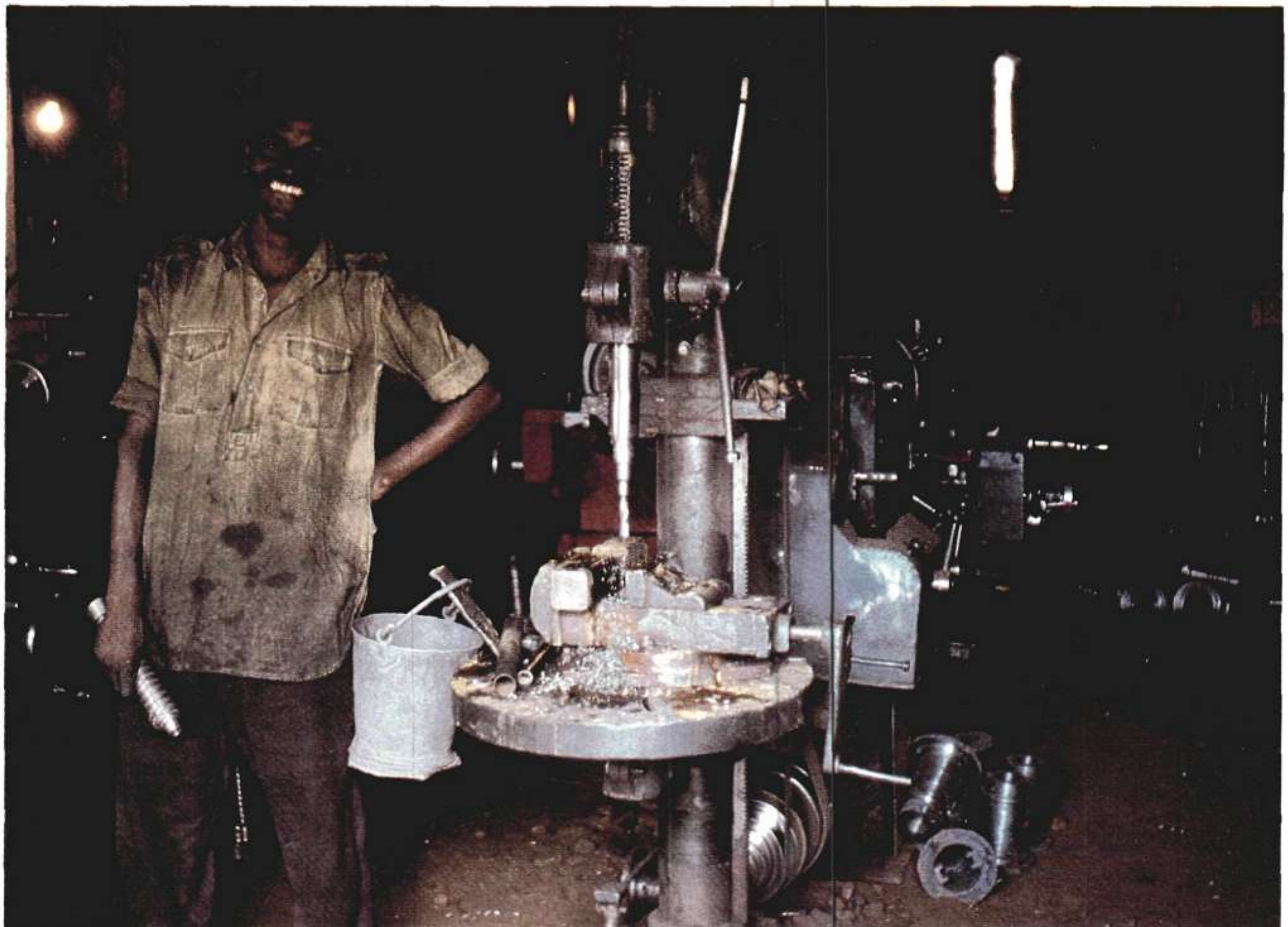
In his presentation at BARC Parpart suggested that in the same way that Bhabha had gotten India involved in nuclear energy research when it was still in an infant stage in the developed countries, today India should step up its research—particularly on the theoretical side—on controlled thermonuclear fusion research. In that way, he noted, by the time the technology is mastered in the advanced industrialized nations, India will be in a position to fully understand and assimilate it as well.

During his visit in Bombay Parpart also spoke on fusion energy at the Nehru Center and discussed India's economic development potential with leading industrialists.

The last 10 days spent in New Delhi—India's administrative center—were devoted to meeting with members of the government and the Planning Commission, as well as with scientists, businessmen, and economists.

On June 6, Parpart delivered a lecture on "The Status of International Research in Fusion Energy and Its Implications for Economic Development" at the leading scientific institution, the Indian National Science Academy (INSA). The lecture, presided over by INSA president and director of the Indian Council of Medical Research, Dr. V. Ramalingaswamy, was attended by 50 leading Indian scientists, and there was a lively discussion on the problems of technology transfer, appropriate technologies, and economic development.

The next day Parpart spoke at the prestigious Nehru Memorial Library, established in memory of India's first prime minister, to a group of 60 leading economists, planners, and scientists on the FEF study for India's long-term development. Presiding at the event was Dr. Raja Ramanna, scientific advisor to the Ministry of Defense. The lecture, covered widely by the Indian press, highlighted the fact that India has the potential to become an industrial superpower by the turn of the century. Parpart stressed that this can be done by focusing economic activity on those sectors of the economy that can have a shock-wave ef-



A machinist in Agra proudly poses in his shop.

Uwe Parpart

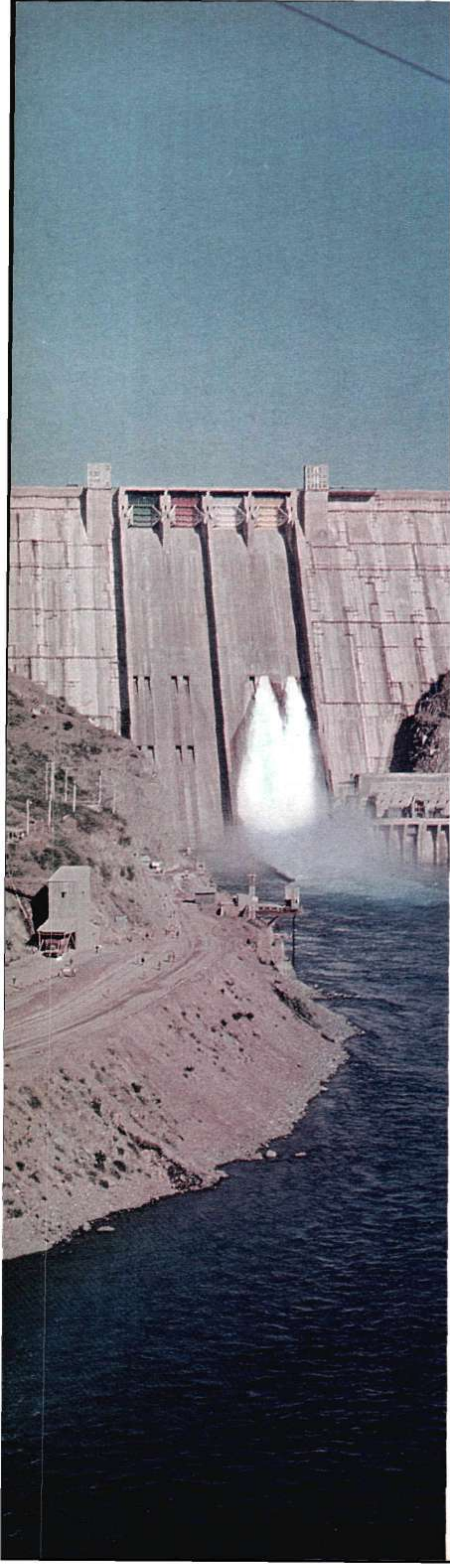
fect on the entire economy. After looking closely at the Indian economy, he noted, it was clear that the two main components of such a program should be: large-scale water management and an intensive energy development policy with heavy emphasis on nuclear energy that can make use of India's large thorium resources.

As Parpart emphasized time and again during his tour, what allows India to move forward at a rapid pace today is not its natural resources per se, but the fact that it has built up a sizable scientific and technical manpower pool second only to that in the Soviet Union, the United States, and Japan. After meeting with numbers of scientists during his tour, Parpart stated that there was no question that this manpower is India's most valuable asset for any development policy.

Parpart found widespread agreement among scientific layers with the basic points of the program—despite the large ruralist, "small is beautiful," solar energy lobby that has been built up in India during the past few years with support from the World Bank, UN agencies, and private and public institutions in the United States, Great Britain, and West Germany.

In fact, many scientists and economists who have been battling the "small is beautiful" outlook were surprised to hear a non-Indian advocating exactly the type of development strategy based on industrialization and assimilation of advanced technologies originally pursued by Prime Minister Nehru. The closing remarks delivered by Dr. Raja Ramanna, an eminent nuclear scientist and current scientific advisor to the Defense Ministry, after Parpart's lecture at the Nehru Memorial Library, encapsulated the response of many of those who heard the FEF's views on energy and development during Parpart's three-week tour:

"I must say that Parpart has cheered us up quite a lot. Especially living in Delhi one sometimes gets depressed about the progress being made. And then you suddenly go abroad and come back and you find that the progress made in India is really enormous. When people like Dr. Parpart come along and tell us that this is so it is very heartening. It is more heartening to me because it does not often happen that somebody coming from abroad makes a case for nuclear energy. It is so popular to run it down in all its aspects. So when a person who has thought about it sufficiently comes and says, 'that's your answer,' well, I must say I feel cheered up."



Developing India's Water

Editor's Note: On his recent tour of India, FEF director of research Uwe Parpart invited several scientists, engineers, and government officials to comment on the FEF's proposed 40-year industrial development program for India. We are pleased to publish one of the first responses. Author R. Rama Rao discusses the potential of India's land and water systems and presents two different water plans as well as an interim plan that combines the best features of both.

The first plan, proposed by Dr. K.L. Rao, suggests a pump lift scheme for transferring northern Himalayan water across the Ganges Valley to the high plateau of the southern peninsula. The second plan, proposed by Captain Dinshaw Dastur, calls for a huge canal and pipeline storage and transfer system with little pump lift required. This is a bold but probably impractical concept for the gravity transfer of water from a 3,000-feet elevation contour canal in the Himalayan Range across the Ganges Valley to a 1,500-feet elevation contour canal in the southern peninsula.

The FEF water plan, part of the 40-year development program summarized in Fusion *(May 1980), is a modified version of the Rao plan, but with a tenfold increase in the ultimate Ganges-Brahmaputra diversion capacity. Staged in time and scale to cohere with other development, the plan is based on capturing monsoon runoff in both conventional surface reservoirs and an extensive system of groundwater storage. Nuclear explosive methods would be used to fracture geologic water formations and riverbeds in conjunction with combined recharge-extraction wells of the highly prolific radial design.*

The Bhakra Dam, India's largest.
Shostal

Although India is perhaps not as well endowed in terms of natural resources as Australia, Brazil, Canada, China, South Africa, the Soviet Union, or the United States, its resource endowments are far from negligible. It holds fairly extensive reserves of bauxite, iron ore, chrome, manganese, rare earths, coal, and thorium, the last two being valuable energy sources. There are other mineral reserves as well, but important as all these resources are, India's principal natural resources are its fresh water, which is perpetually regenerated by annual precipitation and snow melt; its extensive arable land; its long coastline and warm tropical waters with their infinite richness; and, finally, its human resources.

India's fresh water is now being allowed to run to waste uncontrolled, causing avoidable loss of life and property in its wake. Its arable land is being allowed to deteriorate gradually, in part because of indiscriminate felling of trees and overgrazing and in part because of past failure to provide adequate soil nutrients, especially organic nutrients, to preserve soil texture and soil fertility. India's land resources can create substantial wealth only when water, now running to waste, is taken to places where it is needed for cultivation. The third can be profitably exploited when the people become conscious of the full potentialities of this resource.

At present the country's principal asset, its human resource, is only a potential asset that will be realized only when it is trained and when an environment is created and sustained in which the individual is encouraged to attain his or her full potential and so contribute the maximum toward national development.

The resources listed here would have to be developed first in order to lift from the depths of poverty an

Resources by Colonel R. Rama Rao

estimated 200 million people now going hungry, ill clad, and unable to find adequate work. And in order to implement programs designed for scientific utilization of the country's water wealth, certain basic industries would need to be developed concurrently.

Once a firm foundation of broad-based agricultural development is built, the country can march ahead, to step up the input of science and technology to raise crop production further, making full use of available land and water, and to usher in a period of rapid industrial growth based on locally available raw materials. The first phase of development, however, would have to be centered around skillful water management.

Water Economy

Out of an estimated annual precipitation of 400 million hectare-meters or Mha-m, the country was using only 38 Mha-m in 1974. Present planning envisages utilization of 75 Mha-m by the year 2000, and 105 Mha-m by 2025, which gives some measure of the country's unutilized potential.

Because water is not being harnessed (that is, it is not being taken to where it is needed), arable land is left unirrigated. Although such land is cultivated, its output is dependent entirely on timely and adequate rainfall. Thus, of the net sown area of 140.2 Mha, only 35 Mha was under assured irrigation; that is, roughly one-quarter of the country's currently developed land resources. Even if only the very conservative projections of Indian planners are translated into action, the irrigated area would double by the turn of the century as would food production, taking India into its proper position as a major food producer.

Further, because more than 90 percent of tropical rain water and mountain snow melt is allowed to run to waste, the country's rivers, streams, and natural waterways overflow their banks after heavy rainfall almost every year, submerging cultivable lands and villages close to river banks. Flood incidence and flood damage have been steadily increasing over the years, thanks to indiscriminate felling of trees on hill slopes and river catchment areas. A recent estimate puts the direct loss due to flood damage at 3,000 million rupees ($400 million) a year. If to this is added the indirect costs in terms of disruption of communications, the nation is probably paying about 10,000 million rupees ($1,275 million) a year for its failure to harness its water resources.

Harnessing Flood Waters

An estimate of the water potential of India, derived from rainfall and river flow data over a number of years, is presented in Figure 1. As can be seen, of the available 400 Mha-m, the country now uses only about 38 Mha-m.

Vast quantities of water are carried into the Bay of Bengal by India's two major river systems, the Ganges (Ganga) and the Brahmaputra, which together account for almost 60 percent of the country's river flow. The waters of the Ganges, because the river flows across the northern Indian plains, are fairly well utilized in the northern region. The Brahmaputra flows through the northeastern region, an area where rainfall is the highest in the world.

The problem here is to arrange disposal of surplus water, generating as much hydroelectricity in the process as possible. These waters can be best used if diverted across northern Bangladesh into India. Bangladesh could irrigate at least another 5 Mha of dryland and step up its crop production spectacularly. After meeting Bangladesh's legitimate requirements, Brahmaputra waters could be diverted back into India. This plan could be taken up for implementation when Bangladesh shows interest.

The table gives details of the total annual flow of Indian rivers and the extent to which they are now used.

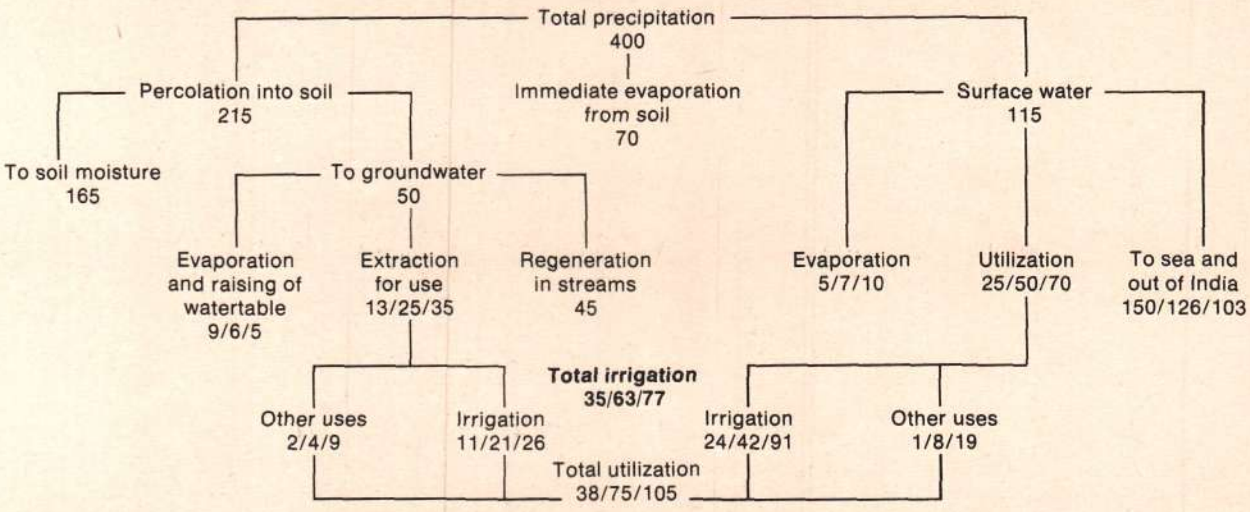
The waters of the southern rivers are better utilized than those of the more important northern rivers, but this region as well as central and western India needs more water. Thus, an important national task is to draw off excess water from the major river systems—the Brahmaputra and Ganges—and divert at least some of it to the relatively water-starved areas of central and western India (Madhya Pradesh, Rajasthan, and Gujarat). Considering the vast unutilized potential of these rivers, a good fraction of the surplus can also be diverted south for irrigating the parched lands of the Deccan and the southern peninsula (Orissa, Andhra, Maharashtra, Karnataka, and Tamil Nadu).

The other sector of the country where fresh water from monsoon rains is allowed to run to waste is the entire west coast from Bombay to Kerala, where numerous rivulets and streams flow into the Arabian Sea down the slopes of the western Ghats. At least a portion of these waters can be diverted eastward to bring considerable areas of the southern states under assured irrigation.

Proposed Solutions

Indian engineers and planners have put forward two suggestions for harnessing surplus northern river waters. The first, proposed by a distinguished engineer and former minister for irrigation and power, Dr. K.L. Rao, envisages the drawing-off of surplus Ganges waters, leading them southward to link up with the Godavari, Krishna, and Cauvery river systems. This would certainly upgrade vast dry tracts of east central India and provide much needed water to the south.

Figure 1
APPROXIMATE DISTRIBUTION OF INDIA'S AVERAGE ANNUAL WATER RESOURCES IN 1974, 2000, AND 2025
(in million hectare-meters)



The flow chart and table at right indicate the vast amount of fresh water in India that is not currently utilized. The first of the three numbers in the flow chart items refers to 1974 actual figures; the second number is a projected figure for the year 2000 based on a very conservative development plan; the third number is the projection for 2023, given the same plan.

Source: Report of the National Commission on Agriculture 1976, Part 5, Resource Development, page 5.

However, the scheme suffers from the limitation that water has to be lifted from low-level water channels to points at higher elevations. Therefore, several high-capacity pumping stations would have to be installed along the main waterways. The energy requirements of the plan alone could render it unviable at present.

The longitudinal section of the proposed water link, presented in Figure 2, gives some idea of the magnitude of the problem and the energy inputs necessary for lifting and transporting the several million hectare-meters of water that the proposed water grid will have to carry.

The second proposal is also attractive. Its initiator, Captain Dinshaw Dastur, notes with justification that "we [India] are a poor country only because nobody has bothered to look for and exploit our resources," pointing out that "we have more wealth in our fresh water alone than Arabia has in all her oil."

Captain Dastur's plan hinges on the construction of a 1,200-mile canal at an altitude of 3,000 feet above sea level along the lower slopes of the Himalayas, in order to catch rain water and mountain snow melt, and a Garland canal 5,800 miles long girdling central and southern India. Water is to be conveyed from the Himalayan canal to the Garland canal through a system of high capacity pipe lines. The Dastur proposal is presented schematically in Figure 3.

Captain Dastur's elegant plan has immense potentialities, although, in the outline form now presented, it also has several limitations. For one thing, the Himalayan canal, which in effect acts as a vast storage cum flow channel, would be much longer than Dastur tentatively assumes if it has to be at a uniform height along its entire length, requiring a good deal of excavation and building work in an area that is still geologically unstable. For another, far more pipeline-systems than the two described would be necessary to draw off the flood and river waters impounded by the main canal.

There are also several engineering problems concerning the Himalayan as well as the longer Garland canal that would result in a significant increase in the costs as well as in the time needed for executing the project. The main difficulty is that the Himalayan canal, as well as the Garland canal, must have appropriate gradients to ensure water flow. This would call for installing booster pumps to pump water or for redesigning the entire canal system. Other limitations are that thousands of villages may have to be shifted not only in the scarcely populated hilly regions but in the densely populated central and peninsular India to enable canal systems to be built.

Conceptually, however, Captain Dastur's Garland canal scheme is excellent and if modified suitably would free Indian agriculture from dependence on monsoons, solve the flood problem, provide employment to millions, and set the stage for massive industrial development.

An Interim Program

A basically simple interim program can be devised that would incorporate the more advantageous aspects of the Rao and Dastur plans, present

ANNUAL FLOWS OF INDIA'S RIVER SYSTEMS

	Average annual flow	Utilization flow	Approximate present utilization
	(in million hectare-meters)		
Indus basic	7.7	4.6	3.7
Ganga basic	51.0	25.0	8.5
Brahmaputra (including Barak)	54.0	2.4	0.5
Mahanadi and other east-flowing rivers up to Godavari	12.3	9.1	2.8
West-flowing rivers south of Tapti	21.8	3.0	1.1
Godavari, Krishna, and other east-flowing southern rivers	22.5	19.0	7.3
Narmada and Tapti	6.2	4.9	0.6
West-flowing rivers north of Narmada	2.5	2.0	0.5
Total:	178.0	70.0	25.0

Source:
Report of the National Commission on Agriculture 1976, Part 5, "Resource Development," p.8

as few engineering problems as possible, and generate hydro power by making use of the lay of the land (instead of requiring energy inputs for transporting large quantities of water). Such a program would tap at least a part of the Brahmaputra waters for diversion across the northern sector of West Bengal, linking with Bihar rivers for irrigating south and southwest Bihar and simultaneously reducing flood incidence in the region.

Should Bangladesh extend its cooperation, the bulk of Brahmaputra waters can be utilized for irrigating the dry areas of northern Bangladesh, converting that country in a matter of a few years from a food-deficit country into a food-surplus country. Till then, part of Brahmaputra waters can be diverted to Bihar, along the proposed canal across North Bengal.

Other segments of this plan would link the flood-prone Mahanadi, Baitarni, and Subernaleka rivers of Orissa with the Godavari and Krishna systems, extending irrigation to millions of hectares of dry land. Additionally, power could be generated in the upper reaches of Orissa. The Narmada and Tapti waters, for which plans for harnessing are already afoot, would extend irrigation considerably in Madhya Pradesh and Gujarat as well as marginally benefiting Maharashtra and Rajasthan.

Sutlej waters, which are yet to be fully utilized, can be conveyed to Haryana and, likewise, part of Jamuna and Ganges waters can be diverted from Himachal Pradesh and Delhi westward into Rajasthan. The importance of this lies in the fact that Rajasthan—the most heavily populated desert region in the world—has immense agricultural possibilities if water is made available. Rajasthan is, in fact, India's land bank. However, in order to realize its vast agricultural potential, the region must be provided with water and the eastward drift of desert must be halted by creating a series of green belts, which, hopefully, would at least conserve the environment.

The water needs of the southern peninsula and the Deccan can be met fully by diverting eastward the streams that flow westward from the western Ghats. Detailed engineering studies for this part of the project have yet to be made. It may involve tunneling through the hills in certain sectors but even so, the benefits in terms of hydroelectricity generation and increasing area under assured irrigation would outweigh costs.

The main advantage of this modified scheme is that *all* the projects covering northeastern, northwestern, central, southeastern, and southern regions can be started simultaneously, and benefits in terms of increased area under irrigation and increased crop production would accrue within two to three years. It would also elicit maximum cooperation from regional authorities since the regions concerned would garner immediate benefits both in the form of increased food production and in vastly increased rural employment opportunities.

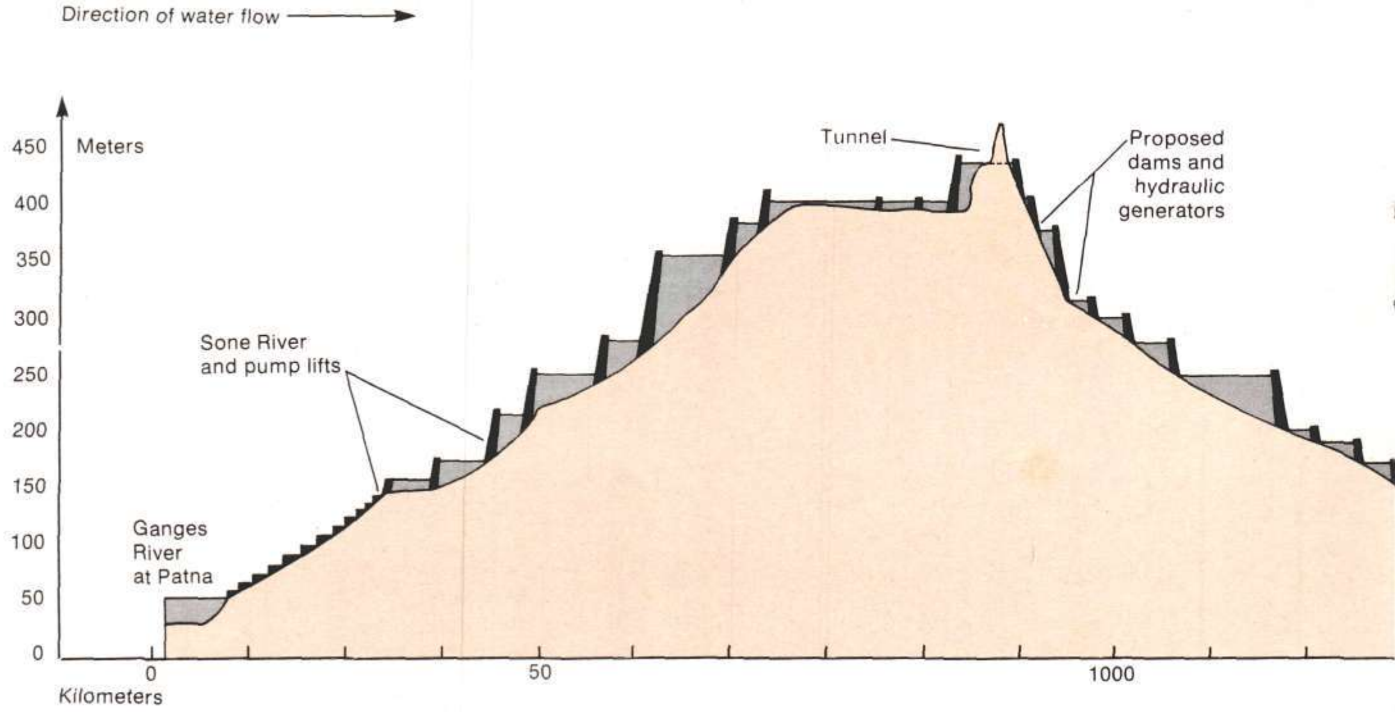
Likewise, exploitation of ocean fisheries supplemented by the development of inland fisheries would immediately provide not only high-quality protein food for millions in the country but also adequate quantities for export and the earning of foreign exchange. The potential fish catch in the seas adjoining India's coastline is estimated at 10 million tons a year. Of this Indian fishermen now catch no more than 1.5 million tons, which gives some measure of the unexploited potential that awaits harvesting.

Again, this is an employment-intensive industry and, therefore, ought to be attractive to state governments.

Afforestation, by its very nature, can yield results only over a period. But a long-range plan must be evolved now and vigorously implemented in order to prevent land slides in the Himalayan and other slopes and erosion of river catchment areas. In the process, of course, such projects would grow valuable timber.

Of the country's geographical area of 328.8 Mha, no more than 66.4 Mha (or just 20 percent) is covered by forests. Every endeavor has to be made to increase the area under tree cover by at least 34 Mha, bringing the area under forests to about 30 percent

Figure 2
THE GANGES-CAUVERY LINK CANAL FROM PATNA TO CAUVERY RIVER



of the country's land surface. This is the minimum area needed to prevent environmental degradation and is the most effective long-term insurance against soil erosion and flood damage.

Furthermore, a well-regulated forest policy would enable the country to step up production of industrial wood from the present disappointing level of 11 million cubic meters a year to at least 20 million cubic meters a year over a 10-year period. Likewise, production of nonindustrial (or fuel) wood could be stepped up by a factor of 2 from the present low level of 15 million cubic meters per year.

The essential elements of a comprehensive water utilization program are easily spelled out; but for any program of this nature to be carried out effectively, there are several prerequisites.

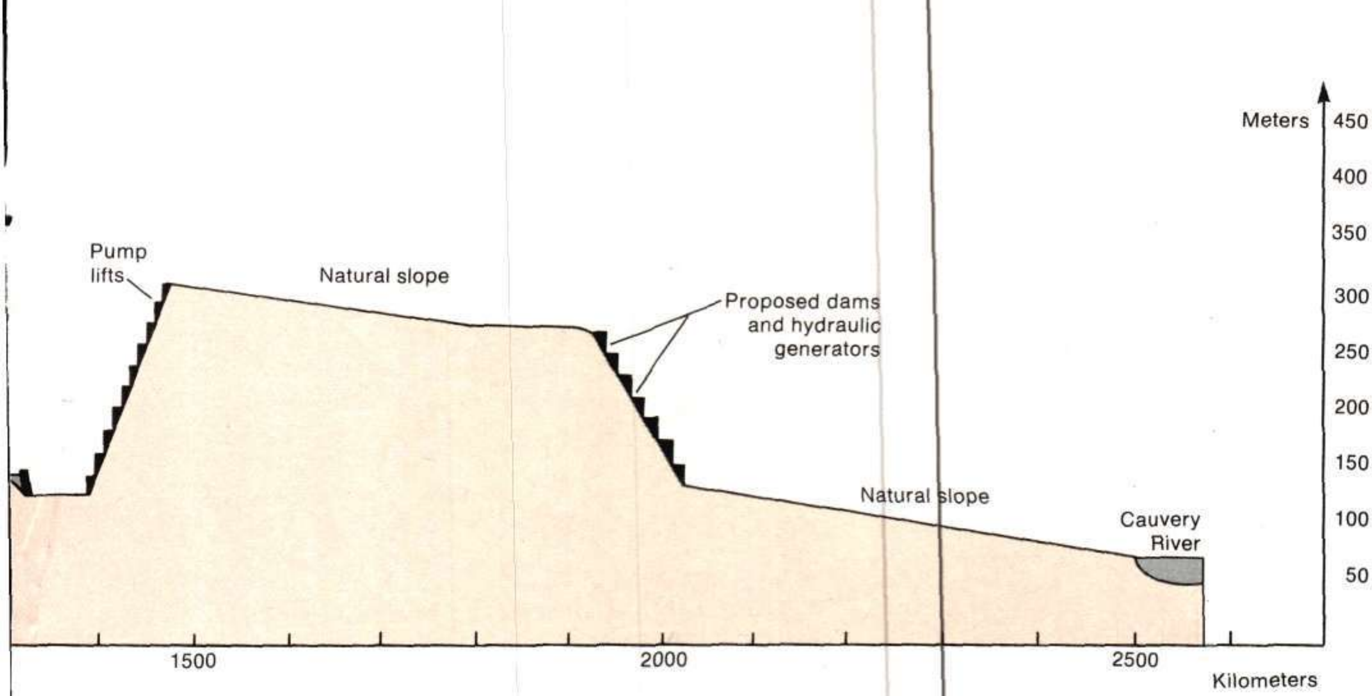
First, a viable industrial infrastructure is necessary in order to put through a vast water utilization scheme involving the construction of a network of canals, sluices, associated water storage dams, and other irrigation and power-generation structures. Adequate building materials (cement, structural steels, tools) as well as power and transportation facilities must exist or become available as irrigation work progresses.

Second, in order to reap full benefits of new irrigation potential as it is created, farmers should have the assurance of adequate and timely supplies of high-yielding varieties of seeds, organic and inorganic soil nutrients, crop protection agents, and facilities for regular soil testing so that soil additives may be applied as necessary. This would call for the establishment of more fertilizer factories and stepping up fertilizer production so as to meet the vastly increased demand for soil nutrients that the plan would generate.

Third, to implement an expanded fisheries program requires the establishment of a network of boat and trawler building and repair yards, facilities for manufacturing nets and ancillaries, and the training of personnel.

More important than all three areas is the need to restructure India's administrative machinery. Professor John Kenneth Galbraith, former American ambassador at New Delhi, described India a decade ago as a "functioning anarchy." In a manner of speaking, the country still functions in spite of, rather than because of, its bureaucracy. Planning and its implementation is unlikely to be purposeful in India until such time as the Indian bureaucracy realizes that it exists to serve the country and not the other way round. Hopefully, the present government with its strong popular support will accord high priority to the task of taming the bureaucracy and literally cutting it to size, so that at least during the 1980s the country can get on with the urgent tasks of agricultural and industrial development.

Colonel R. Rama Rao, now retired from the Indian Army, is with the Birla Institute for Scientific Research in Delhi, India.



Source: *Water World*, Vol. 2, No. 1, July-Sept. 1979.

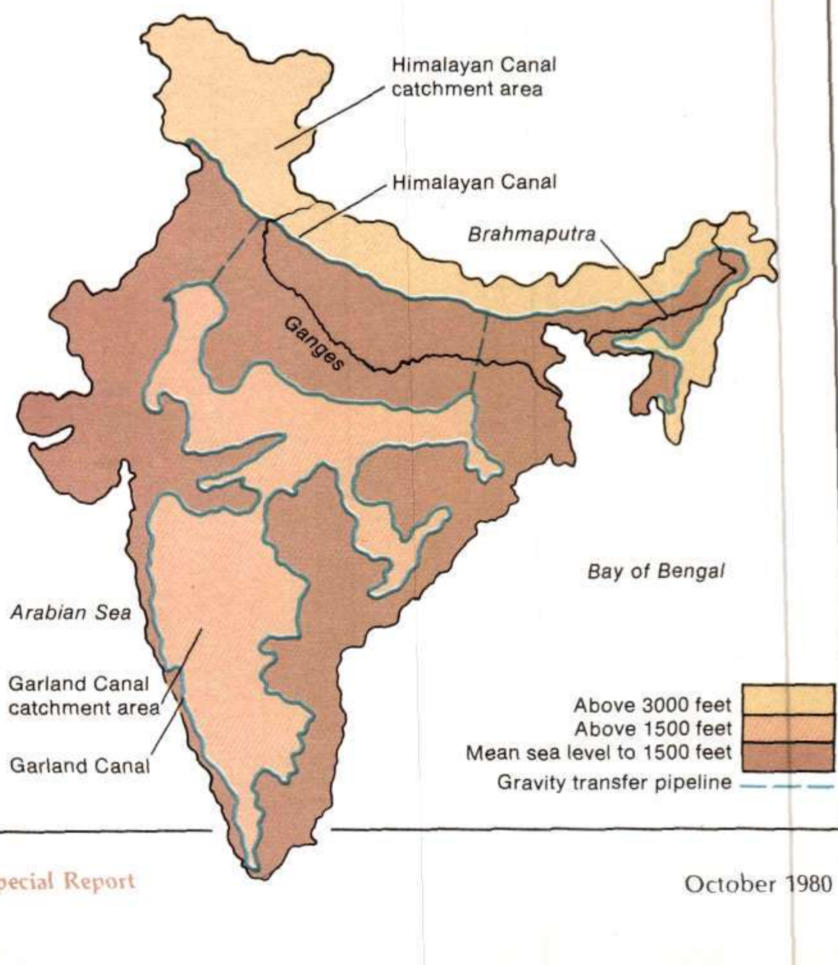


Figure 3
GARLAND CANAL FOR HARNESSING FLOOD WATERS

Length:
Himalayan Canal, 1,200 miles. Central and Southern Garland Canal, 5,800 miles

Width:
1,000 feet (both canals)

Depth:
30 feet (both canals)

Canal position:
The Great Himalayan Canal is on the slopes of the Himalayas at exactly 3,000 feet above mean sea level (MSL). The Garland Canal on the Central and Southern Plateaus is at exactly 1,500 feet above MSL.

Lake area and capacity of the canal:
The flow of water from the Himalayan Canal into the Garland Canal will fill out the latter one-third of its full capacity every year. The Himalayan Canal area is 15 square miles with a capacity of 196.08 billion cubic feet of water. The Garland Canal is 33 square miles with a capacity of 818.72 billion cubic feet of water.

Source: *The Illustrated Weekly of India*, Oct. 20, 1974, p. 13

The Buchsbaum Report

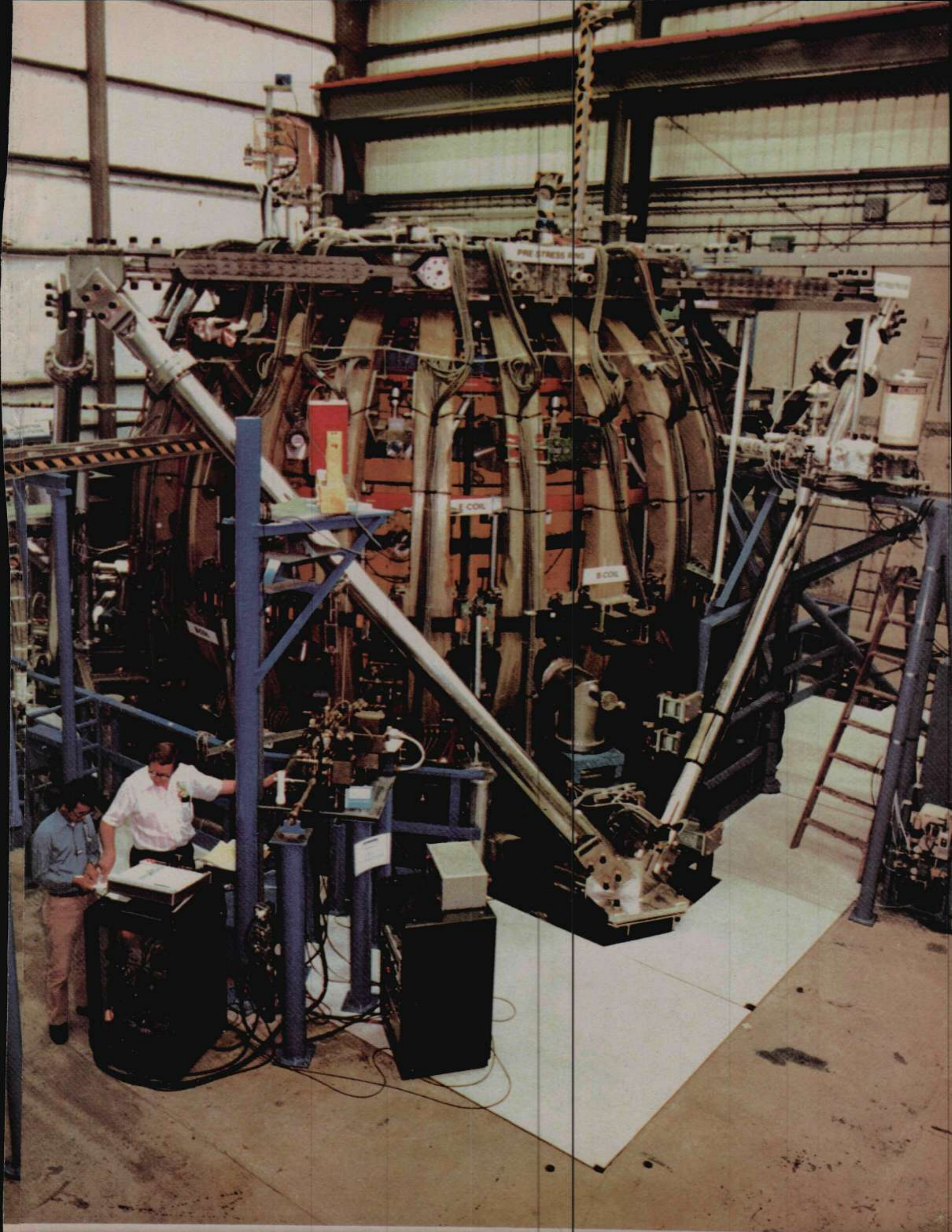
A Fusion Reactor Before the Year 2000

Editor's Note

This Report of the Fusion Review Panel of the Department of Energy's Energy Research Advisory Board (ERAB), released June 24, evaluates the "impressive" progress of the U.S. magnetic confinement program and recommends that the DOE upgrade the program in order to ensure that prototype fusion electric power plants will be a reality by the year 2000. The text of the 35-page draft report, which the ERAB will review August 18-22, is reprinted here in full, along with the report's glossary. A news article on the report appears in the Washington section.

The Fusion Review Panel is chaired by Dr. Solomon Buchsbaum, vice president of Bell Laboratories, who is also a member of ERAB, and the report is known by his name. Panel members include Dr. Robert Conn, professor, School of Engineering and Applied Science, University of California; Dr. James Fletcher, vice chairman of the Burroughs Corp. and former NASA head; Dr. John S. Foster, Jr., vice president for science & technology, TRW, Inc.; Dr. Eugene Fubini, head of E.G. Fubini Consultants, Ltd.; Dr. Marvin Goldberger, president of the California Institute of Technology; Dr. Roy Gould, chairman of the Division of Engineering and Applied Science, California Institute of Technology; Dr. Wolfgang Panofsky, director of the Stanford Linear Accelerator Center.

The Doublet III at General Atomic in San Diego. The report suggests that its conversion to a long-pulse, high beta tokamak should be considered.
General Atomic


PRE STRESS RING

Bell Laboratories

Dr. Solomon Buchsbaum, chairman of the DOE Fusion Review Panel.

Introduction

In February 1980, Dr. Edward A. Frieman, director of energy research, requested that the Energy Research Advisory Board (ERAB) review the Department of Energy (DOE) Magnetic Fusion Program. Of particular concern to the DOE is the judicious choice of the next major steps to be taken in proceeding from the current generation of experimental devices toward demonstration of economical power production from fusion. Of equal concern is the overall soundness of the DOE Magnetic Fusion Program: its pace, scope, and funding profiles.

This report is in response to Dr. Frieman's request. The present review follows a similar ad hoc DOE review of the fusion program that was carried out two years ago under the chairmanship of J. S. Foster, Jr., a member of the present Review Panel. The Foster report stimulated the DOE to enunciate a comprehensive policy for the fusion program. Rapid scientific progress since the writing of the Foster report has made the present review desirable.

To carry out the review, the ERAB appointed an ad hoc Fusion Review Panel. The panel heard extensive presentations from Mr. Edwin E. Kintner, the associate director for fusion, Office of Energy Research (OER), and his staff, and from numerous scientists and engineers in the program. The panel spent 11 days in plenary sessions in Washington, at the Princeton Plasma Physics Laboratory (PPPL), and at the Lawrence Livermore National Laboratory (LLNL). Members of the panel visited the Massachusetts Institute of Technology (MIT), the Oak Ridge National Laboratory (ORNL), the Los Alamos National Scientific Laboratory (LANSL), and General Atomic (GA). The panel also received testimony from members of the public.

The DOE Magnetic Fusion Program is large: In fiscal year 1980 some $355 million will be expended; in fiscal year 1981 nearly $400 million is included in the president's

"The panel is pleased to record its view that the taxpayers are receiving their monies' worth."

budget. (There is, in addition, some private funding, but this is not more than a few percent of what the government spends.) The panel is pleased to record its view that the taxpayers are receiving their monies' worth. The program is being well managed and is conducted by a cadre of dedicated, capable, and hard-working scientists and engineers. As we document in the body of the report, recent progress in plasma confinement is impressive. While the U.S. program represents only about a third of the worldwide effort in magnetic fusion, the United States has become its unquestioned leader.

As a result of this progress, the United States is now ready to embark on the next step toward the goal of achieving economical fusion power: exploration of the engineering feasibility of fusion.

The engineering program should augment the continuing basic work in fusion research and related technology. Such work is indispensable to the success of the fusion program.

The engineering program that the panel envisages is a long and a difficult one. It will require the expenditure of significant additional funds; a doubling in the size of the present program (in constant dollars) in five to seven years must be expected.

Although the panel did not examine magnetic fusion in the context of the overall balance of DOE programs, we believe that this large increase is justified. This next step in the fusion program is both sound and timely. The United States should determine as soon as is programmatically feasible whether or not fusion is a viable option; that is, whether or not fusion reactors can compete favorably with alternate energy sources from economic, environmental, and safety standpoints. Such knowledge would have a profound influence on U.S. energy policy. . . .

Executive Summary

Recent progress in plasma confinement justifies confidence that demonstration of scientific feasibility of magnetic fusion, that is, energy breakeven, is near. Such demonstration should take place in at least one of the devices presently under construction. There is also confidence, shared by the panel, that a device containing a burning, even an ignited, plasma can be built and operated successfully. [See glossary for definitions of burning and ignited plasmas.]

However, the state of knowledge is not adequate to determine an optimal configuration of plasma and magnetic field for a working reactor. Nor can we be sure today that a safe, environmentally acceptable, economically attractive fusion reactor can be built and operated.

These conclusions lead the panel to the following recommendations:

(1) *The magnetic fusion program can, and should, embark on the next logical phase toward its goal of achieving economic feasibility of magnetic fusion. To this end a broad program of engineering experimentation and analysis should be undertaken under the aegis of a Center for Fusion Engineering (CFE).*

A key element of the program should be a device containing a burning plasma, and incorporating in its construction those technological features which can serve as a focus for the development of future reactor technology. Some of the objectives of the recently proposed Engineering Test Facility (ETF)—in particular, the level of neutron flux and duty cycle, as well as the role envisioned for the ETF on the road to commercialization of fusion—are inappropriate at this stage of fusion development. Rather, *the program we advocate should center around a more modest tokamak-based Fusion Engineering Device (FED)* which should have the following goals:

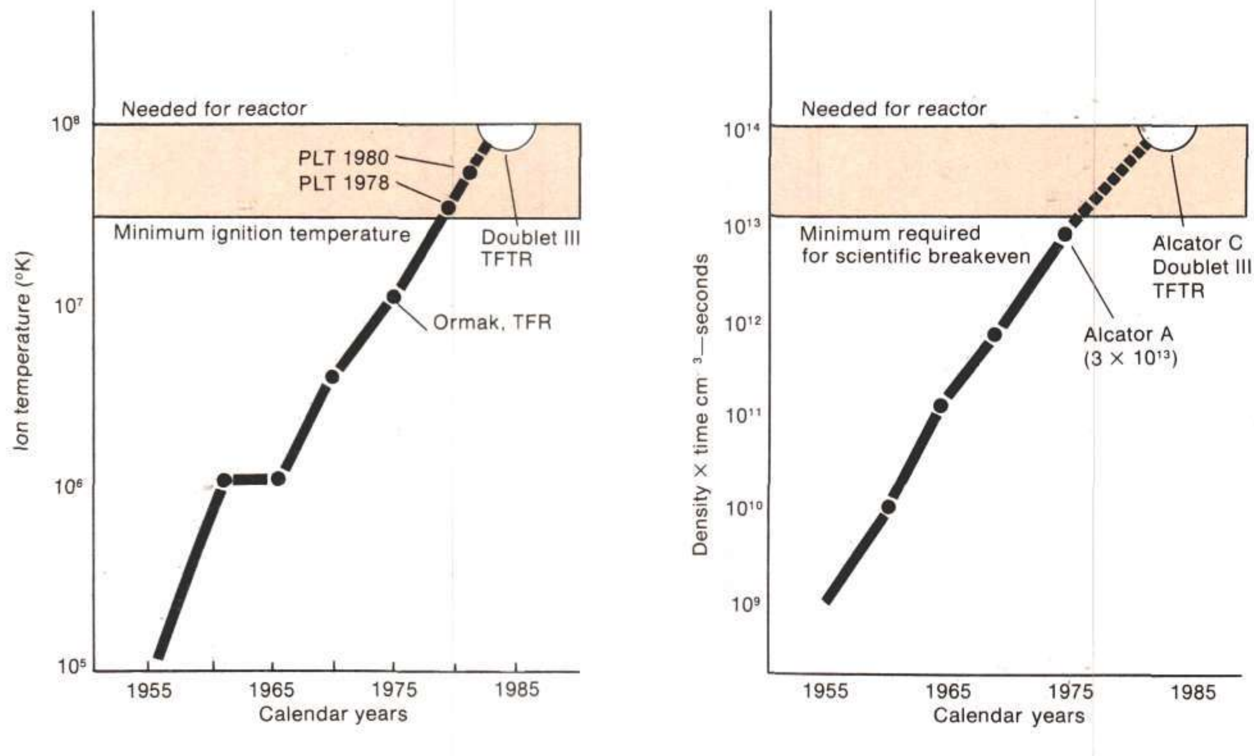
• Provide a burning, perhaps even an ignited, plasma;
• *Provide a focus for developing and testing reactor-relevant technologies and components;*
• Explore and firmly delineate problems of operator and public safety.

The device should be in operation within 10 years and cost not more than about $1 billion of current dollars. The last two goals necessarily require certain limitations in other objectives; the extent of such limitations should emerge during the design phase of the device. Still, the device we envision will require a large, complex undertaking. *A single-line management approach is necessary to help assure the success of such a large design and construction project supporting a viable experimental and test program.* Broadly based industrial participation as well as continuity of management are essential.

It will take time, planning, and modest additional funding to organize the CFE and to launch the engineering program we envision. Large increases in the cost of the fusion program dedicated to engineering aspects of fusion would not be needed until about 1983-1984. At that time results from the Tokamak Fusion Test Reactor (TFTR), *presently under construction at PPPL, will be available and* will help confirm (or deny) the design details of the FED.

Because of the uncertainties in the prognosis for fusion and in projecting the cost of alternative energy sources, a date for a competitive commercial prototype reactor, or the number of steps needed to reach the prototype stage, cannot now be firmly specified. However, if the program we recommend is implemented and is successful, then after operation of the engineering device (in about 10 years), the data should be available to predict when fusion energy could become economically competitive. A more definitive assessment of safety and environmental aspects can then also be made a part of this determination. Today, the panel is optimistic that with progress comparable to that in the past decade, a power unit, not necessarily an economically competitive one, could be built at or shortly after the turn of the century.

As the fusion program proceeds to determine engineering feasibility, it must retain sufficient variety and flexibility to ensure that fusion's highest potential is ultimately ascertained. There remain many design options for



PROGRESS IN U.S. MAGNETIC CONFINEMENT EXPERIMENTS

U.S. experimental fusion reactors have made steady progress in the past two decades, on the way to achieving breakeven conditions for temperature and density-confinement time. Both the Doublet III and the Princeton TFTR are expected to reach the temperature conditions necessary for a fusion reactor by 1985, and these machines plus MIT's Alcator C are expected to reach the density-confinement time requirements for a fusion reactor by 1985.

a reactor. Excessive haste toward commercialization may lead to a demonstration of a less-than-adequate fusion reactor, delaying rather than accelerating commercial acceptability.

(2) *To ascertain the highest potential of magnetic fusion, a broad-based program in plasma confinement should be continued, based on the following new major elements:*

(a) Following recent experimental results and favorable theoretical projections, *the U.S. mirror program should proceed with the construction of the large tandem-mirror facility (MFTF-B) as a proof-of-principle experiment for open confinement systems. Its design should be sufficiently flexible to permit the incorporation of various projected configurations.* Successful deployment of the MFTF-B will require extensive supporting developments in physics and in technology at LLNL and at other institutions. Therefore, an accelerated MFTF-B construction program is not called for.

(b) Assessment of the reactor potential of tokamaks requires deeper understanding of many issues of plasma physics and technology which were not of immediate urgency when the present generation of machines (TFTR included) was being designed and built. Therefore, in addition to the large engineering device discussed earlier, *the DOE should plan and implement a coherent, comprehensive advanced tokamak program.* Such a plan should involve the phasing out of some presently operating machines, the conversion of others to more relevant studies, and the construction of some new devices. Maximum advantage should be taken of the strong international cooperative program, especially the joint program with Japan.

(c) *Work on the Elmo Bumpy Torus (EBT)*—a hybrid configuration which combines many of the attractive features of mirrors and tokamaks—*should be strengthened,* with effort aimed at clarifying some near-term key physics questions. The EBT-P construction should wait for additional confirming results of work in progress and proposed herein, especially an exploration of the possibilities of *more modest experiments. Today, the proposed EBT-P* investment is too large given the existing uncertainties in the physics of the EBT configuration.

(d) *Work on alternate concepts,* that is, plasma and magnetic field configurations other than tokamaks, mirrors, and the EBT, *should continue commensurate with new discoveries in physics.* Research on alternate concepts is essential to the full development of the plasma physics base for fusion research. However, each concept need not be pushed to, or even be expected to reach, the proof-of-principle state of plasma parameters and performance. *The DOE should be highly discriminating in advancing existing alternate concepts much beyond their present scopes.*

(e) The DOE should support a strong research program on fuel cycles (and their requisite containment systems) other than deuterium-tritium, since reactors based on such cycles would have major advantages in the long run.

"The last five years have been marked by notable achievements in the tokamak program."

Status of the Fusion Program

The Magnetic Fusion Program has two main experimental thrusts, the tokamak and the magnetic mirror. Several other alternate approaches are being explored as well, of which the EBT is the leading example. In the past five years, serious efforts were also started in some areas of fusion technology: the Tritium Systems Test Assembly Project; the Large Coil Project; the neutral beam and RF development programs; and the Fusion Materials Irradiation Test Facility.

The substantial progress referred to earlier is being made at the national laboratories, at universities, and in industry. There is a cohesion in the program despite its breadth of scope and variety. A spirit of cooperation has been a key factor in the program's progress. This speaks well of the management of the program by the Office of Fusion Energy.

In this section, we review progress in major areas of magnetic confinement: the tokamak, the mirror, the EBT, and other alternate concepts; and in fusion technology. (The nontechnical reader may be helped by referring to the glossary.)

Tokamak Physics Status

The last five years have been marked by notable achievements in the tokamak program. Contributions have been made by a number of tokamaks (Alcator-A, PLT, and ISX in the United States and the T4, DITE, TFR, and DIVA abroad). There is a momentum in the program which should continue until the mid-1980s with new machines coming on line (D-III, PDX, Alcator-C, and TFTR in the United States and JET and JT-60 abroad).

The principal accomplishments have been:

(a) The validity of the empirical "Alcator scaling" for electron energy confinement time has been established over a wide range of parameters, and it has been determined that ions remain nearly classically confined. Specifically, confinement of $n\tau = 3 \times 10^{13}$ sec/cm^3 has been achieved on Alcator-A. (This value is about a factor of 5 smaller than that required for ignition.)

(b) Efficient plasma heating by neutral beams has been demonstrated and preliminary results with ion cyclotron and electron cyclotron resonance heating (ICRH and ECRH) are encouraging. Thus it appears that heating to ignition is feasible.

(c) PLT has demonstrated ion heating to a temperature of 7 keV and has shown that there is no degradation of performance at levels of collisionality needed in reactors. In the absence of good theoretical understanding of microturbulence, this demonstration is the key to confidence in obtaining ignition, although behavior in a device which has simultaneously the proper collisionality and β is yet to be tested.

(d) ISX/B has demonstrated stable confinement at β's of about 3 percent. This is slightly in excess of what present theory predicts and is compatible with extrapolation to what is needed for a reactor (about 6 to 10 percent).

(e) Impurities have shown no tendency to accumulate in the center of high-density plasmas, at least for the pulse lengths used so far. Preliminary divertor studies on PDX, DIVA, DITE, and Doublet-III are encouraging for further reduction of impurity levels, and PDX will greatly expand the knowledge of divertor operation.

(f) Plasma disruptions are now predictable from plasma current profiles. Disruptions still occur in present devices when unfavorable current profiles are produced by machine malfunction. Low-q operation, if it can be reached, should be favorable in this respect as has been demonstrated in Alcator-A and DIVA. Other disruption controls appear feasible but have not been experimentally implemented.

(g) Pellet fueling has been successfully demonstrated on ISX.

(h) Although not yet experimentally attempted, several schemes for steady-state current drive with RF or particle injection appear promising. (A low-temperature plasma carrying no ohmic current has recently been confined in a stellarator in West Germany.)

(i) With the important exceptions of the lack of quantitative understanding of nonlinear microstability (anomalous electron thermal transport) and impurity transport, theoretical understanding has also flourished in this period. There is considerable confidence in predicting improved β-levels and resistance to disruption in D-shaped devices. Stable operation with $q < 1$ also has been predicted at high temperatures but has not yet been tested.

(j) Key remaining issues are helium removal, long-pulse impurity behavior, and the possible excitation of Alfvén waves by α particles produced in the fusion process. Early theoretical assessment suggests that such excitation will not be dangerous, but experiments are needed to study the problem.

In short, tokamak confinement is understood sufficiently well that a realistic extrapolation to ignited plasmas can be made. This understanding will be deepened and extrapolation further tightened when the TFTR comes into operation—early in 1983—at plasma parameters close to, or even at, energy breakeven.

Mirror Physics Status

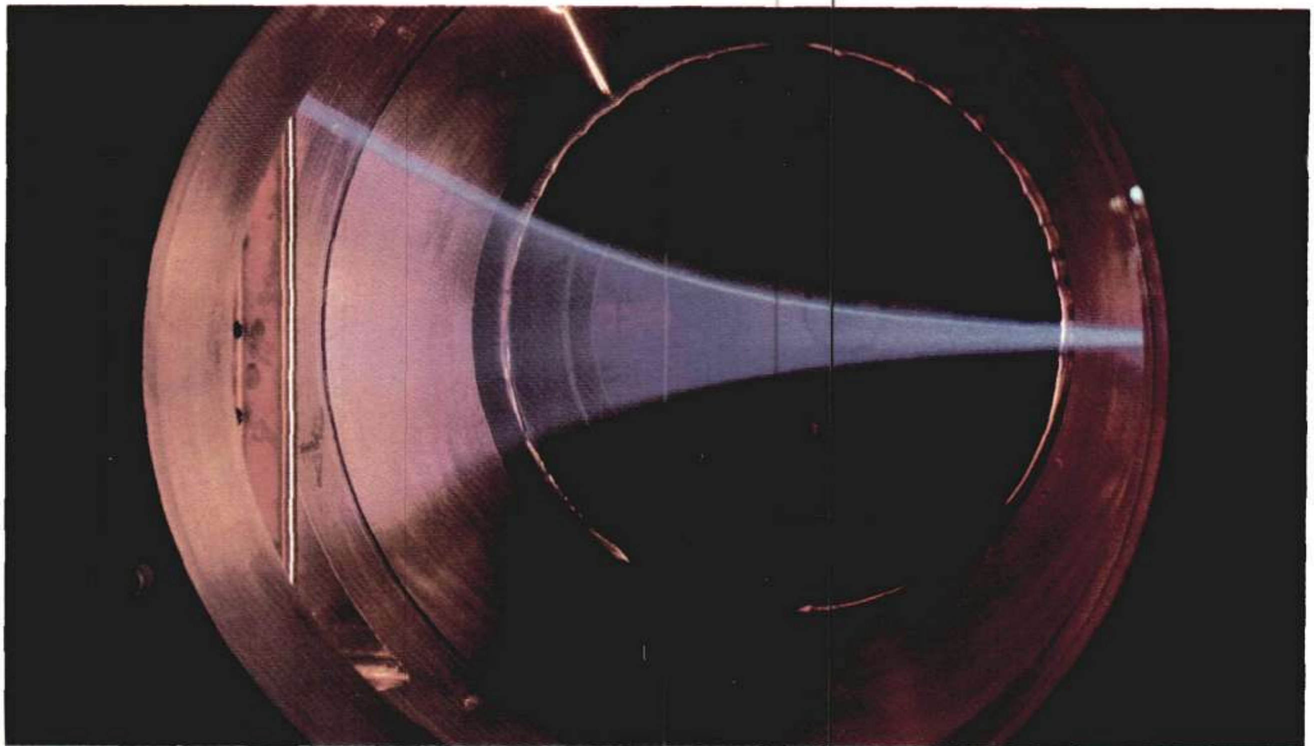
The historical development of the magnetic mirror concept has been marked by four principal inventions: mirror confinement itself; the concept of a magnetic-field well which assures hydromagnetic stability; the tandem mirror with its electrostatic potentials for enhancing ion confinement; and the thermal barrier as a refinement of the tandem which could, in principle, dispose of high frequency instabilities. The last two of these inventions have been made within the last five years. If these inventions can be successfully implemented, the mirror could be an attractive fusion reactor.

The macroscopic stability of mirror plasmas in magnetic-well configurations has been demonstrated in many devices, including those at LLNL, at values of β close to unity. Such high β represents a great potential advantage for mirror reactors. However, there are two fundamental problems that have plagued mirror plasmas. First, the classical lifetime, governed by ion scattering into the loss cone, is inadequate for reactors. The second problem arises from the fact that mirror-confined plasmas necessarily have anisotropic velocity distributions which spawn microinstabilities—specifically, the drift-cone mode. For over a decade, these microinstabilities have dominated plasma behavior in mirrors, keeping the $n\tau$'s in 2X-II experiments at LLNL at the 10^{10} cm^{-3} sec level, several orders of magnitude below the value expected classically.

In the early 1970s a beginning was made toward stabilization of these modes by introducing warm plasma streams to fill the loss cone in the 2X-IIB experiment at the LLNL. In this way, $n\tau$'s of 10^{11} cm^{-3} sec were achieved, while the noise created by the instabilities was suppressed. In these experiments the plasma had ion temperatures of 10 keV, and β's of about unity; electron temperatures were low, about 100 eV, the electrons being cooled by conduction along the field lines resulting from the use of external plasma streams.

As quantitative understanding of these experiments evolved, a new strategy was developed for further suppression of the drift cone modes. This was based on theoretical predictions that the microinstabilities could be stabilized in a very large mirror (about 75 ion gyroradii in radius and length). It was also realized that a more modest increase in radius would allow stabilization with much less warm plasma. Calculations indicated that in a device of about 20 ion gyroradii electron temperatures of 700 eV and $n\tau$'s of 10^{12} cm^{-3} sec could be reached. This is the goal for the Mirror Fusion Test Facility (MFTF) now under construction at LLNL.

The inventions of the tandem mirror and of the thermal barrier represent potential solutions to the two problems that have been plaguing mirror plasma. The thermal barrier concept is complex and as yet untested. Preliminary



A plasma formed inside a vacuum chamber showing the fan shape caused by the field of a magnet similar to that planned for the Mirror Fusion Test Facility.

experiments on the tandem mirror concept (TMX) at LLNL are encouraging. In particular, in the central cell of TMX, thermal plasmas have been obtained with β's of 15 percent and nτ's of about 10^{11} cm^{-3} sec. The latter figure represents a confinement improvement of a factor 10 above that in a simple mirror and demonstrates the tandem principle, while the relatively high β indicates that hydromagnetic stability should be achievable at reactor-level β's.

Tokamaks now operate with nτ's of about 10^{13} cm^{-3} sec. To bring mirrors to a comparable level will require raising the electron temperature by heating and thermal insulation of the plasma from the ends of the mirror (in order to reduce collisional end-loss), as well as successfully suppressing loss-cone instabilities in the end-plugs. The use of warm plasma streams to fill the loss cone in 2XIIB experiments, as well as the partial suppression of RF in the TMX, indicate at least a qualitative understanding and mastery of the high frequency instabilities. This lends certain credibility to thermal barrier calculations, although the real exploration of three-dimensional thermal barriers will require extensive theory and well planned experiments.

Based on these theoretical and experimental advances, LLNL is proposing to modify and expand the MFTF into a large tandem experiment, dubbed MFTF-B. The MFTF, authorized prior to the invention of the tandem mirror concept, is a single-mirror, quadrupole-field device. In MFTF-B, the quadrupole MFTF coils would be duplicated, the pair serving as plugs to a long (100 ft) solenoid. The plugs and thermal barriers would be created in the quadrupole fields by neutral beams and by electron cyclotron heating of the electrons. If the thermal barrier works well, the MFTF-B could attain nτ of about 5×10^{13} sec/cm^3 at ion temperatures of 15 keV; i.e., nearly proof-of-principle for mirror breakeven. This nτ value is to be compared with $n\tau \approx 10^{12}$ sec/cm^3 forecasted for the simple MFTF or for the tandem MFTF-B without thermal barriers.

Recent theory also indicates that axisymmetric end-plugs might be able to provide MHD stability by employing hot electron rings, surface magnetic fields, or cusps, thus avoiding the physics and engineering complications inherent in the quadrupole plugs. LLNL plans an early study of thermal barriers in the TMX-upgrade program.

For the past decades the great bulk of mirror thinking and experimentation has been concentrated at LLNL. It is a healthy symptom of renewed optimism about mirrors that recently there has been an upsurge of activity outside LLNL, in universities such as Wisconsin and in industry (for example, the TRW program).

In summary, mirrors are at an earlier stage of development than are tokamaks. The last five years have seen the initiation of a systematic approach to controlling the nonthermal particle distributions, and to isolating different distributions at different points along the field lines so as to minimize end-losses and eliminate microinstabilities. Encouraging experimental results have been obtained on the TMX, but the mirror program still is in the early stage of exploring this approach.

Elmo Bumpy Torus (EBT) Physics Status

The EBT concept is an outgrowth of magnetic mirror research and combines attractive features of both toroidal and open-ended devices. In the EBT, two to three dozen single-mirror cells are linked to form a torus. In each cell a relativistic electron ring, produced by high-power microwave heating, provides hydromagnetic stability normally obtained in mirrors by creating a minimum-B magnetic well. This leads to a device with physics features similar to those of mirrors but without the end-loss that is characteristic of mirrors. Rather, it is the plasma transport across the magnetic lines of force, as in any toroidal device, that is the central confinement problem.

At present, there is one EBT experiment in the United States, EBT-S, at ORNL. (There are also EBT experiments in Japan.) The experiment operates at steady state (continuously for hours at a time). Electron rings with energies of hundreds of keV have been stably produced at modest values of β; the upper β limit has not been determined. Plasma densities of 10^{12} cm^{-3} have been achieved, with core electron temperatures of 300 eV and ion temperatures of 100 eV. Recent advances include the use of 28 GHz ECRH heating, the achievement of rings with an electron energy as high as 0.5 MeV, accurate measurements of stable and unstable operating regimes, the demonstration that the range of neutral gas pressure for stable operation increases with microwave heating power, a more definitive measurement of core plasma electron temperature by laser scattering, and a measurement of the plasma potential.

There have also been important advances in EBT theory. In particular, a neoclassical theory of core plasma transport indicates that $n\tau$ should improve with increasing aspect ratio. There have been important advances in understanding RF wave propagation and absorption both in the rings and in the core plasma. Much additional work remains in areas such as MHD stability limits for the rings and the core plasma, and the scaling of the ring power balance. Much of the attraction of EBT arises from its potential for steady state, moderate-β operation (15 to 20 percent in the core) at large aspect ratio (which can permit modular construction with extensive access). These features are advantageous for reactors.

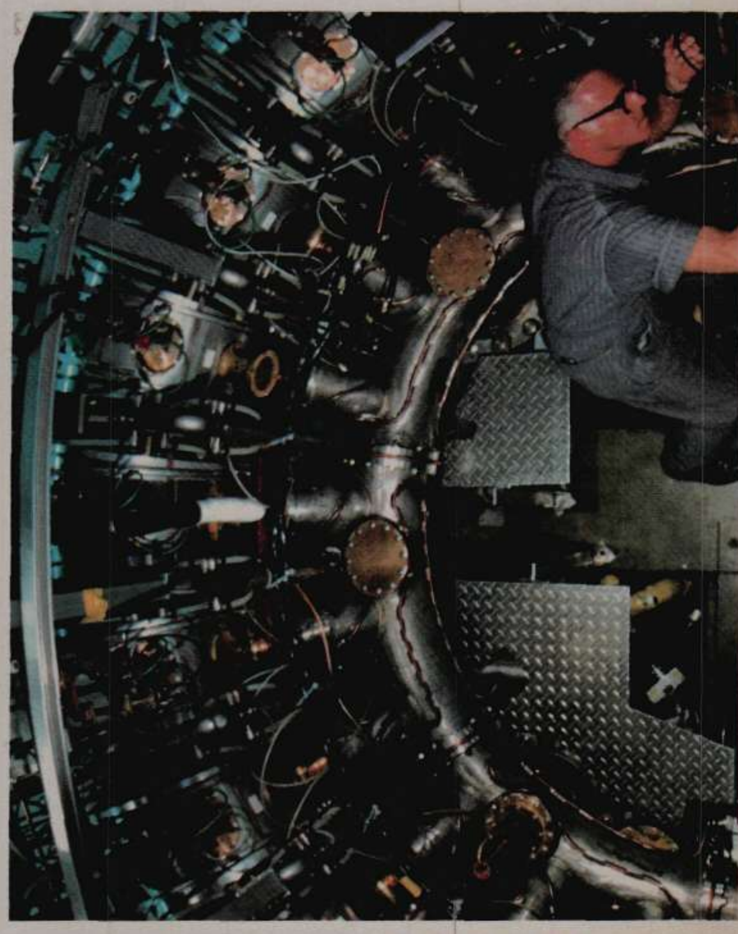
These physics advances and reactor features have led ORNL, in conjunction with four industrial teams (led by EBASCO Services, Inc., Grumman Aerospace Corp., McDonnell-Douglas Astronautics Co.—East, and Westinghouse Electric Corp.), to propose a new proof-of-principle experiment called EBT-P. The device would have approximately twice the magnetic field strength of EBT-S, approximately 70 percent larger values for the aspect ratio and plasma radius, superconducting magnets, ECRH heating at 28 and 60 GHz, and separate ion heating. It would cost an estimated $75 million in current dollars, not including a parallel technology development effort costing approximately $20 million. The goal for EBT-P is to prove the principle of the EBT concept by addressing the central issues of $n\tau$ scaling, β limits, and ring scaling and power balance in high temperature plasmas.

In summary, EBT is in a less-developed state than are tokamaks and mirrors, a not surprising situation since there is only one device currently operating in the United States. Nevertheless, the recent results are encouraging, and a major new EBT machine has been proposed to extend this line of research.

Alternate Concepts Physics Status

Fusion research is presently rich in concepts that provide a broad base from which to develop a reactor that is both economically viable and acceptable to the public. The state of development, however, varies among concepts. The tokamak is nearing the end of its exploratory phase and is ready to enter the next phase, that of fusion reactor engineering. Magnetic mirrors could be brought to the end of the exploratory phase with the proposed MFTF-B experiment.

Alternate concepts is a phrase used to categorize magnetic confinement schemes other than the tokamak and the mirror. In addition to the EBT, they include field-reversed configurations (often generically referred to as compact toroids), the reversed field pinch, and multipoles. Field-reversed mirror experiments have just begun at LLNL while at LANSL and the University of Maryland field-reversed configurations of the spheromak type (toroidal B ~ poloidal B) have been formed and stably maintained for about 100 Alfvén times in a theta pinch with a barrier

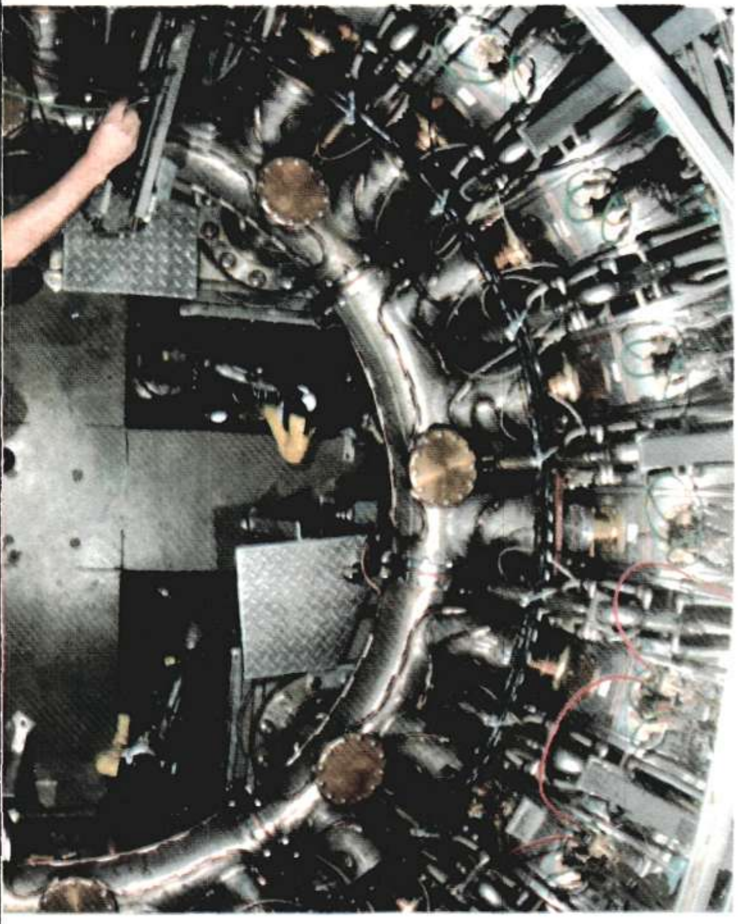


field. An earlier field-reversal experiment at Cornell University was successful with an electron ring. While the results to date are encouraging with respect to prospects for compact plasmas, much work remains to elucidate the complex physics of these configurations.

Also at LANSL, research has progressed on the reversed field pinch (RFP) through work on the ZT-40 experiment. It is found, consistent with research abroad, that when a self-reversed magnetic field state is achieved, density fluctuations decrease markedly at β values of at least 10 percent but at low plasma temperatures. We note, however, that the requirements associated with pinch magnetic-field reversal may be too onerous in a reactor.

Experiments at both the University of Wisconsin and UCLA have achieved high-β in multipoles (in excess of 30 percent without sign of MHD instability in the Wisconsin experiments) well in excess of ideal MHD predictions. The plasmas are, however, collisional and the results must be confirmed in hotter, less collisional, regimes.

Not all alternate concepts have proven successful in principle or have contributed as much to basic knowledge in the field. For example, research on the Tormac concept has been halted by DOE, as has work on the Scyllac and on the Astron. Nevertheless, alternate concept research contributes to the fundamentals of the field and often suggest methods for improving the more highly developed approaches.



Fusion Technology Status

In reaching the fusion plasma conditions in hydrogen that have been achieved to date, it has been necessary to advance substantially several important technologies. Most notable is the development of neutral beam injectors operating at the megawatt level for plasma heating. High vacuum and energy storage and control technologies have also been extended. It has long been recognized that the burning-plasma phase of fusion energy research and the actual production of energy will require other technological developments as well.

Systematic studies of fusion reactor concepts and design began about 10 years ago and now represent an important ongoing activity in the national laboratories and the universities. These studies help provide continuing guidance to the program and develop specific reactor concepts. The studies have identified many critical design issues which must be faced in building a fusion reactor. They helped scope the required critical technology developments such as:

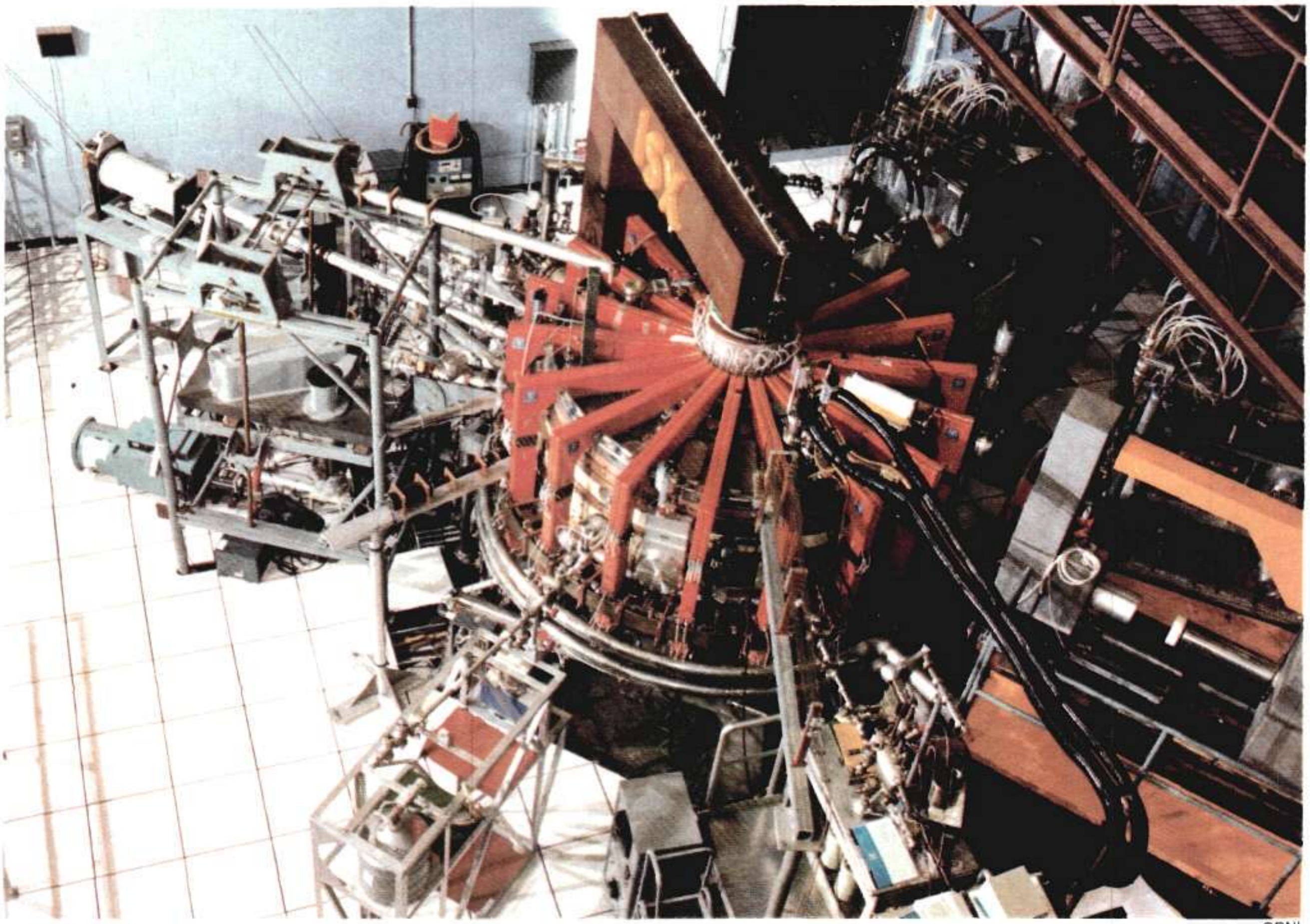
- large high-field superconducting magnets
- tritium processing and handling
- materials for the first wall and blanket
- blankets for heat transfer, tritium breeding, shielding
- remote handling and maintenance methods
- auxiliary heating systems
- fueling, impurity control, and ash removal
- energy storage, transfer and switching systems
- reactor control systems.

The directions which these developments must take, as well as the critical questions which need to be answered, have been identified. Programs have been put in place to help answer many important questions associated with the critical technologies and to provide the needed design information.

Major facilities associated with these programs under construction and expected to become operational over the next several years are:

The Large Coil Project (LCP). A tokamak-oriented program in which six large, 8-tesla superconducting coils are under construction (three in the United States and three abroad) for testing and evaluation at the Large Coil Test Facility at the ORNL, beginning in fiscal year 1982.

An overhead view of the Elmo Bumpy Torus, which combines many of the features of mirrors and tokamaks. The report recommends strengthening work on the EBT in order to clarify some near-term key physics questions.
ORNL



ORNL

The ISX tokamak at Oak Ridge National Laboratory, which has demonstrated stable confinement. The neutral beam injector is shown at right and the pellet injector at left. The Oak Ridge laboratory developed the neutral beam system that successfully brought the Princeton PLT up to record tokamak temperatures in 1978.

The Tritium Systems Test Assembly (TSTA). A facility under construction at LANSL which is dedicated to the development, demonstration, and interfacing of the technology for the management of radioactive tritium in kilogram-per-day quantities (TSTA is scheduled for completion in fiscal year 1982).

The Fusion Materials Irradiation Test Facility (FMIT). A facility under construction at the Hanford Engineering Design Laboratory (HEDL) for accelerated life-testing of materials in a high-energy neutron environment comparable with that in a fusion reactor (scheduled for completion in fiscal year 1983). Selected problems in materials irradiation are already being studied at LLNL with the Rotating Target Neutron Source.

Programs are also in place to develop coating materials for limiters, beam dumps, and other critical components; to develop gyrotrons for electron cyclotron heating of plasmas; to advance further the performance of neutral beam injectors; and to develop advanced conductor and structural materials for high field (12 tesla) superconducting magnets.

Thus a good start has been made on the development of the various technologies which will be needed in the engineering of fusion. This activity constitutes about 25 percent of the magnetic fusion effort. However, there is not yet a project which would integrate these technologies in a single facility for the purpose of testing and gaining experience in combined operation.

International Cooperation

The panel did not examine in detail the international cooperative programs in fusion. Several benefits of such programs did, however, become clear during our review: U.S. participation in the INTOR studies has helped identify critical areas of engineering and systems research needed in the next large tokamak project, such as an FED; data from tokamaks abroad have been consistently valuable for over a decade to the progress of the U.S. tokamak program; and the recently instituted joint program with Japan has been highly beneficial. We wish to encourage such cooperation in the future—full exchanges of technical information and, to the extent they prove practical, joint experimental ventures.

"We find that there is remarkable consensus within the U.S. Magnetic Fusion Program that an engineering facility of some sort should be built forthwith."

Conclusions & Recommendations

Fusion Engineering

The panel spent a considerable portion of its time reviewing the concept of an Engineering Test Facility (ETF). The ETF is being scoped and its goals and objectives being defined by a multidisciplinary, multiorganizational group at ORNL. The panel received much written material on the ETF and heard extensive testimony regarding it.

We find that there is remarkable consensus within the U.S. Magnetic Fusion Program that an engineering facility of some sort should be built forthwith. There is confidence, based on the recent progress, that a facility containing a burning plasma, perhaps even an ignited plasma, can be built and operated reliably to serve as an engineering focus and test bed for a variety of engineering tasks. We also find that the program has not yet reached a consensus on what the specific goals and objectives of such a facility should be, except that it contain a burning plasma.

The panel, too, has misgivings about the ETF as it was presented to us. We find it too ambitious. Specifically, we question the role being envisioned for the ETF on the road to commercialization of fusion, namely, "to bridge the gap between the base of magnetic fusion knowledge at the start of ETF operation and that required to design EPR/DEMO devices" (ETF Mission Statement, Oct. 1979, p. 3). In our view, the number of steps between such a facility and a commercial reactor cannot now be specified.

Some of the goals of the ETF are overly ambitious, resulting in part from the desire to use the ETF as the ultimate material testing facility, as well as a test bed to pin down engineering design parameters. Such goals result in stressful requirements: the required fluence levels are very high; component downtime is very low; burn times are very long. As a result of these multiple goals, the complexity, cost and risk of failure are high.

Nevertheless, *the panel is firmly of the view that the development of the requisite engineering experience requires a broad program of engineering experimentation and analysis having at its focus a test device with a burning, even an ignited plasma.* A device that contains an ignited deuterium-tritium plasma can be built based on knowledge now in hand and soon to be obtained in new machines. *In this connection, it is important that the TFTR,* presently under construction at PPPL, be exploited as early as possible. *The U.S. Fusion Program is ready, in our view, to embark on such an engineering program.*

Consequently, we recommend that the DOE proceed with the engineering program outlined below:

The DOE should establish a Center for Fusion Engineering (CFE) operated by a strong, single-line management. We provide a broad outline of such an organization and a possible approach to achieving it.

The CFE would lead and coordinate a broad, well-balanced program of engineering experimentation and analysis to encompass all areas pertinent to reactor engineering, such as: heat removal equipment and technology; tritium handling and control; tritium blanket technology; magnets; RF power supplies; remote maintenance technology; fuel injection and ash removal; and first-wall technology. The present technology development program represents a good start. An early action of the CFE and OFE should be to assess the pace and the scope of the present development program in the light of the broader engineering charter.

The CFE should undertake the design and construction of what we call the Fusion Engineering Device (FED). The FED we envisage is a more modest device than the ETF that was described to us; the FED would be built and brought into operation during this decade at a cost not to exceed about $1 billion of current dollars. Still, it would require a large, complex undertaking. Among its objectives would be . . . :

- to provide a burning, even an ignited, plasma;
- to provide a focus for developing and testing reactor technologies and components;
- to explore and firmly delineate problems of operator and public safety;
- to serve as the focus for the broadly based program of engineering experimentation and analysis.

More specific objectives must, of course, be worked out during the design phase of the project.

It will take time, planning, and modest additional funding to organize the CFE and to launch the engineering program we envision. Large increases in the cost of the fusion program dedicated to engineering aspects of fusion would not be needed until about 1983-1984. We note that at that time results from the TFTR will be available and will help confirm (or deny) the design details of the FED.

Fusion Physics

The engineering program we recommend should accompany the continuing basic work in fusion confinement. Such work is indispensable to the success of the fusion program and should be shielded, if necessary, from encroachment by the FED construction. More broadly, no operating funds that support scientific and engineering experimentation and analysis should be diverted to support construction.

Tokamaks. Though scientific progress on tokamaks now makes it feasible to mount a serious attack on engineering problems, that progress has not yet optimized the tokamak concept, nor made it adequate for design of a commercially viable reactor.

Progress in the following areas is required to make the tokamak attractive as a reactor: convenient heating; steady-state current drive; understanding of plasma-wall interactions and impurity behavior in long pulses, with methods for control through divertors or improved limiters; and understanding and control of plasma disruptions.

On a more basic level, an understanding of anomalous transport, particularly at relevant collisionality and β, is needed. Macroscopic behavior in the high-β, collisionless regime is as yet untested, and so is the interaction of super-Alfvénic particles with the plasma. Behavior at low-q and the physics of β limitation (specifically the influence of plasma shaping) must be better understood. The potential payoff in size and cost of tokamak machines for improvements in these parameters is very large. Recent theoretical results give some grounds for optimism that: (a) low-q tearing modes may be stabilized at high temperatures allowing low-q operation, and (b) ideal MHD stability can be achieved at considerably higher β than heretofore estimated.

The desirability of very high field, relatively inexpensive devices devoted to studying the physics of plasmas at interesting plasma parameters has been enhanced by the recent theoretical developments. Even though it is unlikely that a reactor could be based on this principle, inexpensive high-field tokamaks should continue to be exploited. Other variants, such as stellarators or the more recent compact tori, should be pursued on a modest scale, but could eventually appear sufficiently promising for more extensive experimentation.

Thus, *a balanced program directed toward a tokamak reactor will require, in addition to large devices devoted to engineering studies, a vigorous advanced tokamak research program to study physics issues and improved directions. The DOE should plan and implement such a program.*

While such a program will entail considerably increased funding, it could be paid for in part by discontinuing or converting some present devices. For example, the doublet-shaped part of the Doublet III program should be discontinued because the doublet shape no longer appears advantageous for a reactor. However, the Doublet III facility should be examined for conversion to a long-pulse (10 sec), D-shaped, high-β tokamak where relevant advanced studies can be made.

The U.S. program should continue to take advantage of the productive international cooperation in tokamak research and avoid unnecessary duplication. The joint program with Japan appears especially attractive.

Mirrors. In the past, the mirror approach has lagged because of the large end-losses and the loss-cone instabilities caused by anisotropic distributions that are inherent to mirrors. In the last several years, however, two inventions—the tandem mirror and the thermal barrier—have led to a resurgence of interest in the reactor potential of mirrors with the realization that by carefully controlling the particle distributions at different points on the magnetic field lines these problems might be overcome. If such control can be achieved, the linear mirror could become a very attractive reactor.

The program is now faced with a decision whether or not the large Mirror Fusion Test Facility (MFTF)—a single-mirror experiment authorized before the tandem invention—should be expanded at about twice the original cost into a comprehensive test (MFTF-B) of the new ideas. The thermal barrier concept is as yet untested experimentally, and thus MFTF-B represents a large extrapolation. Such a large step is required because the physics of mirrors, and especially of tandems and thermal barriers, is strongly dependent on the collisionality regime and only a large, high-powered, and consequently expensive device can attain the desired parameters.

In view of the importance of understanding the physics of open confinement systems and of assessing their reactor potential, we believe that such a step is now warranted and we recommend it. Because successful deployment of the MFTF-B will require extensive supporting developments in physics and in technology, *an accelerated MFTF-B construction is not called for.* The pace of construction of the MFTF-B can use results from the TMX-upgrade program as design verification check points.

Recent theory also indicates that axisymmetric end-plugs might be able to provide stability while avoiding the complications inherent in the quadrupole plugs. Because of the preliminary nature of this concept, it would not be prudent to proceed now on the MFTF-B scale with axisymmetric plugs. Nor is a delay of the MFTF-B of two or three years warranted while these plugs are assessed because they can be included later. We urge that the TMX-upgrade program devoted to studies of thermal barriers give high priority to assessment of axisymmetric end-plugs. *The MFTF-B design should be sufficiently flexible to permit, without excessive cost or delay, a future conversion to alternate end-plug designs if these become desirable.*

The mirror program has been highly concentrated at LLNL. In view of the many open physics issues, and the high rate at which new insights and inventions have been appearing recently, the participation of other groups, at universities and in industry, in theoretical and modest-scale experimental work should be encouraged, especially in studies of axisymmetric mirrors.

The Elmo Bumpy Torus. The Elmo Bumpy Torus (EBT) concept contains attractive features of both open (mirrors) and closed (toroidal) confinement concepts. *The present results and positive reactor prospects warrant strengthening of the EBT program.* In particular, the management of the EBT program should see that additional effort is focused on clarifying a number of outstanding physics questions using the EBT-S facility and on the development of theory. Examples of important questions include verification of predicted transport scaling laws, clarification of the appropriate gradient scale length for diffusion, and scaling of the ring power balance. While the EBT-P project can explore these and other issues, a more modestly scoped experiment (which can test ion transport scaling and aspect ratio enhancement using 60-GHz ring-heating and separate core heating) may be both possible and appropriate. Today, the EBT-P represents too large an investment given the present physics uncertainties of the EBT-P configuration. *We conclude that a decision to proceed with the EBT-P should await additional results from EBT-S, further development of the theory, and an exploration by ORNL and one or more industrial partners of alternative development paths for EBT.*

If additional research points to favorable resolution of issues such as core plasma-β limits, transport scaling and sensitivity to the sign of the potential, and self-consistent ring power balance, we would then recommend proceeding with EBT-P. If resolution of these issues appears in doubt, then a more modest experiment aimed specifically at the key difficulties would be in order.

Alternate Concepts. Alternate concepts are typically at the beginning or the middle of their scientific phases. Particularly if the physics discoveries are abundant, such concepts should continue to be developed even though reactor prospects are not immediately apparent. With the exception of EBT, *we find that the present level of effort on alternate concepts is appropriate and recommend that the level remain commensurate with new discoveries in the physics.* We view research on alternate concepts as essential to the full development of the plasma physics base of fusion research but do not recommend that each concept eventually be pushed to the proof-of-principle level of plasma parameters and performance. *The DOE should be highly discriminating in advancing existing alternate concepts much beyond their present scopes.*

Advanced Fusion Fuel Cycles. At this stage of fusion development it remains prudent to sustain a strong research program on alternate fuel cycles beyond D-T and on configurations with the potential to burn these fuels. Deuterium-based cycles such as D-D would eliminate the need for tritium breeding and may reduce the levels of induced radioactivity. It is conceivable that the D-D cycle will prove feasible in high field, high-β tokamaks or in advanced versions of the tandem mirror and EBT.

Proton-based cycles are even more difficult to attain but offer correspondingly higher potential rewards. In particular, reactors based on hydrogen cycles have negligible levels of gaseous radioactivity and produce four to five orders of magnitude fewer neutrons per unit of power output. Energy is primarily released as electromagnetic radiation, which opens new possibilities for chamber and reactor design. Hydrogen-based cycles require high ion and electron temperatures (exceeding 100 keV). The configurations to confine such a plasma must therefore have the prospect of high-β operation to maximize the power balance and minimize synchrotron radiation. *We recommend a strong, balanced program of theory, experiment, and reactor analysis.*

Role of Universities and Industry

Universities. The university component of the fusion program has made significant physics contributions over the past 20 years and more limited, but central, contributions to fusion engineering, particularly on the fundamentals of reactor design. The education of quality people has, of course, been a major product of the university program. Significant contributions have been made, for instance, in plasma confinement and heating, new fusion concepts, diagnostic development, clean plasma production, and fusion plasma theory. Being somewhat freer of the constraints imposed by large machine operation and immediate programmatic goals, universities are able to conduct modest investigations of more exploratory nature where individual creativity is a major factor.

Although the universities are playing a significant role in fusion plasma physics, university programs in fusion technology and engineering are still at a very modest level. As fusion technology and engineering receive greater emphasis, *the universities should be called upon for an expanded role in engineering as well.* They can contribute to fusion reactor concept development, to supporting technology experiments, to fundamental studies in heat transfer, radiation damage, magnet design, superconductivity, etc., and, as an essential by-product, the education of the engineers with appropriate background who will be needed in the forthcoming years.

Industry. As fusion enters the engineering phase it is clear that industry must become more centrally involved. To date, the role of industry in the fusion program has been largely that of a supplier of equipment and services. Of necessity, the utility industry has had the role of an informed spectator. With the notable exception of General Atomic, industry has not yet acquired sufficient expertise in fusion confinement to enable it to play a more central role. The panel is pleased to observe that this situation is changing, albeit slowly.

Industry has recommended, and the panel concurs in, a future program that will encourage fuller participation of industry in the planning and research phases as well as in engineering development. Some of the experience of industries currently involved in the design and construction of other types of power-producing facilities may be directly applicable to fusion engineering, particularly in guaranteeing serviceability and maintainability. But industry will not invest heavily, particularly will not contribute its best people, to a fusion program which does not have the manifest long-term interest and support of the government, and in which initial competition for design research does not receive direct government support. The concept of the CFE is being proposed with these considerations in mind, and with the intent of securing competitive industrial participation.

Glossary of Abbreviations & Terms

ORGANIZATIONS

GA: General Atomic Corporation, La Jolla, California
HEDL: *Hanford Engineering Development Laboratory, Richland, Washington*
LANSL: Los Alamos National Scientific Laboratory, Los Alamos, New Mexico
LLNL: Lawrence Livermore National Laboratory, Livermore, California
OFE: Office of Fusion Energy, U.S. Department of Energy, Washington, D.C.
ORNL: Oak Ridge National Laboratory, Oak Ridge, Tennessee
PPPL: Princeton Plasma Physics Laboratory, Princeton, New Jersey
UCLA: University of California at Los Angeles, California

FACILITIES

Alcator-A, -C: tokamak, MIT
CFE: Center for Fusion Engineering (proposed herein)
DITE: tokamak, Great Britain
DIVA: tokamak, Japan
Doublet-III (D-III): tokamak, General Atomic
EBT-P: proposed Elmo Bumpy Torus Experiment
EBT-S: Elmo Bumpy Torus, ORNL
ETF: Engineering Test Facility
FED: Fusion Engineering Device (proposed herein)
FMIT: Fusion Materials Irradiation Test Facility, HEDL (under construction)
ISX: Impurity Studies Experiment, ORNL
JET: Joint European Tokamak, Euratom (under construction)
JT-60: *tokamak, Japan (under construction)*
LCP: Large Coil Project, ORNL (under construction)
MFTF: Mirror Fusion Test Facility, LLNL (under construction)
MFTF-B: *Proposed expansion of MFTF to a large tandem mirror*
PDX: Poloidal Divertor Experiment, tokamak, PPPL
PLT: Princeton Large Torus, PPPL
T4: tokamak, USSR
TFR: tokamak, France
TFTR: Tokamak Fusion Test Reactor, PPPL (under construction)
TMX: Tandem Mirror Experiment, LLNL
TSTA: Tritium Systems Test Assembly, LANSL (under construction)
2XIIB: mirror machine, LLNL

TECHNICAL TERMS

Alcator scaling: Experimental observations that $n\tau$ is proportional to the squared product of plasma density and plasma radius ($n\tau \propto n^2a^2$).

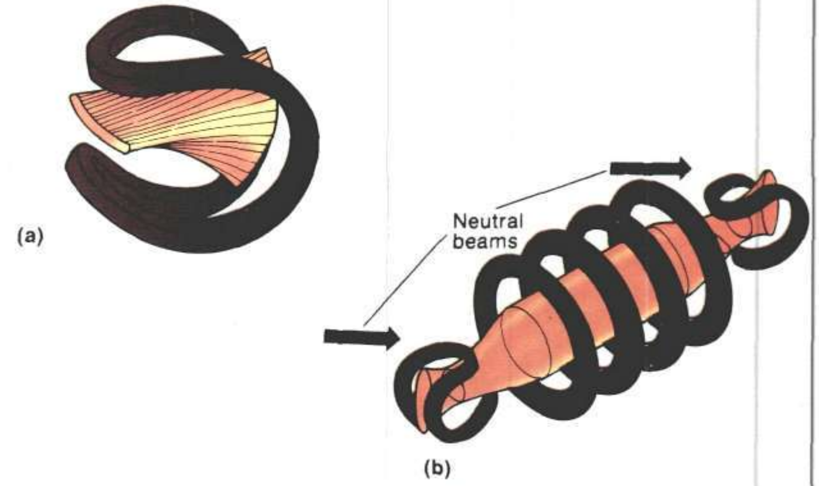
Alfvén time: *The time it would take an Alfvén wave to* travel a given distance, particularly between boundaries of an experimental device.

Alfvén wave: A particular form of hydromagnetic wave or disturbance.

alpha (α) particle: Nucleus of a helium atom.

aspect ratio: The ratio of the major radius of a toroidal device (R in accompanying tokamak figure) to the radius *of the confined plasma (a in the figure).* Larger aspect ratio implies easier maintainability and serviceability, but also larger volume and cost.

beta (β): The ratio of plasma pressure to the strength of the magnetic pressure containing the plasma.



MAGNETIC MIRROR CONFIGURATIONS

In the standard mirror machine, a, *the magnetic field strength increases in all directions from the machine's geometric center, where the plasma is stably trapped. However, some plasma still escapes out the open ends. In the tandem mirror,* b, *a standard mirror cell is placed at each end of a cylindrical solenoidal cell. The plasma is then "end-plugged" by the electrostatic forces of the two mirrors.*

burning plasma: A plasma in which fusion reactions supply energy in excess of that needed to sustain the plasma.

classical confinement: Confinement limited only by collisions among plasma particles.

classical diffusion: Motion of particles, particularly across magnetic lines of force, calculable by assuming only ordinary charge particle collisions.

collisionality: The measure of the extent to which a plasma may be approximated as a fluid, rather than as a collection of many individually interacting particles. The high temperatures associated with fusion reactors imply very low collisionality.

deuterium (D): Heavy hydrogen (a hydrogen atom or nucleus containing one neutron), a component of fusion fuel occurring naturally.

divertors: Magnetic field configurations that direct the trajectories of impurity atoms out of the fusion plasma.

doublet-shape: Plasma shape resembling a dumbbell.

D-shape: Plasma shape resembling the letter D.

ECRH: Electron Cyclotron Resonance Heating, techniques of RF plasma heating which put energy directly into the plasma's electrons.

EPR/DEMO: Experimental Power Reactor or Demonstration Reactor, a first-generation fusion reactor, practicable, though not yet fully commercially engineered.

eV: Electron volt, a unit of energy (the energy gained in accelerating one electron through a potential difference of one volt). Temperature may be expressed in energy units using eV; 1 eV is approximately 11,600°K.

gyroradius: Radius of orbit of an ion or electron as it rotates around a line of force of a magnetic field.

hydromagnetic stability: A plasma's property of stable containment in magnetic fields against forces that tend to make it flow as a fluid out of the contained volume.

ICRH: Ion Cyclotron Resonance Heating, techniques of RF plasma heating that put energy into the plasma's ions; uses RF of lower frequency than ECRH.

ignited plasma: A plasma in which fusion reactions proceed without external supply of energy.

impurities: Atoms heavier than the fusion fuel whose presence in the fuel volume can remove by radiation the energy needed to sustain ignition.

keV: A thousand eV, or, roughly speaking, tens of millions of degrees Kelvin. Temperatures of about 4 keV or greater will be needed to create burning plasmas.

Lawson criterion: See $n\tau$.

loss cone: In a mirror machine, particles with certain ranges of velocities may be lost directly out of the ends; these ranges are called loss cones. The existence of loss cones tends to generate microinstabilities, which must somehow be prevented or compensated for.

magnetic containment or confinement: Any scheme that seeks to isolate a hot (fusion) plasma from its surroundings by using magnetic lines of force to direct the charged particles.

magnetic well: A region where the magnetic field strength increases in every direction from a point in space. A plasma in such a region is known to be hydromagnetically stable.

MeV: A million eV.

MHD instabilities: Magnetohydrodynamic instabilities. (See hydromagnetic stability.)

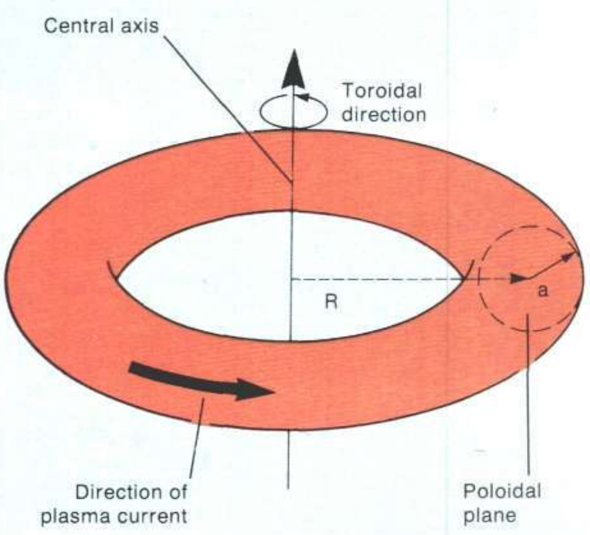
microinstabilities: Collective interactions of individual plasma particles through electric (and/or magnetic) fields that may tend to degrade containment. (See microturbulence.)

microturbulence: Fluctuating local electric/magnetic fields (and associated local densities of charged particles) arising from the behavior of the plasma as a conglomeration of individual particles. Microturbulence may be responsible for the degradation of confinement.

mirror machine: A magnetic containment device in which magnetic lines of force in the plasma do not close upon themselves, but in which particles may be reflected from the ends of the machine by magnetostatic and/or electrostatic forces. Mirror machines are thus topologically linear, rather than being figures of revolution.

neoclassical diffusion: Motion of particles across magnetic lines of force at rates greater than classical diffusion, arising from the existence of trapped particle orbits in localized magnetic wells.

TOKAMAK MAGNETIC CONFINEMENT CONFIGURATION



nτ: The product of plasma density (n) and confinement time within magnetic fields (τ), an important measure of success in sustaining contained fusion reactions. The minimum value (called the Lawson criterion) for attaining a burning plasma is about 10^{14} sec/cm^3.

neutral beam heating: Heating of contained plasma toward ignition by injection of beams of energetic (typically greater than 100 keV) neutral atoms, which can cross the magnetic lines of force but which are ionized in the contained plasma, thus being themselves contained.

plasma: A gas comprising some large fraction of charged particles.

poloidal: Occurring in any plane of the torus that contains the central axis (see tokamak figure).

q: The inverse of the number of turns of magnetic field lines in the poloidal plane per turn in the toroidal direction.

RF: Radio frequency electromagnetic power (loosely speaking; microwave power is included under this rubric) which, when in resonance with the electric properties of the plasma, can be used to deposit energy in it, thus heating toward ignition.

stellarator: A toroidal device wherein plasma equilibrium and stability are achieved by externally imposed magnetic fields rather than by toroidal currents within the plasma as in the tokamak.

super-Alfvénic particles: Particles whose velocity exceeds the velocity of an Alfvén wave in the plasma.

tandem mirror: A magnetic containment device in which two mirror machines close the ends of a simple magnetic solenoid.

thermal barriers: Proposed techniques for increasing the containment properties of tandem mirrors with lower-density, hot plasma in end-cell mirror machines.

tokamak: A magnetic containment device in which the magnetic lines of force are closed on themselves in the shape of a torus, with a large current flowing through the plasma (see accompanying figure).

toroidal: The direction of rotation about the central axis in a toroidal containment device (see tokamak figure).

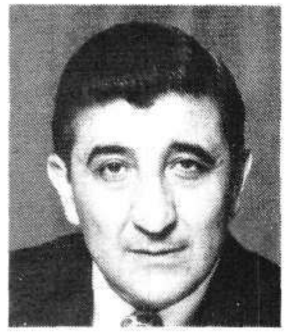
tritium (T): A hydrogen atom containing two neutrons; with deuterium, the first fusion fuel which will be used. Tritium is radioactive and must be produced using neutrons.

Four men who did not subscribe to

EIR

Executive Intelligence Review

Lee Iacocca, *Chairman of the near-bankrupt Chrysler Corporation*



Robert Abboud, *ousted Chairman of the First National Bank of Chicago*

Frank Fitzsimmons, *beleaguered President of the Teamsters union*

Robert Dole, *unsuccessful Republican candidate for President*

and missed out on what EIR readers knew—

- **Volcker's October credit policy** would lift inflation to 20% and push major banks toward the brink of bankruptcy.
- **Volcker's policy** would also strangle the industrial sector, starting with auto and steel.
- **the deregulation of trucking** would be rammed through the Senate— its passage will cost the U.S. economy more than the Vietnam war, not to mention thousands of Teamster jobs.
- **the Trilateral Commission** would rig the Presidential primary process to eliminate any candidates it couldn't control.

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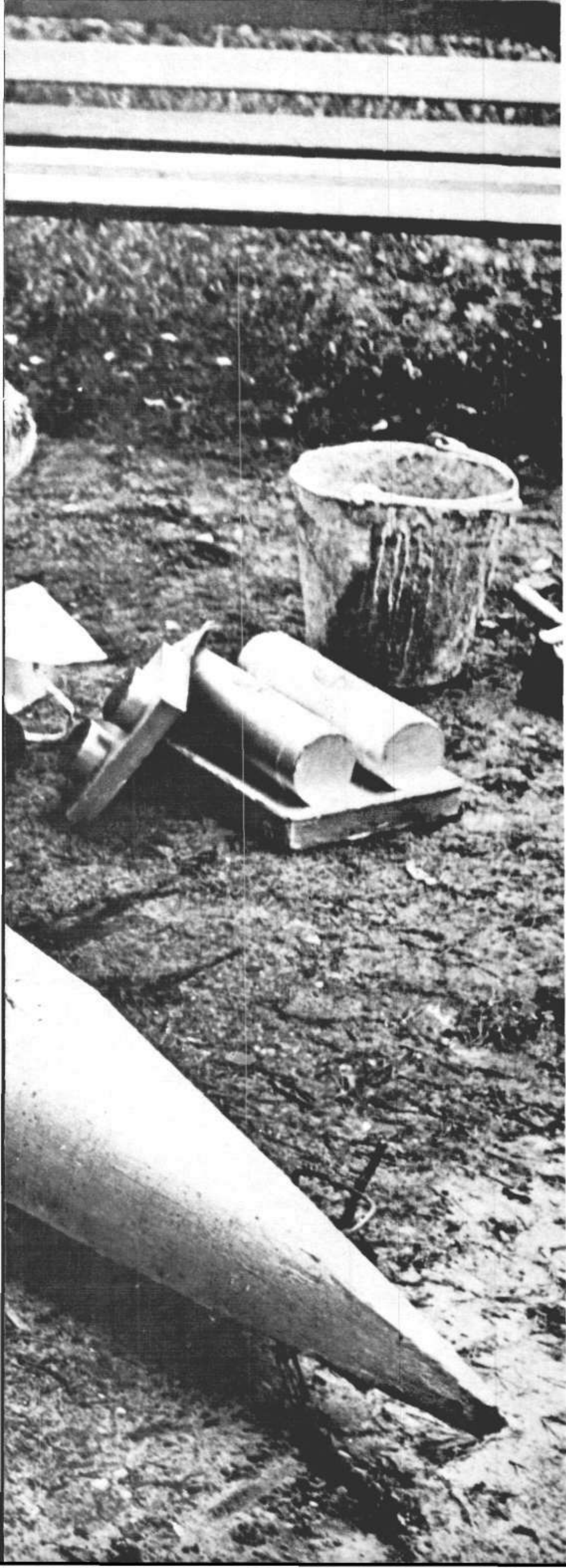


Meeting the Soviet Challenge In Education

by Mel Klenetsky and Carol White

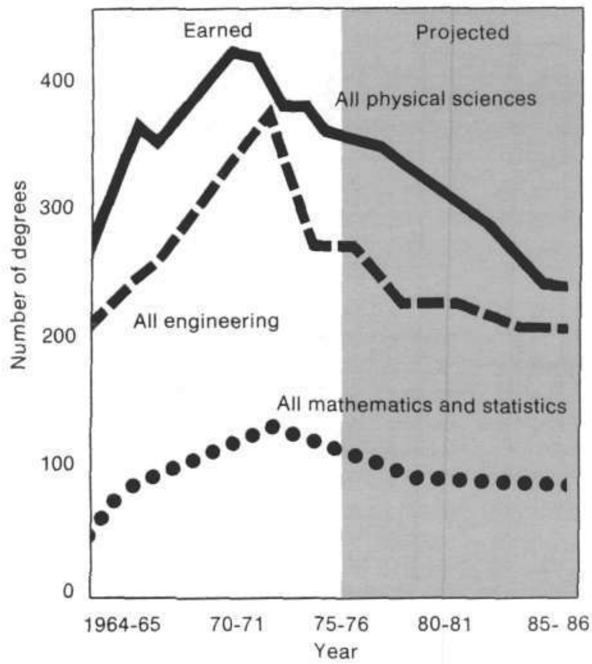
This spring a detailed report prepared by Dr. Isaak Wirszup of Chicago University on the Soviet program for mathematics and physics education began making headlines in the U.S. press. Wirszup's conclusions were a devastating corroboration of previous observations that compared the skill level of soldiers in the U.S. volunteer army to their Soviet counterparts. Wirszup wrote:

> For the 98 percent of the school-age population that now completes secondary school or its equivalent, the Soviets have introduced science and mathematics curricula whose content and scope place them far ahead of every other nation, including the United States. Their foremost scholars and educators are engaged in improving the school curricula and perfecting teaching methods in a concerted drive to provide mass education of unmatched quality. . . .
>
> In order to appreciate the scale of Soviet educational expansion, it is worth remembering that during

"The recent Soviet educational mobilization poses a formidable challenge to the national security of the United States."—Isaak Wirszup

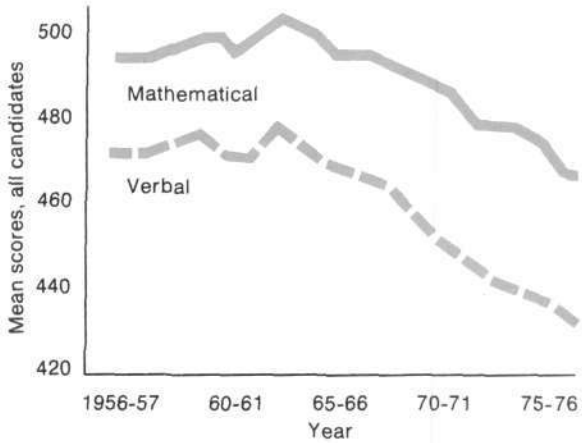
Photo by Novosti Press courtesy of the Soviet Mission to the United Nations

EARNED AND PROJECTED PhD's IN FIELDS RELATED TO FUSION DEVELOPMENT



Source: Data obtained from the National Science Foundation.

MEAN SCHOLASTIC APTITUDE TEST (SAT)
(Scores for all candidates, 1956-76)



Source: Data obtained from the College Entrance Examination Board.

THE COLLAPSE IN U.S. EDUCATION

The United States has been turning out fewer PhD's in mathematics, engineering, and science since the 1970s, and the projections for the 1980s, based on current enrollment, look even worse. At the same time, the mean scores on the standard test for students applying for college entrance have plummeted.

the Stalin era the secondary school graduation rate was as low as 4.9 percent—out of 1,000 children entering the first grade in 1930 only 49 completed the tenth grade in 1940. In 1957—the year of Sputnik, and just prior to the Khrushchev reforms of 1958—no more than 1,729,000 students graduated from secondary schools. In June of 1978, however, after years of extraordinary investment and effort culminating in the introduction (1975) of compulsory 10-year schooling, over 5,000,000 students graduated from secondary schools of all types, a success rate of 97.8 percent. (In the United States, by contrast, nearly 75 percent of all 17-year-olds—about 3,150,000 students—graduate from high school.)

As discussed in greater detail later, the Wirszup report documents the impressive range and depth of the Soviet mathematics and science curricula. Wirszup has been writing similar warning memoranda over the past 10 years from his vantage point at the University of Chicago where he directs two projects funded by the National Science Foundation, the Survey of Recent East European Mathematical Literature and the Program on Soviet Works in Application of Computers and Management. This time, what Wirszup had to say struck a responsive chord nationally because his warning intersected growing concern about the general deterioration of the U.S. economic and military position internationally. The discrepancy between the U.S. standing and that of the Soviets is registered on every level—from the education system, through basic science, to on-the-job performance.

Where Does the U.S. Stand?

In July 1976, Leonid Rudakov, the head of the Soviet Union's electron beam fusion program, presented U.S. scientists with the results of a series of Soviet experiments that demonstrated amazing new developments in electron beam fusion. At the time Dr. Steven Bardwell reported on "The Rudakov Case," as it became known (*Fusion*, Jan. 1978, p. 54):

> As the files show, the Rudakov case spurred six months of bureaucratic bickering and a factional fight within the Department of Energy and the Energy Research and Development Administration. The documents present a picture of a bureaucracy totally befuddled by the Soviet diplomatic initiative of sending a scientist to a U.S. military laboratory to reveal information not only classified in this country but unknown! For the month following the Rudakov visit, the documents show that there was a flurry of telex messages, letters, meetings, and telephone calls, all attempting to hush up as quickly as possible the Rudakov results. One scientist described the attempts by these officials even to classify the blackboard that Rudakov had used in his lectures.

The failure of the Carter administration efforts to suppress the scandal around the Rudakov case was largely the result of the Fusion Energy Foundation campaign against the classification of basic science. Recently, the continuing fight for basic science and technological development and against the trend toward deindustrialization that threatens to turn the United States into a banana republic was joined by such mainstream institutions as *Business Week* magazine.

Business Week devoted a special issue (June 30, 1980) to the necessity to reindustrialize the United States. Spurred on by recent German and French moves to collaborate with the Soviet Union on energy development projects and massive programs for Third World high-technology exports, *Business Week* took as its entry point the decline of U.S. productivity. As *Business Week* documented, the United States has led the world in productivity and dominated economically precisely because of its lead in generating new technologies, and now that situation is in imminent danger of being reversed.

Business Week painted a gloomy picture:

> Over the past half-dozen years, more than 90 percent of the growth in employment has been in the services-producing sector of the economy. But productivity growth has been abysmal in the industrial sector of the economy. Mining, construction, and utilities have shown absolute declines in output per worker, largely as a consequence of government regulation and skyrocketing energy costs. Manufacturing employment has risen only modestly in recent years; nonproduction workers employed by manufacturing companies have accounted for 80 percent of these gains. And in manufacturing, the rate of growth of productivity has fallen sharply. From 1967 to 1973 output per manhour increased at a compounded rate of 2.9 percent. From 1973 to 1979 the gains dwindled to 1.6 percent a year.

As other sources (most notably the LaRouche-Riemann economic modelers) have documented, this has led to a situation in which West Germany and Japan are quickly catching up to the United States. *Business Week* cited the following statistics: "In 1950 the real gross domestic product per employee in Japan was only 16 percent of that of the United States and Germany's was 40 percent. In 1973 the average Japanese worker was producing 55 percent as much as a U.S. worker, while in Germany the ratio moved up to 74 percent. By 1979 those ratios increased to 66 percent for Japan and 88 percent for Germany."

Military Disaster

The picture in the U.S. military is no better. Nobel Prize recipient Dr. Edward Teller was not exaggerating when he asserted in a Feb. 1980 interview published in *Forbes* magazine that the Soviet Union would "win" a nuclear war with the United States. This is not simply a matter of hardware capability, or the decline of U.S. in-depth industrial potential. The ravages of the drug-rock counterculture have taken an enormous toll on the U.S. population, particularly on that vital section under the age of 35. This shows up not only in the increasing shortages of skilled labor in every section of industrial life but also in the deplorable state of the all-volunteer U.S. Army, whose high percentage of drug use is a national disgrace.

Just how bad the military situation is was documented by the U.S. Army itself in a $300,000 report called the "Army Training Study." Completed a year ago, the study relied on 35 tests involving thousands of soldiers in all 16 divisions over a two-year period. As reported in the *Chicago Tribune* Feb. 4, 1980, the study indicated that the $61 billion of super-sophisticated equipment that the Pentagon is in the process of purchasing is too "advanced" for the army units, which are having difficulty learning to maintain and accurately employ conventional tanks and air defense systems. The study concluded that the intelligence levels of many of the crews manning the tanks and air defense systems may be too low to operate them at the army's standards for combat-ready performance.

The army study was classified "for official use only" by army Chief-of-Staff General Bernard Rogers, thereby preventing its public disclosure. However, the *Washington Star* obtained a copy of the study and reported in some detail. Among the problems revealed in the army study the *Star* noted the following:

First, in a sample of 1,288 crewmen for the M-60 tank, the army's main battle tank, 28 percent of the tank gunners tested in the United States and 21 percent of the NATO gunners tested in West Germany "did not know where to aim when using battle sights."

Second, in a test of 666 tank repairmen the chances that a problem would be correctly diagnosed were between 15 percent and 33 percent. And the chances of getting that tank correctly repaired were between 33 percent and 58 percent once the problem was found.

Finally, the percentage of high school graduates among recruits has dropped and recruits in general have a lower ability to read maps, remember complex firing sequences, and recognize enemy targets.

A 'Permanent Underclass'?

Concern with the state of education goes beyond military circles. Last November the Carnegie Council on Policy Studies in Higher Education issued a 322-page report stating that one-third of all U.S. youths are "ill-educated, ill-employed, and ill-equipped to make their way in American society." The Carnegie Council expressed a fear that the nation is in danger of creating "a permanent underclass, a self-perpetuating culture of poverty, a substantial 'lumpen proletariat.' "

Although the Carnegie Council correctly diagnosed the problems in the nation's high schools, its proposals are in exactly the opposite direction to that which is needed to regain the industrial and scientific strength of the nation. Among other things, the Carnegie Council recommended ending compulsory schooling at age 16 and creating work-study programs. This may be a short-term remedy, as part of a process of "drying out" those young people whose mental capacities have been severely damaged by repeated drug use and the almost equal destruction of constant exposure to rock "music," but it is no solution to the problem. Any proposal like this that does not set as a number one priority the elimination of drug traffic and immediate reversal of the present national trend to decriminalize drugs can only feed into the general tendency toward deschooling.

It is important to understand that the decline of the schools is not a sociological phenomenon, an inevitable outcome of U.S. society. Not only are drugs circulated freely on school property, not only does rock music obliterate a student's possibility for concentrated thought in classrooms as well as elsewhere, but the teaching of sexual and moral perversion is being mandated as part of a new liberal sex curriculum designed to introduce students to "alternate life styles." Increasingly, courses such as this, which cater to an artificially created counterculture, crowd out mathematics and science, which, at best, become "electives." And when they are taught, science courses become the sounding board for environmentalist, antiscience propaganda.

Since the 1960s with the introduction of the New Math antimathematics programs that substitute logic-chopping for training in either traditional skills or the development of concept-formation abilities, and with similar inroads in every other discipline, American children have begun to fall behind in educational performance.

The Wirszup Report

This, in brief, is the situation in which the Wirszup report on the successes of the Soviet mathematics and science educational program has been receiving circulation.

Wirszup details exactly how the Soviet Union is increasing the level of training of its citizenry, especially in math and the sciences, as the key means of implementing the most rapid technological and industrial development possible. This type of approach is now attracting adherents not only in military and scientific layers but in industry as well. The Wirszup report has found advocates in such high-technology industries as Bechtel and General Telephone Electronics as well as in groups like the American Society for Training and Development, Inc., whose members are those responsible for employee education and training. The Wirszup findings were eagerly reported in the 20,000-circulation ASTD newsletter.

Wirszup presented his investigation into the preuniversity status of Soviet mathematics and science training to the National Science Foundation on Dec. 14, 1979. The challenge to U.S. education is sharply posed in Wirszup's conclusion:

> The Soviet Union's tremendous investment in human resources, unprecedented achievements in the education of the general population, and immense manpower pool in science and technology will have an immeasurable impact on that country's scientific, industrial, and military strength. It is my considered opinion that the recent Soviet educational mobilization, although not as spectacular as the launching of the first Sputnik, poses a formidable challenge to the national security of the United States, one that is far more threatening than any in the past and one that will be much more difficult to meet.

Wirszup's report describes the changes that were made in the Soviet education system after the Nov. 10, 1966 resolution of the Communist Party Central Committee that followed the 23rd Party Congress. The resolution, titled "On Measures for Further Improving the Work of the Secondary General Education School," addressed the demands of the "scientific and technological revolution" for a skilled labor force with a broader general education and a higher intellectual level. The reforms did not come overnight and involved a fight that lasted many years: The new program did not begin to get implemented in full until 1975.

The reforms began with the agencies responsible for conceptualizing the math and science curriculums. The Soviet Academy of Sciences and the Soviet Academy of Pedagogical Sciences were given the full responsibility for developing the curricula. Leading mathematicians and scientists took responsibility for developing the curriculum, textbooks, teaching manuals, and so forth for the 10-year compulsory schooling program. The team of scholars from both academies was headed by A. N. Kolmogorov, a leading Soviet mathematician.

Soviet 10-year compulsory schooling is equivalent to 13 years of American schooling and graduates students at the age of 17. Just a glance at the math and science curricula reveals the intensity of the Soviet approach. In 10 years of compulsory schooling virtually the entire young Soviet population receives 3 years of arithmetic, 2 years of arithmetic combined with algebra, 5 years of algebra, 10 years of geometry, and 2 years of calculus.

In the sciences, students receive 5 years of physics, 4 years of chemistry, 1 year of astronomy, 5½ years of biology, 5 years of geography, 3 years of mechanical drawing, and 10 years of workshop training. All these courses are compulsory.

The comparison with U.S. figures is telling. National Science Foundation data for 1977 based on an enrollment of 15.7 million show that of U.S. high school graduates 9.1 percent receive 1 year of physics, 16.1 percent 1 year of chemistry, and 45 percent 1 year of biology. Significantly, the Soviets have 5 million graduates with 2 years of calculus whereas the United States has 105,000 high school graduates with 1 year of calculus. The American 1-year geometry course obviously offers just a small fraction of the Soviet course of 10 years. And the quality and scope of the Soviet programs are further enhanced with the physics course, which includes an introduction to Einstein's theory of special relativity, and the chemistry course, which includes 1 year of organic chemistry.

The Soviets not only report a very high success rate of graduating students (97.7 percent of enrolled students graduate); but also they have conducted studies to demonstrate the direct correlation between increased educational levels and increased productivity. In a study of the production unit output per worker at the Volga Automobile Plant, for example, workers who had completed secondary school training were demonstrated to be superior to those who attended only a 1-year secondary technical-vocational school. The output, in fact, was almost double—in a ratio of unit output of 320.7 to 529.2.

Studies such as this, which demonstrate the advantages of in-depth training in science and mathematics over purely apprenticeship on-the-job vocational training in specific skills, are being used more broadly in the Soviet Union to polemicize against the kind of work-study apprenticeship program proposed by the Carnegie Council here in the United States.

The Khrushchev Period

The Soviet educational system has gone through a process of change. In 1957-1958 under the Khrushchev regime, the concept of polytechnical education was stressed. At that time the Soviets made an effort to extend compulsory education beyond 10 years, coupling it with work-study programs. In a memorandum published in September 1958, "The Politics of Soviet Education," party chairman Khrushchev motivated the proposed changes by attacking Soviet schools as "divorced from life," leaving graduates "ignorant of production."

Although on the face of it this might seem like a tendency toward deschooling (later criticism by the Soviets, in fact, indicates the detrimental side of taking the student out of the classroom), there were some positive benefits in this approach at the time. Typically, students would be given experience with advanced technologies at an early age, experience that otherwise would have been denied them given the generally backward condition of the Soviet economy in the 1950s compared to that of the United States.

Reports by an American team of educators who visited the Moscow schools confirmed this:

> The fifth-grade class for polytechnical courses was divided into two groups, each with 18 pupils. Elementary classes in metal work and locksmithing followed in the junior divisions. Starting in the eighth grade the course included machine repair and power lathes together with some agriculture. In the ninth grade students were sent to factories one day each week for four hours. . . . The automobile course apparently was considered a highly important operation because it contained all kinds of parts and gadgets. On one of the walls were road signs that were all electrically hooked up so that one could push a button and flash individual signs. Moreover there was an electrically controlled engine and an actual truck, complete with plastic hood so that one might view the engine as it operated.
>
> We were informed that this was a required subject and that one might obtain his driver's license after taking the course. This is quite an accomplishment because a license can be obtained only if one is able to disassemble a motor, reassemble it, and install it in a vehicle.

Photo of Soviet chemistry class by Novosti from Sovfoto

"Brilliant scientists can be developed from among the present Soviet student body, but their creative development will be exogenous to the formal course of study offered."

At the same time that students were receiving this vocational training, they were still exposed to a strenuous academic curriculum. As early as tenth grade, students in physics courses dealt with problems in electricity involving the use of Ohm's law and electrical field theory.

The main problem, as American and Soviet observers alike noted, was the excessive formality of instruction, which stressed rote learning and memory rather than concept formation. Frequently, students gave the appearance of learning without the actuality and in later life showed gaps in the basics which they had supposedly mastered. Essentially then, Soviet schools suffered from many of the same problems being criticized in American schools in that same period, with perhaps a greater emphasis on formality than was typical in the United States in the 1950s. Ironically, introduction of the New Math was motivated here precisely because of the need to compete with the Soviets at a time when the Soviets were complaining of the inadequacies of their own schools.

The most serious problem the Soviets were attempting to remedy was the relatively poor training of mathematics and science teachers. Since the Soviet economy was absorbing trained mathematicians and scientists directly into production, teachers often barely understood the courses they were obliged to teach. Therefore, at the same time that there was an increasingly vocational emphasis in the lower schools, the Soviets undertook a successful program to increase the quality of teacher training, particularly in math and science.

In his report, Wirszup cites a number of booklets (available in English) produced in this period that reflect what was no doubt one of the most important parts of the upgrading process. Throughout the Soviet Union, practicing scientists and university professors participated with school teachers in a broad spectrum of extracurricular programs to create math-science study groups, summer camps, national competitions, booklets and magazines, and so on, that are still a major feature of Soviet education today. It was from these programs that students with special aptitude were selected and nurtured to become the nation's scientific elite.

It is not possible competently to assess the Soviet educational program merely on the basis of curriculum because of the intangible but nonetheless enormous benefits to students from the direct participation of leading scientists in these broader cultural activities. Furthermore, throughout the country there are special schools open to the most promising students that not only offer enriched science and math curricula but also give students the benefits of working directly on special projects under the supervision of practicing scientists in a laboratory setting.

The 1966 Reforms

The 1966 Soviet reform, reported by Wirszup, represented an attempt to upgrade the early educational approach to the next highest stage. In contrast to the tendency under Khrushchev to remedy formalism by introducing practicality into the curriculum, the 1966 resolution passed by the Central Committee and the Council of Ministers went to the root of the matter. The existing mathematics curriculum in particular was overburdened with demands for logical rigor and overelaborated computational expertise. The greater the discrepancy between student performance and goals, the more the leading pedagogical institutions had exaggerated their demands. The flavor of the 1966 policy debate that followed publication of the proposed changes is well captured in this comment by A.N. Kolmogorov that appeared in a 1967 article dealing with criticisms from these pedagogues:

> *In principle, everyone agrees that teaching should not be subject to the interests of those students who intend to enter higher educational institutions after school. In spite of that, many statements were addressed to the tasks of continuing the study of mathematics in technological and physics-and-mathematics higher educational institutions, and even more to the special task of preparing students to pass the competitive college examinations. Both themes played a large role in the debate. Recently, the situation has developed in which the work of a mathematics teacher in the upper grades has begun to be judged to a significant extent by the success of his students in the competitive examinations for the most difficult higher educational institutions. It is very doubtful that the exaggerated attention paid to learning the special techniques of solving competitive-exam problems is useful even for the insignificant minority of students who will enter these difficult colleges. In any case there is no doubt that for the majority of students this tendency greatly decreases the practical results of covering the school mathematics course: Artificial details are forgotten, while basic concepts remain vague and incomplete. . . .*
>
> *As for the larger group of higher educational institutions, they are not presently suffering from the secondary school graduates' inability to solve ingenious exponential and trigonometric equations, but rather from their lack of overall mathematical development, including the absence of any conception of evaluating absolute and relative error in approximate calculations. Yet a clear understanding of such basic concepts as the concept of derivatives will create new opportunities for constructing courses in physics and other natural-science and technical disciplines in higher educational institutions of the most different kinds.*

One of the best features of the revised curriculum is its deemphasis on false demands for rigor in the early stages of education, favoring proof by construction instead and allowing students to accept the inductively obvious in elementary courses without elaborate logical justification. The Draft of the Secondary School Mathematics Program is emphatic on this point: "The clear demonstration of the essence of the axiomatic method in geometry and algebra should be the culminating moment in the overall system of the mathematical preparation of the students."

In the same vein, the program emphasizes the desirability of allowing students to use calculating devices and handbooks with lookup tables rather than be burdened with acquiring an excessive computational expertise or with memorizing formulas that are otherwise available.

As Kolmogorov reported, the mathematics-science curriculum was the subject of heated debate, and its final form was revised after the physics community complained of the tendency by the more algebraically oriented mathematicians to structure the curriculum more along the lines of what is known in the United States as the New Math. Kolmogorov described the revision as bringing school instruction closer to the structure of mathematical sciences and technology: "We must combine raising the logical level of instruction with increasing its clarity and orientation toward an organic link with an absorbing natural science interpretation of mathematical facts," he wrote.

The course of study is structured to accomplish this, and physics lessons anticipate the mathematics curriculum on every level. For example, the principle of free fall is taught before the differential calculus is introduced into mathematics and serves as a point of reference for the latter. Similarly, harmonic oscillations are studied in advance of their mathematical treatment.

Within the math classes themselves, a special point is made to introduce the use of the slide rule two years before exponential functions are introduced. A special point is also made warning teachers not to anticipate the curriculum by explaining the logarithmic principle on which the slide rule depends. The consistent approach is away from overburdening the students with logical deductive proof structure.

Although Kolmogorov himself favored an earlier and more complete introduction of algebraic axiomatics into the curriculum, incorrectly in our opinion, he emphatically rejected the New Math tendency, which was coming into dominance in the United States and to a lesser extent in Europe at that time. Kolmogorov attacked "widely publicized efforts by mathematicians in many countries to systematically cultivate such an approach 'from above' (from logically elementary structures to those most useful to their specialties in the beginning) in secondary and even in primary schools."

Nonetheless, the Soviet curriculum is still flawed by a tendency to compromise with the axiomatic, algebraic tendency.

What Is the Debate?

Kolmogorov is a mathematician of stature, whose work has been directly connected with the advanced physical conceptions typified by the discoveries reported by fusion scientist Rudakov. In this regard, he is to be compared with other top Soviet mathematicians such as Kinchin and Alexandroff. However, Soviet mathematics as a discipline has not been immune to the devastating ideological impact of the work of Bertrand Russell and Alfred North Whitehead.

Specifically, there is a Soviet faction of so-called pure mathematicians who follow the Russell-Whitehead turn-of-the-century work *Principia Mathematica*, which was an attack on Bernhard Riemann. Ironically, it is Riemann's discoveries in mathematical physics that form the basis for the accomplishments in physics today and in particular for the Soviet accomplishments in high-energy physics.

The *Principia* was also a direct attack on Georg Cantor, whose theory of the transfinite elaborated Riemann's epistemological standpoint. By putting Cantor's set theory on a so-called rigorous logical foundation, Russell and Whitehead turned it upside down, in the process creating the abortion known as the New Math.

In brief, Russell and Whitehead, picking up from the tradition of Cauchy, asserted a program to detach mathematics from lawfulness. This will seem paradoxical at first glance, since their project was to elaborate mathematics

Least Action Principles and Projective Geometry

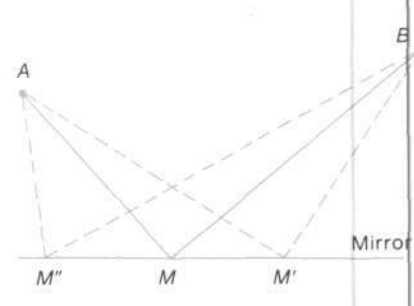


Figure 1
PATH OF LEAST DISTANCE

The distance $AM + MB$ is the shortest path between the points A and B that touches the mirror M.

$$AM + MB < AM' + M'B$$

$$AM + MB < AM'' + M''B$$

The angles AMM'' and BMM' are equal.

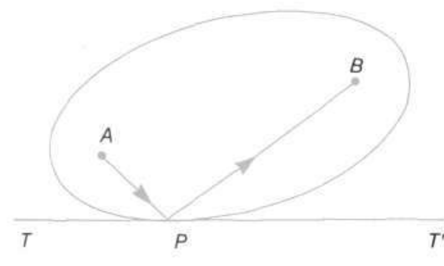


Figure 2
LEAST DISTANCE IN ELLIPSE

A light beam originating at one focus of an elliptical mirror will be reflected through the other. After multiple reflections, the path converges on a line between the two foci which is the major axis of the ellipse.

The light beam has an equal angle of incidence and reflection with the tangent to the ellipse; that is, angle APT equals angle BPT'.

as a rigorously based, self-contained, axiomatic system. In the Russell-Whitehead approach, the structure of mathematics is primary. The content of mathematics, its connection to physical geometry, economics, and so on is relegated in their treatment to the application of "pure" mathematics. Therefore, the intrinsic lawfulness embedded within processes that take place in the real world is denied in place of the sterile apparent lawfulness of axiomatics.

For Russell and Whitehead the mathematician is "free" to invent any set of axioms he chooses and mathematics becomes simply the elaboration of the chess moves that follow once the rules of the game are laid out.

Russia's Neoplatonic Tradition

Russell's New Math approach met the greatest resistance in the Soviet Union. Russia has had a Platonic tradition in science and mathematics since the St. Petersburg Academy of Science was set up by Gottfried Leibniz, and it was there that the great 18th-century mathematician Euler based himself for many years.

It is by no means irrelevant that Riemann's maternal great-grandfather was a collaborator of Leibniz. More directly, Riemann's development was shaped by his residence at Göttingen University, which was set up according to plans drawn up by Leibniz (although realized only after his death). Göttingen flowered as the institution that housed the great mathematician Gauss and carried on in Germany the work of the Ecole Polytechnique set up in Paris by Monge and Carnot out of the wreckage of the French revolution. The interconnections of this Russian, French, and German Neoplatonic network are underscored by the fact that it was in Paris that Leibniz began to work seriously in mathematics in collaboration with a group of scientists brought together by Colbert.

Thus, Soviet mathematics and science has its own roots in the same humanist tradition out of which Riemann himself developed. The Neoplatonic tradition exemplified by the works of Riemann and Cantor views science and the branch of it known as mathematics not as a chess game but as the study of the lawful ordering of the universe into which man, its highest product, directly intervenes. Science is not a given systematic body of knowledge. It is the *process* by which any given level of knowledge is superseded as man tests his understanding of the universe by his ability to enlarge its potentialities.

Properly then, mathematics seeks to describe the continuous process of evolution of the universe. The job of the mathematician is to identify invariance within a continuous sequence of transformations. This is the significance of Riemann's treatment of higher-ordered manifolds and, in fact, it is the guiding principle of the whole body of his work. The axiomatic treatment of mathematics cannot achieve this even when the axioms are strictly chosen to mirror physical reality. It is not the structure at any given moment that is primary but the process in time through which that structure is lawfully changing.

Despite this, because Marxism, the official Soviet ideology, is flawed by its ideological ties to British materialism, the fight against the Russell tendency in the Soviet Union could not be fought out on the highest epistemological level. Materialism, whether it be Russell's brand of British empiricism or Marx's dialectics, denies the existence of the infinite. For the materialist, man's intellect mirrors the material universe by its ability to receive the imprint of sense data. The immediate structure of reality as a collec-

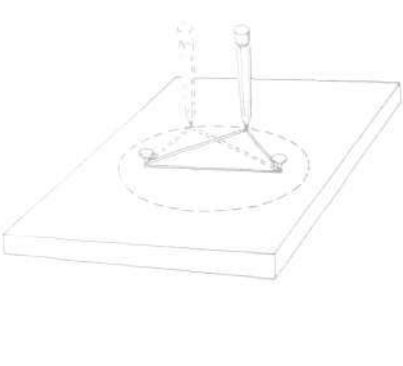


Figure 3
ELLIPSE MAKER

A device to draw an ellipse can be constructed from the locus definition of the curve. The ellipse is the locus of points the sum of whose distance from two fixed points is constant. This can be demonstrated with two tacks, a loop of thread, and a pencil as shown.

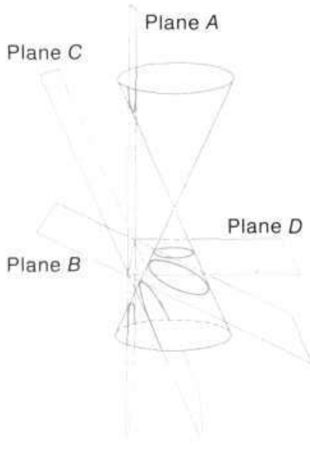


Figure 4
CONIC SECTIONS

By varying the angle at which a right-circular cone is sliced, the four conic sections are produced. Plane *A* produces the hyperbola; plane *B* the ellipse; plane *C* (parallel to the side of the cone) yields a parabola; plane *D* (parallel to the base) yields the circle.

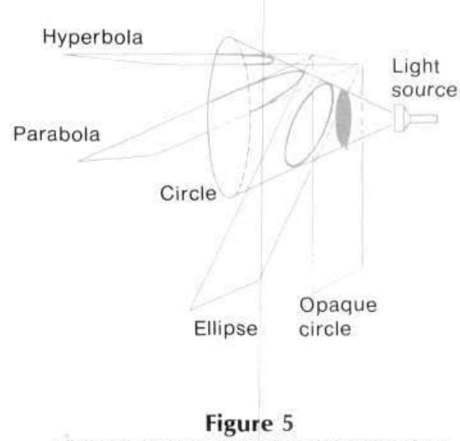


Figure 5
CONIC SECTIONS BY PROJECTION

The conic sections can also be produced projectively. If an opaque circle is held in front of a point light source, a shadow cone is created. By rotating the screen, the curves of the conic sections are produced as sections of the light cone.

tion of facts is primary, and process is a derived notion. This is the basis for Russell's theory of sets.

For the Platonist the process is primary. Moreover, man has direct access to this process through studying his own mind. It is in the act of creative discovery, whether in science or the arts, that man expresses the true lawfulness of the universe. This is best expressed by Cantor's notion of the transfinite; for the nonmathematician it is best expressed by the Christian notion of man's divinity. It is precisely this level of the discussion that is axiomatically outlawed by Marxist ideology. The best Soviet mathematical physicists apply the method of Leibniz, Riemann, and Cantor, but they are prevented from defending its epistemological basis.

For this reason the Soviet curriculum does not offer a model for the United States. Although it is a useful confirmation of the accelerated pace that can be taken within the schools and is not grossly flawed by concessions to the algebraically oriented "pure" mathematics tendency, it is deficient in precisely the areas of epistemology that are the necessary basis for effective pedagogy. It is here where the Soviets' vulnerability emerges to the entrance of New Math through the back door.

The accomplishments of physicists such as Lev Landau in high-energy physics, or Zel'dovich, who attacked the Second Law of Thermodynamics, or Tanin and Rudakov, who dealt with the nonlinearity of energy-dense plasmas, are the best examples of the existence of the Leibniz scientific tradition as an active force in Soviet science today. It is the grouping associated with these men that criticized the concessions Kolmogorov was otherwise willing to make to the "pure" mathematics faction in the Soviet Union.

How Mathematics Should Be Taught

The evolution of man is the critical experiment that proves that the universe is negentropic, and the process of that evolution has been accompanied by the increasing ability of the biosphere to maximize the amount and quality of energy. Therefore, it is to those processes that maximize energy efficiency that we must look for the highest order of governing physical lawfulness.

Leibniz set this search for causality as the primary task for physical mathematics, describing it as the Principle of Sufficient Reason. Thus, he rejected Newton's supposed law of gravitational force, despite the fact that it was a descriptively correct application of Kepler's discoveries, because it was *acausal*.

As Leibniz polemicized repeatedly, it is useful to understand the correlation of events but we have knowledge about them only when we understand those invariant qualities that govern them as a series taken as a whole—in other words, we must understand the reason for their being, or the principle of their generation, or, as Cantor put it, their transfinite ordering.

The most potent tools for locating these invariant characteristics are *least action principles.* In optics, for example, the path a light takes upon reflection from a mirror is determined by the fact that it is the shortest distance between the source and the receiver. Its wave-particle qualities are properly understood only in this way.

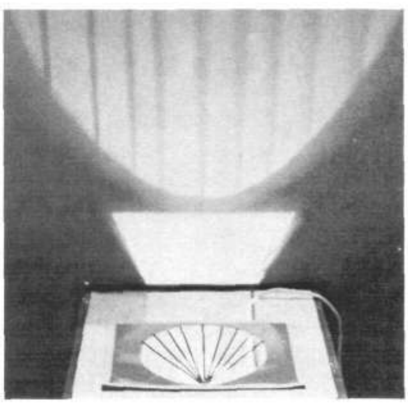


Figure 6
LIGHT BOX PROJECTIONS
This construction allows the student to understand the principle of the generation of conic sections in its simplest form—according to the intersection of a circle with the "vanishing line." The light box consists of a box, a light source, and a cutout circle. The light source is placed inside the box and against one wall projecting upward. When the cutout circle is placed on top, it forms an oblique cone of light. The wall of the box where the light source originates is placed opposite the screen and functions as the vanishing line. Rays of light projected from the light source to the vanishing line will intersect the screen only at a point at infinity.

By varying the position of the cutout circle with respect to the vanishing line, the fundamental projective properties of the conic sections become apparent. The parabola occurs when the circle touches the vanishing line at one point, which projects to a point at the line at infinity (shown here). The hyperbola is created when the circle is moved back to overlap the vanishing line so there are two points at infinity. If the cutout circle does not touch the vanishing line at any point, an ellipse is seen on the screen.

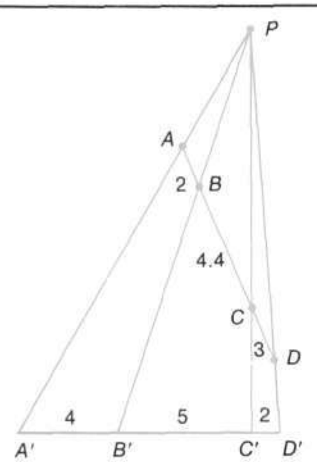


Figure 7
PROJECTIVE INVARIANCE
Segments of the line *ABCD* are transformed by projection from the point *P* into corresponding segments on the line *A'B'C'D'*. The length of these segments is *not* preserved under projection as the figure shows. However,
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Incredibly, although the Principle of Sufficient Reason is still taught to Soviet students, its contents have been banalized beyond recognition. For example, the Soviet publishing house MIR has circulated a series of booklets in Russian and English based upon lectures given to extracurricular mathematics study circles throughout the Soviet Union. One booklet, *Proof in Geometry* by A.I. Feisov, published in 1977, states the following:

> The need for proof follows from one of the fundamental laws of logic (logic is the science that deals with the laws of correct thinking)—*the law of sufficient reason.* This law includes the requirement that every statement made by us should be founded; i.e., that it should be accompanied by sufficiently strong arguments capable of upholding the truth of our statement, testifying to its compliance with facts, with reality. Such arguments may consist either in a reference to observation and experiment by means of which the statement could be verified or in a correct reasoning made up of a system of judgments.

The danger inherent in this nonsense is that it robs the student of precisely the vantage point necessary to understand the difference between appropriate rigor and axiomatics. The axiomatic method is well known to most mathematics students. Russell and Whitehead, as described above, reduced geometry to a branch of formal logic. As anyone familiar with the New Math knows, this destroys a student's ability to learn and ultimately poses the choice for the student either to drop the subject or disrupt his or her ability to think. Similarly, Euclid's own method obscured the actual science of geometry as it had been developed by the Platonic Academy by arbitrarily rearranging geometric theorems in a pseudorigorous deductive format. That screens out the process of discovery. No one reading Euclid could know how or why he chooses any given theorem to be proved.

Geometry indeed must be learned rigorously, but rigor is neither a matter of convincing argument nor of sterile axiomatics. It is established by demonstrating the necessary and sufficient conditions for the generation of a given function. On the level of elementary geometry this reduces to establishing the *locus definition* for the construction of given figures.

The official Soviet curriculum is weak on just this point. In an effort to avoid formalism, as Kolmogorov explains, many Euclidean axioms are accepted without proof as intuitively obvious. Construction is an important part of the instruction; in fact, he particularly recommends paper cutting in the early grades. However, the criteria for rigorous constructive proofs are lost because solid figures are introduced into the curriculum only in the seventh grade, and only in grades nine and ten is projective geometry studied. Even then the emphasis is upon parallel projections that can be treated by vector algebra. Yet, it is only by studying two-dimensional geometry as a projection from three-dimensional space that the conditions for rigorous constructive proof can be established on a nonaxiomatic basis. This is the only way to show that even the simplest space is self-determining.

Projective Geometry

The correct approach to elementary geometry demands taking the projective approach to plane geometry from the outset so that the student constructs the circle, ellipse, parabola, and hyperbola as sections of a cone. In this way the focal properties of the conic sections can be estab-

Continued from page 75

the ratio of ratios of the lengths is invariant under projection.

The ratio of ratios,

$$\frac{B'A'/B'C'}{D'A'/D'C'} = \frac{BA/BC}{DA/DC} = .145$$

This ratio of ratios is known as the cross ratio and will be the same for any projection of the given line *ABCD* through *P*.

A special form of the cross ratio occurs when the line segment is divided in the fashion the ancient Greeks called *harmonic*. In this case, the cross ratio is equal to 1 (or minus 1 if the direction of the line segment is considered). For example, in the following line segment,

A — 3 — *B* — 1 — *C* — 2 — *D*

the cross ratio is: $\frac{3/1}{6/2} = 1$

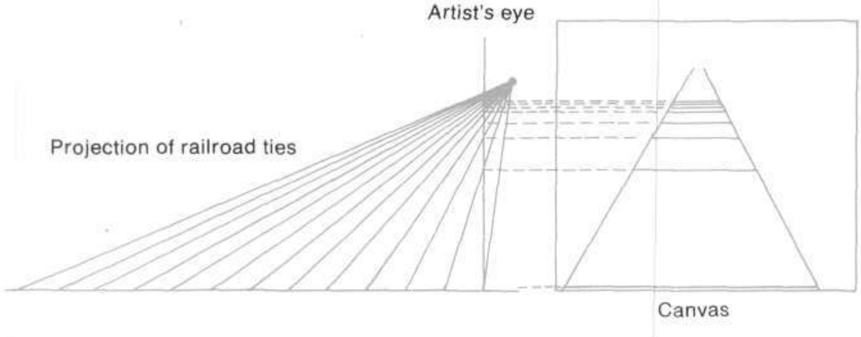


Figure 8
CROSS RATIO AND ARTISTIC PERSPECTIVE

Railroad ties are laid at equal intervals along the ground. In a painting or photograph these lines are represented by lines that converge to a point at the horizon. The distances between ties will no longer be equal. The cross ratio of the distance, however, will be maintained. The cross ratio of the spacing between any four adjacent ties must be the same as for any other four adjacent ties.

This cross ratio is invariant under projection. On the canvas, therefore, the cross ratio of the spacing must be the same as the cross ratio on the ground. The figure shows how an artist accomplishes this using the science of perspective.

lished that then become the locus definition of their construction in the plane; for example, by drawing an ellipse using a string connected to two fixed points.

On this basis not only can the student deduce the locus property of these figures as plane figures, but the geometry of triangular figures emerges as well. By considering the reflection of light on conic mirrors and studying the projection of conic sections from a point source of light, the student directly learns physical geometry as a self-organizing property of physical space. The conic sections have unique properties, yet they can be generated from a cone by a continuous process of rotation. Therefore, they offer the simplest example of Cantor's transfinite.

Precisely here is where the Soviets run into serious pedagogical difficulty. Another booklet published by MIR in 1975, *Dividing a Segment in a Given Ratio* by N.M. Beskin, illustrates the point. Here projective geometry is reduced to an extension of metric geometry by an excessive dependence upon Euclidean two-dimensional proofs for concepts that are otherwise clearly taught as three-dimensional space projections. The sorriest example is Beskin's treatment of the point at infinity. As Riemann established in his 1854 Habilitation paper, following the lead of Gauss, discrete things can be counted, but measurement is always known only in terms of *rates*. Measurement depends upon the comparison of the physical properties of spaces. An approximation of Riemann's idea is found in Einstein's theory of General Relativity. Projective geometry is the best way of introducing students to this distinction because it studies the countability of space—the invariance of the incidence of lines. In general, projective geometry does not preserve metric relations, but it does preserve partial ratio relationships.

Thus, four points on one line will be projected to four points on another, altering the distances between them. Yet, the ratio of the ratio of their distances will be invariant.

An apparent anomaly occurs in the closure of the system of projective geometry in the case of parallel lines. If incidence is to be preserved, every two lines must intersect in one point; yet, parallel lines do not meet. If we make an exception of parallel lines, then we are taking account of an exogenous metric feature—their direction or angle measurement—in this one special case. Furthermore, if we project one line onto another using parallel lines, then we are forced to distinguish between parallel and point projection.

Typically, in an axiomatic treatment the problem is solved by adding a point at infinity to space—the point at which parallel lines meet in the far distance. By doing this the special parallel projection need not be treated as a special case. Metric "affine" geometry is then added on to projective geometry as that special case in which parallel lines are admitted to play a special role—preserving similarity relations, since parallel projections presume proportionality. In a correct treatment, pure projective and affine geometry must be taught simultaneously as a study in the generation of metric relations.

Properly, both epistemologically and pedagogically, the point at infinity is a transfinite point that unifies the metric and purely projective properties of a given space and demonstrates how metricity emerges out of the projective invariance of cross-ratio. It is the point at infinity that defines how the space is constructed. It is important at the earliest possible point to give a student experience in dealing with the interplay of different geometries so that the student studies the transformation of figures and the transformation of geometries at the same time.

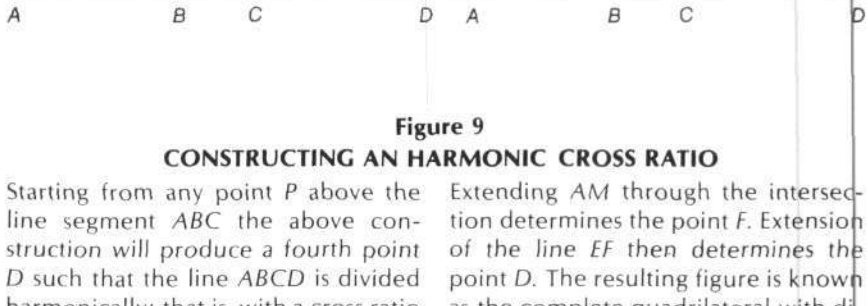


Figure 9
CONSTRUCTING AN HARMONIC CROSS RATIO

Starting from any point P above the line segment ABC the above construction will produce a fourth point D such that the line $ABCD$ is divided harmonically; that is, with a cross ratio of -1.

E is an arbitrary point on the side AP. By connecting the points PB and EC, an intersection is created at M. Extending AM through the intersection determines the point F. Extension of the line EF then determines the point D. The resulting figure is known as the complete quadrilateral with diagonals drawn in.

The position of D is independent of the choice of location of P as Figure 9b shows.

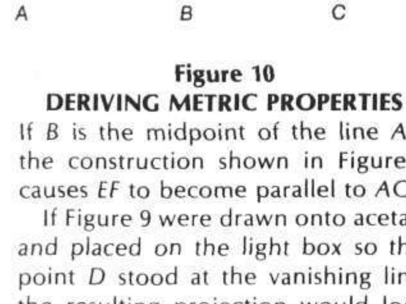


Figure 10
DERIVING METRIC PROPERTIES

If B is the midpoint of the line AC, the construction shown in Figure 9 causes EF to become parallel to AC.

If Figure 9 were drawn onto acetate and placed on the light box so that point D stood at the vanishing line, the resulting projection would look like the above with $AB = BC$. Thus, projection from the point of infinity introduces metric properties into projective space.

Beskin not only fails to adequately treat the projective standpoint, but also totally confuses the whole idea of the point at infinity by giving it false reality. He treats it as a sign that indicates the direction of parallel lines rather than a point in projective space. He goes so far as to indicate it as a circle with a little arrow inside it, unwilling to accept the reality of projective space as an extension of "material" space. The existence of the infinite point as the bridge between two geometries is lost; thus, the standpoint from which Riemann and later Cantor elaborated Leibniz's Principle of Sufficient Reason is also lost. For Riemann and Cantor the existence of a succession of transfinite points at infinity provides the rigorous basis upon which to determine causal relations between the geometries in which events occur. The process of evolution of the universe occurs as a succession of such geometries, one leading to the next, each of a higher order, governed by transfinite principles of least action.

That this problem is not simply idiosyncratic to Beskin is proved by the relegation of the whole treatment of solid geometry to a minor feature of the official Soviet curriculum. Furthermore, it is exemplified by the removal of the treatment of complex numbers from the standard course and by the way in which the calculus is introduced.

Complex geometry is properly the generalization of the study of projective geometry. So too is the calculus, which if it is taught in the tradition of Leibniz will take the definite integral as a point of departure. The Soviet curriculum introduces the differential calculus one year before integration is studied; in other words, using the approach of the Newtonian calculus. Only by employing the Leibnizian method, however, can the calculus be taught as physical geometry rather than as an extension of algebra.

A Model for the U.S.

Taken as a whole, there is no doubt that the Soviet educational system is and will be effective not only in selecting those students who will go on to become scientists but also in bringing the whole population to that level of scientific culture that is the foundation of an industrial republic. Nonetheless, again taken as a whole, the particular weakness we have singled out for comment forms part of a more general tendency governed by the compromise that Kolmogorov described. It is not sufficient to guard against the worst expressions of the Russell formal logic disease. The early introduction of science into the curriculum in anticipation of a correlated development of the mathematics is a corrective, but it is insufficient in itself to provide the correct epistemological standpoint. Brilliant scientists can and probably will be developed from among the present student body, but their creative development will be exogenous to the formal course of study they are offered.

In contrast, the approach to mathematics we have indicated here was used in the Platonic Academy. To some extent it was revived in the first 10 years of the Ecole Polytechnique and at Göttingen University in Germany. In fact, it is still the case that most of the leading physicists internationally, particularly in the fields of hydrodynamics and plasma physics, were educated at Göttingen University or by teachers who studied there before World War II.

More recently, Carol White and Fusion Energy Foundation director of research Uwe Parpart have further developed that method, in collaboration with Lyndon H. LaRouche, Jr., in a series of classes given in New York City to a group of 150 adults over a three-month period. It has also been tested by Parpart in an after-school program with children ranging in age from 7 to 11. (See *Fusion*, Feb. 1980, p. 61.)

Students typically attend a weekly lecture and a workshop. The class began with a thorough study of the conic sections combined with optical experiments and went on to explore projective geometry. Within the three-month period students were introduced to conformal mapping through the device of stereographic projections and are now studying the generation of surfaces as an introduction to the study of differential equations. Few had any mathematical training beyond half-forgotten geometry lessons, yet they have proven the efficacy of the method outlined here by the rapidity with which they were able to assimilate and use these concepts.

The unique efficacy of this method must be sought not in any particularity of the presentation but in its governing principle: treating mathematical physics as appropriate to the actual principles that govern the human mind. The same principles that govern the evolving universe are reflected in its highest expression, the use of reason. The healthy human mind forms concepts by searching out the relatively invariant features of any given situation in order to locate those possibilities for progress in which he or she can intervene. That same transfinite ordering process governs the actual process of concept formation within the mind itself.

No doubt many people seeing the Wirszup report or similar studies will find the threat of Soviet preeminence so alarming that they will be moved to demand an immediate sharp turn in the present disastrous antiindustrial policies of the Carter administration, coupled with a complete overhaul of the school system. Although the perceived Soviet threat may prove useful in spurring into action Americans who have otherwise been passive, it would be an unfortunate blunder if the Soviet educational system was taken as a standard for the United States.

The extent of de facto deschooling in U.S. schools over the past two decades, the perversion of the scientific outlook in the United States, and the depth of antiscience irrationalism make it essential to launch such a program from the highest epistemological level. This country must educate for genius, but it will do so only with the method of Leibniz, Riemann, and LaRouche.

Mel Klenetsky has lectured in mathematics at City University in New York and is a national committee member of the National Caucus of Labor Committees. He is currently leading a workshop in the ongoing geometry project described here. Carol White, who has taught mathematics at City University for several years, is a member of the national executive committee of the National Caucus of Labor Committees. The editor-in-chief of Campaigner *magazine, she is the author of* Energy Potential *and the just released* The New Dark Ages Conspiracy.

Industrial Leadership

Continued from page 32

by the necessity of maximally enhancing the evolution of new fields. (See Figure 3.)

Combined with the R&D policy described, such a strategically formulated investment policy, deliberately overshifting capital stocks into high-technology areas associated with these categories, will permit the United States to "leapfrog" a majority of intermediate developments in Western Europe and Japan and rapidly regain its technological and industrial leadership.

Nor does such a strategic orientation lead to the conclusion of favoring benign neglect of heavy industry, as in the *Business Week* policy. Although I cannot go into detail here, the role of heavy industry is indicated by the following example: The development of high-temperature fission reactors (and their applications to chemical processing and coal gasification) and nuclear-based agroindustrial complexes (nuplexes) creates specific—not arbitrary—demands on output and investment in sectors from construction and coal to steel and metals. Instead of a shutdown or, alternatively, a simple linear expansion in hopes of gaining new markets on the basis of an ill-defined competitive edge, the proper role of heavy industry within an economy is determined by the new generation of high industrial technologies.

Preliminary analyses now underway with the LaRouche-Riemann model are designed to begin to fill out quantitatively the qualitative policy framework presented here; there is little doubt that the U.S. economy could realize growth rates of up to 15 percent and in some cases 20 percent in the first year of a concerted reindustrialization effort in most major industrial output categories.

The basic analytic task now is to connect the present initial state and provable growth rates with a quantified end state representing a significant degree of implementation of the technologies associated with the technology horizon in the four areas specified. The least action path to be constructed will, of course, not be singularity-free, but will be shock-dislocated time and again as increasing energy flux densities cause buildups of productivity threshold values. A first quantitative picture of the high-technology scenario for U.S. industry is projected for a forthcoming issue of *Fusion*.

PERCENTAGE OF MACHINE TOOLS BY AGE IN 1973

	Under 10 years	10-20 years	Over 20 years
United States	33	39	28
Japan	61	21	18

Source: 1979-80 Handbook of the National Machine Tool Builders Association.

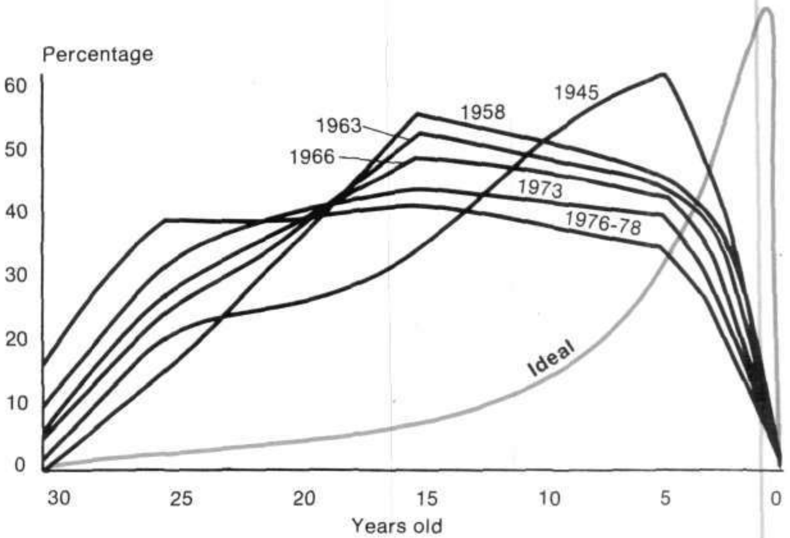


Figure 3
AGE DISTRIBUTION OF U.S. MACHINE TOOLS IN USE IN METAL-WORKING INDUSTRIES 1945-1978

Shown is the ongoing shift since World War II into a situation where a higher percentage of U.S. investment in capital stock is in older equipment. The most desirable situation would be a development in the opposite direction to the point where the ideal curve actually resembles a shock wave phenomenon.

Source: 1979-80 Handbook of the National Machine Tool Builders Association.

Notes

1. "America in the Technetronic Age" is the title of a 1967 paper in which Brzezinski lays out the vision of his brave new postindustrial world. A discussion of Brzezinski's other statements on the subject can be found in "The NATO Plan to Kill U.S. Science," by Mark Burdman, *Fusion*, Sept. 1980, p. 41.
2. See, for example, "Debunking the 'Decoupling' Thesis" by Dr. Steven Bardwell, *Fusion*, May 1980, p. 17.
3. "The Riemann-LaRouche Model: Breakthrough in Thermodynamics" by Carol White, *Fusion*, Aug. 1980, p. 57.
4. "America in the Technetronic Age."
5. An analysis of these shifts appears in the *Executive Intelligence Review* in a series of articles by this author and Dr. Steven Bardwell, "Can the U.S. Economy Survive the Depression?", "The 1980 Recession: Not Like Any Other," and "Energy Conservation: Building Inflation into the Economy," March 18, 1980 and May 6, 1980.
6. This is amply documented in works cited above on the LaRouche-Riemann economic model.
7. "Winterberg Proposes New Pellet Design for Inertial Fusion," *Fusion*, Sept. 1980, p. 65.

Figure 3
NEUTRAL SCENARIO (no change)

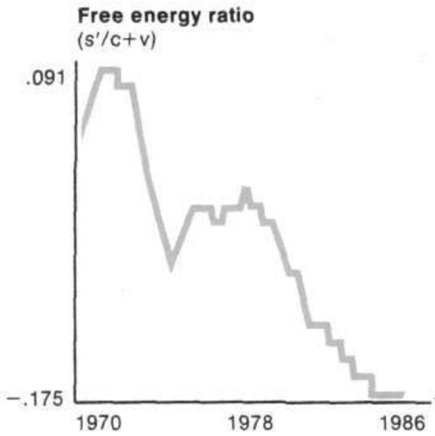


Figure 4
MILITARY BUILDUP SCENARIO

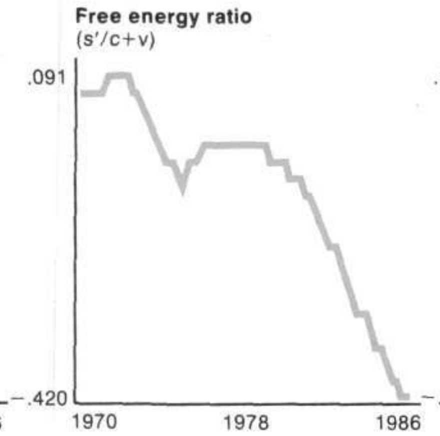
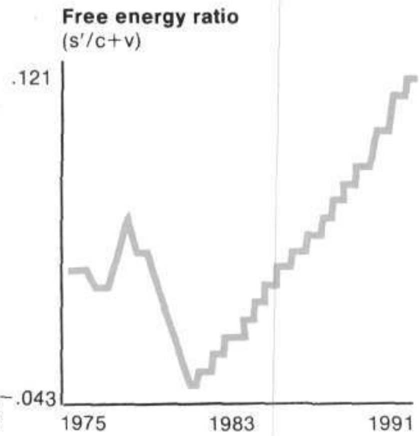


Figure 5
3 PERCENT ANNUAL RISE IN PRODUCTIVITY



Figures 3, 4, and 5
SCENARIOS FOR REINDUSTRIALIZING THE U.S. ECONOMY

The figures show the free-energy ratio (the ratio of reinvested profit to reproduction costs) for the U.S. economy in three alternate scenarios: The first, Figure 3, shows a neutral scenario based on a continuation of the present policies of credit restrictions, declining industrial production, and growing unemployment. The U.S. economy is now so weak that it faces a serious collapse within the next year.

The second graph, Figure 4, shows the same chart for the economy with a reindustrialization effort based on a program of military production "in width." This simulation assumes that there is a significant shift of investment toward heavy industry. Initially, this has a beneficial effect on the economy since the average productivity of these sectors tends to be higher than the average in the economy, and the economy is shifted toward these sectors. However, the additional overhead burden bogs down this increased average productivity after two or two and one-half years, and the economy as a whole collapses in a severe depression by the middle of 1982.

The third scenario, Figure 5, attempts to measure the minimum productivity increase that would be necessary to sustain an increased overhead of the magnitude required for reindustrialization. The initial calculations show that an average 3 percent per year increase in productivity would be sufficient for the modest recovery of the economy shown in Figure 5.

LaRouche-Riemann Model

Continued from page 25

succeed but a reindustrialization program that results in accelerated investment into the frontier areas of new technologies, the translation of these technologies into industrial production techniques, and the training of the increasingly skilled labor force needed to man these new technologies.

In quantitative terms, the model shows the folly of basing a reindustrialization program, as some have proposed, on an expansion of military production "in width"; that is, with little or no investment in the most advanced new technologies and scientific ideas. Figures 3, 4, and 5 contrast this "in-width" military build-up (Figure 4), with a neutral scenario projecting more of the same (Figure 3) and a minimum recovery program (Figure 5). As the graphs show, the model predicts that the present health of the U.S. economy is so poor that it is unable to sustain the additional overhead costs of a military program that lacks technological and productivity spin-offs. Furthermore, even a continuation of present policies with no additional military spending would see the economy enter a serious depression in the next year.

The model's calculations show that a *minimum* 3 percent per year rise in productivity is necessary for the U.S. economy to recover. Given this rate of productivity increase, a much larger budgetary overhead could be sustained—and in fact, must be sustained—to pay for the research and development, education, and training required to make a reindustrialization program work.

As subsequent parts of this series outline, productivity increases of this magnitude can be realized only in an economy where the momentum is supplied by an Apollo-style program of technological development. Investments in the frontiers of science and engineering, most specifically space exploration and nuclear fusion, are the prime ingredients in such a program. The only way a desperately needed reindustrialization program can succeed is to "pull" the economy forward with technological development.

National

Continued from page 16

additional person's contributions to increased knowledge and technical progress."

Using his econometric model he finds that "additional persons, instead of being a permanent drag, lead to an increase in per worker output starting 30 to 70 years after birth—that is 10 to 50 years after entry into the labor force." Thus "economics can therefore be a cheerful science rather than the dismal science Malthus thought it to be."

Simon also counters the doomsayers who insist that shrinkage of farmland and other resources requires drastic curtailment of population; he challenges the statistics on death by famine, and reports that world supply of arable land is increasing at a 0.7 percent annual rate, and per capita food production at a rate of 1 percent per year.

Politics Missing

Here, however, Simon's "optimism" blinds him to the political intervention required if "each additional person's contributions to increased knowledge and technical progress" are to be realized.

The case of Zaire, for example, shows that in a once relatively prosperous country where 70 percent of the production capacity is now idle, the cost of essential foods has risen 540 percent in the past four years and 50 percent of children die before they reach the age of five. Agricultural production has declined every year since 1970, not because of a lack of arable land, but because of the cannibalizing debt payments demanded by the International Monetary Fund's "conditional lending" with the support of the U.S. government.

Under such circumstances, which are multiplying in Africa and elsewhere, it is naive to predict, as Simon does, that "We may expect as they [the less-developed countries] get richer, smaller absolute numbers of persons will be doing the farming for larger populations," unless the strangulating policies of the IMF are replaced with credit and investment policies geared to development.

—*Dr. Richard Pollak*

Wide World

TMI engineers removing protective clothing after their first entry to the Unit 2 containment building July 23. Environmentalist scare stories about low-level radiation failed to stop the venting of krypton gas.

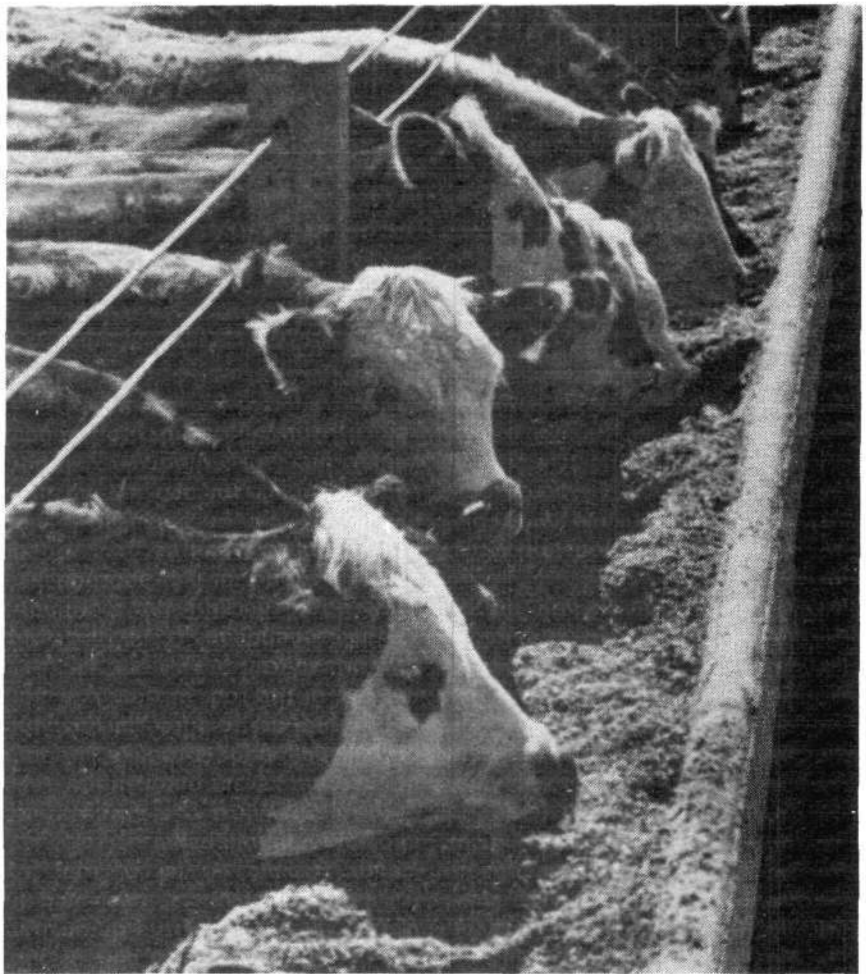
No Increased Cancer Risk After Low-Level Radiation

A recent study published in the *New England Journal of Medicine* (1980, 302: 1101) discredits claims by environmentalists that low-level radiation causes cancer. The study on low-dose radiation and leukemia, conducted by scientsts at the Mayo Clinic in Minnesota, determined that "No statistically significant increase was found in the risk of developing leukemia after radiation doses of 0 to 300 rads to the bone marrow when these amounts were administered in small doses over long periods of time."

Focusing on radiation exposures from medical use, the report indicated that the cumulative effects of long-term exposures up to 300 rads over a 20-year period do not result in an increase in the incidence of leukemias for those individuals when they are compared to a control population. This level of radiation is approximately 3 times larger than the maximum permitted for workers in nuclear power plants for the same time period and is more than 3,000 times that received by an observer standing at the Three Mile Island nuclear plant site for the entire duration of the incident last year.

The fact that the study determined the level of irradiation for bone marrow tissue makes the report even more significant, because radiation effects on this tissue are held most likely to trigger the leukemias studied.

In the antinuclear rhetoric that poses low-level radiation as a killer, the known deleterious effects of very high-dose radiation levels are linearly extrapolated downward to conclude that *all* levels of radiation are harmful. Such extrapolations have repeatedly been demonstrated as fallacious in biological systems, and this study further discredits them.



USDA

DES increases cattle feed efficiency 12 percent.

Beef Herds Jeopardized by Hormone Scare

The U.S. Food & Drug Administration has sent scores of agents to investigate illegal use of the proscribed synthetic hormone DES by livestock producers. By the end of June, 301 violaters in 23 states were on an FDA violators' list and due for "vigorous prosecution" as mandated by Health and Welfare Secretary Patricia Harris and U.S. Department of Agriculture Assistant Secretary Carole Foreman. Each violator can be fined up to $10,000 and imprisoned for three years for each count.

More than 400,000 head of cattle have been quarantined since the investigation was triggered by a disgruntled Texas feedlot employee who notified his company's Chicago headquarters April 1 that the hormone was being used, and the company notified the FDA. Thousands of producers have now been interrogated, along with their veterinarians, consultants, and feed supply users, on possible DES use.

A Costly Ban

Used for 90 percent of U.S. feedlot cattle since 1954, DES was banned in July 1979 on the grounds that 300-milligram-per-day doses given to pregnant women had induced cancer in some of their daughters, although the livers of DES-fed cattle contained 1/300,000 of the medical doses in question. A study performed last year by National Economic Research Associates, Inc., estimated that the DES ban will cost U.S. consumers from $3 to $5.6 billion a year, because DES sharply increases feed efficiency by 12 percent.

DNA Ruling Draws Criticism

The U.S. Supreme Court ruled June 16 that unique bacterial species developed using genetic engineering techniques are patentable. This extension of the patent law to cover a broader spectrum of human-created products encourages R&D investment in the area of recombinant-DNA.

Biomedical products such as insulin, interferon, and human growth hormone should appear in a relatively short time. A longer-range perspective includes products that could have profound effects in the chemical, oil, and agricultural industries.

In addition to the usual environmentalist reactions equating recombinant-DNA work to Frankenstein science, a more scholarly criticism of the Supreme Court decision appeared in an Op-Ed in the June 23 *New York Times* by Harold J. Morowitz. Morowitz, a molecular biophysicist at Yale University, contends that there was a faulty philosophical basis for the Supreme Court ruling:

The Justice's ". . . have decided that in patent law no distinction exists between the living and nonliving. Millennia of awe and respect for the special character of life . . . are being discarded if that life has any element of biological or genetic engineering in its synthesis. . . . The refusal to draw a sharp distinction between animate and inanimate matter is the ultimate in reducing life to physics."

The essential point that Morowitz and the less-philosophical environmentalists miss or obscure is that the "special character of life" is that it must be improved or it dies. Recombinant-DNA practice is a lawful extension of evolution, the process of human scientific and technological activity transforming the biosphere.

Without this activity, especially in agriculture, the biosphere would collapse. It is ironic that the antireductionist Professor Morowitz seems more concerned with the line between biology and physics than with the Constitutional principle and the sovereignty of human Reason over both organic and inorganic nature.

Schmidt-Brezhnev Talks Raise Development Prospects

Sygma

"The results of scientific collaboration are already before our eyes." Giscard (left) and Schmidt have led the European nations in pursuing development policies based on high technology.

Giscard Acclaims Future of Science

Visiting the northern German city of Lübeck July 7 during a state visit to West Germany, French President Valéry Giscard d'Estaing spoke on the future of science and scientific collaboration between the two nations. "What will the scientific and technological universe of the year 2000 look like? And how can we [French and West Germans] prepare for it together?" he asked.

The results of cooperation "are already before our eyes. . . . It was combined teams that developed the rocket Ariane, the satellite Symphony, the airbus that bears witness across the skies to the excellence of our joint technology, the high-temperature reactor at Grenoble, the ionospheric diffusion probe, and now the work of joint teams on the development of space communications and millimetric radioastronomy. In the field of nuclear energy, our scientists and engineers have accomplished impressive progress in the fast breeder. . . ."

Fears of "dizzying progress," Giscard continued, must be dispelled. "It is up to us to bring to those who doubt and worry the certain victory of hope. . . . We must demonstrate and repeat that high technologies do not represent some Faustian version among a handful of people, but that they generate employment, that—like the steam engine and the railroads in their day—they are called upon to free us from constraints, like the limitation of energy resources, which can compromise our very future."

West German Chancellor Helmut Schmidt ended a state visit to the Soviet Union July 1, where he met with President Leonid Brezhnev and, at Schmidt's request, with top-level military officials including Marshal Ustinov. During the trip the two nations signed a 25-year agreement for high-technology economic and scientific cooperation.

Included in the agreement are joint development of nuclear power plants in the Soviet Union; joint exploitation of Soviet raw materials; and West German export of precision instruments, oil drilling equipment, semiconductor materials, calculators, electronic components, coal gasification equipment, and X-ray technology.

In addition, the giant gas pipeline deal first outlined in 1978 was clinched. Detailed negotiations are now underway on a $9 to $13 billion package involving West German pumping equipment and pipeline for a 3,000-mile line from Tyumen, in western Siberia, to the Soviet border. By the mid-1980s, 40 billion cubic meters of gas per year would be exported to the Federal Republic.

Deutsche Bank is heading the finance arrangements on the West German side, Ruhrgas is negotiating the gas imports, and Mannesmann Steel will provide the special pipe, capable of withstanding super-high pressures.

In the final Schmidt-Brezhnev communiqué the Soviet leadership endorsed for the first time the principle of joint East-West cooperation "to find a solution to the economic problems of the developing countries." The Soviet Union has traditionally avoided such cooperation, arguing that socialist countries need not repair damage inflicted by "capitalist colonialist" policies, and has also remained wary of the "appropriate technology" version of Third World development.

The West Geman policy was summarized in Foreign Minister Hans-Dietrich Genscher's report on the trip to the West German parliament July 3. A peace strategy is required for the 1980s, he said, that will surpass the limits of East-West relations and include the "South."

"By the year 2000 there will exist 6 or 7 billion more people, needing food, shelter, employment, and energy," Genscher stated. "We will have to develop new energy sources, and if we fail to meet this challenge there will be no positive place for us in history."

Observers conclude that the Soviet Union is now more open to cooperation in the Third World in the belief that the West German approach will promote industrial development and trade of a stabilizing and mutually profitable kind.

—*Susan Welsh*

France Announces Advance in Neutron Bomb

French President Valéry Giscard d'Estaing announced in a June 26 press conference that France has successfully tested a neutron bomb. He stressed that if the decision is made two to three years from now to produce the bomb, this would not mean that France accepts the possibility of "limited" or "tactical" nuclear war in Europe, as both Gaullists and French Communists fear.

"There is a point that must be understood as central in our system," he stated. "It is that any nuclear attack on French soil will automatically give rise to a strategic nuclear response." According to present French nuclear doctrine, French forces would deliver tactical nuclear strikes as a first warning and then proceed if necessary with a strategic strike against the cities of the aggressor.

A Nuclear Umbrella

Giscard described the place of the neutron bomb in this ongoing strategy as related to "France's direct concern with the security of neighboring Western states." The Western European press interpreted his statements as an expression of French intent to use the French *force de frappe*, or independent nuclear deterrent, as an "umbrella" for West Gemany, which is forbidden to produce nuclear weapons. European commentators have also noted the absence of Soviet protest against the tests.

Given the growing strength of the *force de frappe*, this would undercut arguments for deployment of American Cruise and Pershing II missiles in the Federal Republic. NATO decided in December 1979 to produce these missiles—which for the first time would put the Soviet Union within four to five minutes' warning time of a surprise NATO first strike. At that time, West German hesitation was met with the argument that Soviet intermediate-range missiles targeted on Western Europe represent a dangerous imbalance.

The debate over the new weapon has overshadowed what could be important scientific accomplishments by French scientists testing neutron devices in the Pacific. As *Fusión* has reported (Sept. 1980, p. 61), if French scientists have developed the basis for a "strategic" neutron bomb with unprecedented range and power, the ambitious French nuclear energy program could make parallel progress toward fusion energy. And powerful neutron devices can be used to generate fissile fuel from ordinary uranium ore for fission reactors very cheaply and in unlimited quantities.

—*Dana Sloan*

Japan Emphasizing Nuclear Energy

The Japanese government anounced at the end of June that it plans to spend more than $13 billion in the next decade to develop energy replacements for petroleum. Nuclear power, coal, and liquefied natural gas are the choices emphasized by the Ministry of International Trade and Industry, according to press reports. The goal is to reduce oil to 50 percent from the 1977 level of 75 percent of energy supplies.

Fourteen nuclear power plants will be brought on line by 1985, bringing the total to 35 facilities and doubling total nuclear megawatts to 30,000. In 1990, nuclear power is to supply 10.9 percent of Japan's energy consumption, coal 17.6 percent, and natural gas 9 percent; in 1977, these combined sources provided less than 20 percent of total energy output.

Letters

Continued from page 6

the weak will change sides. Why should we turn their untruths upon our own people?

Dana E. Netherton
Virginia Beach, Va.

The Editor Replies

A lot has changed in 20 years.

As the feature article in this issue makes clear, there is indeed a gap between Soviet and U.S. science education that shows up concretely in the performance of the all-volunteer army and in the civilian job market. Nevertheless, the Soviet curriculum is not an adequate model for the United States. Revitalizing the U.S. education system means a return to the epistemological methods associated with the Platonic Academy and its modern practitioners.

Voicing Support

To the Editor:

I want to thank all of you for making such a gallant stand and helping to dispel so many myths and fears of the uneducated American public. When I walked into Chicago's O'Hare Airport a few months ago and saw a young lady pushing your magazine and openly supporting nuclear energy, I just had to talk to her. As a result, I receive your magazine monthly. Although the technical material presented is above my head, I am learning. Most important, your magazine gives me direction. I was never able to effectively voice my opinion on energy development in my government because everything I picked up was *anti*. Your explanations of federal programs and key personnel in them are very valuable. Keep printing them and I will do my part in writing these people and voicing my support for all programs to develop an energy-efficient America.

Joseph P. Lynch
T Sgt., USAF
Holloman AFB, N.M.

Readers are invited to comment on Fusion *articles. Address correspondence to Fusion, Suite 2404, 888 Seventh Ave., New York, N.Y. 10019*

Fusion News

Figure 1
THE STELLARATOR CONFIGURATION

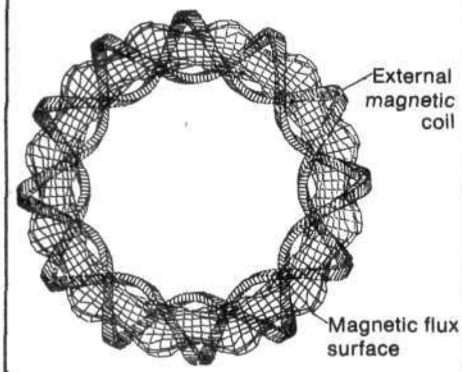
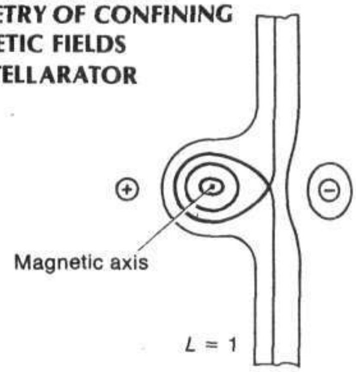


Figure 2
SOME VARIATIONS IN GEOMETRY OF CONFINING MAGNETIC FIELDS IN A STELLARATOR



W. German Stellarator Breakthrough

The world's most advanced stellarator device, the Wendelstein VIIa at the Max Planck Laboratory in Garching, West Germany, achieved a major breakthrough this spring when scientists obtained significant confinement of hot, dense plasma and indications of continuous operation.

The results were close to those of the tokamak, the donut-shaped device that is currently the mainline approach of the magnetic fusion effort internationally. However, the tokamak depends on a plasma electrical current for a pulsed mode of operation, while the stellarator results were achieved without an induced plasma current, which implies the possiblity of a continuous or steady-state mode of operation.

The Wendelstein VIIa results, therefore, confirm the viewpoint expressed several years ago by a leading Soviet scientist: "Tokamaks are good, but stellarators are better." Ironically, the Soviets developed the tokamak, which has almost totally supplanted stellarator research in the United States, although the United States originated the stellarator approach. Meanwhile, a significant stellarator effort is maintained in the Soviet Union.

At first glance, the stellarator seems very similar to the tokamak. It is a donut-shaped, magnetic-confinement system with external coils wrapped around the torus to generate a stable magnetic bottle to confine and insulate thermonuclear plasmas.

Successful stellarator experiments in the 1970s operated in a fashion similar to tokamaks, in that an induced plasma electrical current played a significant role. The results obtained with these plasma-current-driven stellarators were equivalent to those obtained on tokamaks of similar size, indicating that earlier experimental failures were not because of the basic scientific concepts involved, but because of technical problems like magnet design or impurities.

What distinguishes the recent Wendelstein VIIa stellarator experiments is that plasma confinement has been obtained solely with *external* electrical current. Therefore, the results will permit scientists to explore more fully the differences between stellarator and tokamak confinement, leading to a better comprehension of magnetic confinement in general.

The recent results could also provide the basis for a quantum leap in the development of fusion reactor technology because they indicate the possibility of continuous reactor operation. In present fusion reactor designs based on the tokamak, the fusion burn must be interrupted after a period of time—from one minute up to one hour. The plasma must be regenerated and heated to fusion temperatures again—a pulsed mode of operation that involves huge costs and technological difficulties.

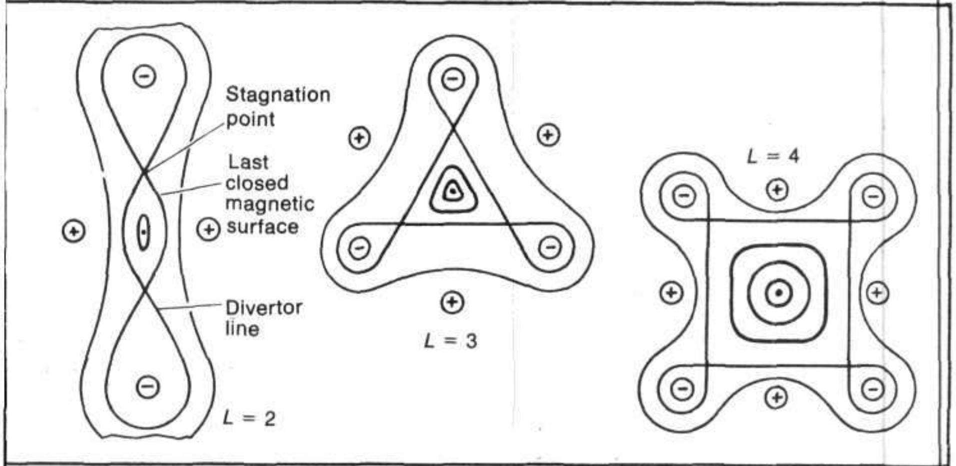
By contrast, the stellarator's currentless operation provides a basis for continuous, steady-state fusion plasma confinement systems, and currentless plasma confinement is theoretically and experimentally expected to improve.

The stellarator is designed so that all components of its confining magnetic field are generated by electrical circuits external to the fusion plasma. In the tokamak, a significant portion of the confining magnetic field— the poloidal component—is produced by the internally induced plasma electrical current. Moreover, the stellarator does not have axial symmetry; that is, unlike the tokamak, which always has a continuous, smooth cross section—circular, elliptical, D-shaped or figure-8—the stellarator donut has a rippled surface (see Figure 1).

These seemingly minor distinctions lead to major differences in theory and practice. Because of its axial symmetry, the tokamak is susceptible to a theoretically simpler analysis; for example, it can be mathematically reduced to analysis in two dimensions, and some approximate models even operate with one dimension. The stellarator, on the other hand, must be analyzed in a three-dimensional mathematical system and is more difficult to build, since it utilizes more external magnets arrayed in a complex series of geometries.

The latter difficulty is probably the only reason that tokamaks overtook stellarators in experimentally approaching fusion conditions.

However, because the stellarator can work without an induced plasma current, the cost and difficulty of pulsed-mode operation in a tokamak can be overcome. To that advantage can be added the ironic fact that the stellarator is actually much more amenable to advanced theoretical com-



prehension than the tokamak. For that reason, stellarator experiments could lead to a more rapid development of plasma confinement theory, which in turn could provide a better understanding of the tokamak's dynamics.

For example, there are a large number of geometric variations in which stellarators can be configured. Figure 2 shows cross sections for some of these different geometries. Comparing these to Figure 1, it can be seen how these profiles of the confining magnetic fields' geometry twist and turn traveling around the stellarator donut. The number L refers to the number of axes of symmetry the cross sections have; in the Wendelstein VIIa, $L = 2$.

How Wendelstein VIIa Works

In order to initiate plasma operation, the Wendelstein VIIa utilizes a plasma current of about 18,000 amps. This start-up plasma has a temperature of several hundred electron volts, both electrons and ions, and an electron peak number density of 5×10^{13}. Confinement times using just this mode of operation have been measured at about four-thousandths of a second; this is comparable to that achieved in tokamaks with similar magnetic fields and plasma sizes.

For currentless operation, the plasma current is ramped down to about 200 amps—a relatively small value. Neutral beam heaters are turned on and more fuel is injected into the plasma with gas puffers. Plasma temperatures in the range of 700 to 900 electron volts are measured. The plasma appears to remain stable, although no measure of the confinement time has yet been made. The reason is that the plasma radiation output is greatly increased from a value of 40 kilowatts in the start-up mode to about 150 kilowatts in the currentless mode. This is believed to be the result of impurities (nonhydrogen elements) migrating into the plasma from the vacuum chamber wall.

The neutral beam heaters are directed almost perpendicularly into the plasma column because the large number of external magnetic coils on the VIIa create limited access. The plasma is not sufficiently thick or dense enough at this angle of incidence to stop all of the neutral beams injected into the machine. Most tokamaks operate with neutral beam injectors directed in a tangential angle to the plasma column. In this way the beam sees more plasma and is more completely absorbed. In any case, it is believed that in the VIIa, a large portion of the neutral beam travels through the plasma and intersects the opposite vacuum wall. This apparently generates the influx of impurities into the plasma that causes the high radiation energy loss rate.

There are plans for changing the magnet coil structure on the Wendelstein in coming months in order to allow for more tangential-like injections. This, together with other impurity control measures developed on tokamaks, could lead to operation with purer hydrogran plasmas in which the results will not be obscured by impurities.

Advanced Fusion Fuels: **Prospects Are 'Excellent'**

A report presented by leading U.S. laboratories to the 8th International Conference on Plasma Physics and Controlled Nuclear Fusion Research in Brussels July 1-10 called the prospects excellent for demonstrating the feasibility of advanced fusion fuels, especially the all-deuterium (D-D) cycle.

The report, presented by teams from the University of California at Los Angeles, the University of Wisconsin, TRW, Argonne National Laboratory, and the University of Illinois, was the outcome of scoping studies of advanced fusion fuels funded by the Department of Energy Office of Fusion Energy. The studies confirm the optimistic views expressed by Fusion Office director Dr. Edwin Kintner at a 1979 Princeton University meeting; namely, that current prospects for D-D and other advanced fuel cycles are equivalent to those for the deuterium-tritium (D-T) reaction.

It is currently believed that the D-T fusion cycle will be the first fusion reaction harnessed for commercial energy production before the year 2000. However, continuing progress in fusion and associated plasma physics research over the past few years has opened up the possibility of an early development of confinement systems that can attain the higher ignition temperatures and more stringent confinement conditions needed for more advanced fusion fuel cycles.

These alternative, non-D-T reactions are important because they could greatly relax the environmental and technological problems of developing fusion reactors, opening up the prospects for improved and altogether new applications of the energy generated.

For example, although the neutrons generated in the D-D reaction are of a lower energy than those produced in the D-T cycle, the total number generated per unit of energy produced is significantly greater. Thus, D-D could be a more prolific breeder of fuel for fission reactors. Simultaneously D-D could lessen the reactor materials problems involved, since the lower-energy D-D neutrons generated could be significantly less troublesome in terms of materials damage; they are very similar to the flux of neutrons encountered in the fission fast breeder.

Also, removing the need for tritium eliminates the potential hazards involved with this radioactive element together with the technological requirements for breeding it from lithium with fusion-generated neutrons.

Higher-temperature fusion reactions beyond those of D-T and D-D become even more attractive. For example, the portion of energy generated in the form of neutrons decreases; and the proton-boron reaction, in fact, is almost neutronless. This means that these cycles could be designed so that virtually no radioactivity is produced. Furthermore, since most of the fusion energy is in the form of charged particles, more advanced magnetohydrodynamic and direct-conversion processes could be utilized to generate electricity.

New Results

The Brussels review of advanced fuels noted that by taking into account new effects, such as the immediate interaction of the high-energy fusion products with each other and with the remaining fuel, it is found that the reactivity of alternate fuel cycle mixtures is greatly increased. The effects are more pronounced at electron temperatures above 550 million degrees Celsius, typical of cycles from D-D to p-^{11}B (proton-boron). In particular it was determined that propagating chains of reactions between initial reaction products lead to sufficient increases in overall reactivity to permit infinite energy gains to be attained. (Energy gain is defined as the fusion energy generated divided by the energy input to maintain the reaction.) Previously, for proton-boron, only very small energy gains were projected.

In terms of reactor designs and projected utilization of various cycles, there is a plan for superconducting coils for an octupole configuration, a donut-shaped magnetic confinement system in which part of the magnet system is located within the fusion plasma itself. This could withstand the fusion environment because of the low neutron environment of an alternate fuel cycle.

For D-D reactors, it was found that the tritium inventory can be 15 times less than a D-T device of equivalent

All the News That Fits...

A prominent news article in the *New York Times* June 24 reported that two dozen dissident Soviet emigres held a public protest at the 11th Quantum Electronics Conference in Boston June 23 "against the presence of N.G. Basov and A.M. Prokhorov," Soviet scientists who shared a Nobel Prize in 1964 for their work on lasers. According to the *Times,* "The Soviet scientists, both officials of the Lebedev Physical Institute in Moscow, stayed out of sight, as did any secret police escort they may have had."

In fact, reports FEF's *Fusion* Technology Editor Charles B. Stevens, who attended the Boston conference, "the newspaper of record was completely off the mark. Dr. Basov and Dr. Prokhorov did not attend the conference."

What makes this *Times* coverage even more interesting is that the same day that Basov and Prokhorov were not at the conference, the Buchsbaum fusion advisory panel released its report to the Department of Energy. To date, the *Times* has not covered the Buchsbaum report.

We think it's a good example of how the *Times* liberally interprets its motto, "All the News That's Fit to Print."

* * *

IT'S ABOUT TIME

The Illinois Power Company has received more than 1,500 requests for its film on the Clinton nuclear plant under construction in central Illinois. Last November, the CBS news feature program, "60 Minutes," presented the project as a mismanaged white elephant. Since CBS refused to air Illinois Power's response to the show, except for a January correction of two minor details, the company put together its own 42-minute point-by-point refutation of the inaccuracies aired nationwide by "60 Minutes'" Harry Reasoner. The film is particularly interesting because Illinois Power filmed CBS's filming, and shows what the network chose to delete.

Harold Deakins in the Illinois Power public information office will be happy to send you a tape of the film. Mail a blank video cassette in either width, and if you plan to use it with a Betamax, specify the speed. You can reach him at Illinois Power Co., 500 South 27th Street, Decatur, Illinois 62525, (217) 424-7021. Tell him you heard about it in *Fusion.*

* * *

HOUSTON CHRONICLE HITS THE MARK

Thanks to a reader for sending us the lead editorial in the June 11 *Houston Chronicle,* which is right on target power. For catalyzed D-D (a cycle in which D-T reactions are generated by designing the system so that tritium generated in the D-D reaction is also burned up), the reduction is 100; for D-^{3}He, it is about 1,000. (^{3}He is a helium isotope not found in nature.) For reactor design of advanced versus D-T reactions, little difference is found in overall fuel handling and vacuum system costs. Reactors with D-^{3}He may result in 10 to 100 times less radiation dose than D-T systems in an accident scenario, but D-D reactors may actually generate higher external doses.

The conference presentation concluded with reactor scenarios that involve generator reactors producing ^{3}He, for a semicatalyzed D-D unit. The ^{3}He is burned in a satellite reactor, which, because of the lower radioactivity associated with this fuel, can be located in urban environments.

DESCARTES

about the international nuclear power situation. It begins:

"The 'lessons' of the Three Mile Island nuclear plant problems are interpreted differently in Paris, London, Moscow, and other seats of power abroad than they are in Washington. While the U.S. nuclear industry remains in a state of inertia, the rest of the world is pushing full steam ahead with the development of nuclear power." There follows a concise listing of French, Swedish, British, Japanese, and Soviet Bloc initiatives that will shortly leave the United States in the nuclear dark ages.

The editorial continues: "For all the self-righteousness of the 'no nukes' protests that have come into vogue, the hard facts are that nuclear power development is not extravagance, but necessity. . . . Yes, there were lessons to be learned from Three Mile Island. But they're the ones being applied by the rest of the world, not by crusaders who would, quite literally, leave us jobless, powerless and in the dark."

AVICENNA

Conferences

MHD Electrical Power Generation, MIT, June 16-20

MHD Conf. Maps Next 10 Years

The Seventh International Conference on MHD Electrical Power Generation at Massachusetts Institute of Technology June 16-20 brought together scientists working on magnetohydrodynamics research in 15 countries. It was the first time in five years that many of these renowned experts in plasma physics, MHD, and electrical power engineering had the opportunity to share knowledge and the results of their national programs and discuss the future of this promising energy technology.

MHD is a direct conversion process that can use any electrically conductive working fluid to produce electric power through the interaction of an ionized fluid and an external magnetic field. Most of the MHD work worldwide is aimed at increasing the efficiency of conversion of thermal energy from the combustion of fossil fuels, but work is also continuing on closed-cycle systems that could use the heat of nuclear reactors to ionize a working fluid for conversion.

In addition to the two volumes of papers presented at the conference, the heads of MHD research in the major programs internationally delivered brief remarks on the status and future of each national program. The directors of the more established programs in the United States, the Soviet Union, Japan, and Poland all reported progress in system-component design, integration, analysis, engineering design, and experimental results.

The director of the younger MHD program in India reported on an exciting perspective for reaching the level of the developing nations in MHD research. For the first time also, data and presentations were available from the People's Republic of China on MHD work. Representatives from smaller programs in Australia, Sweden, Canada, Italy, France, West Germany, and Israel also participated.

One of the most exciting MHD programs in terms of drive and accomplishment is the effort in India. Dr. V.K. Rohatgi, the head of the MHD project at the Bhabha Atomic Research Center in Trombay, began his remarks on the Indian program by observing that "the growth of civilization is the history of the growth of energy."

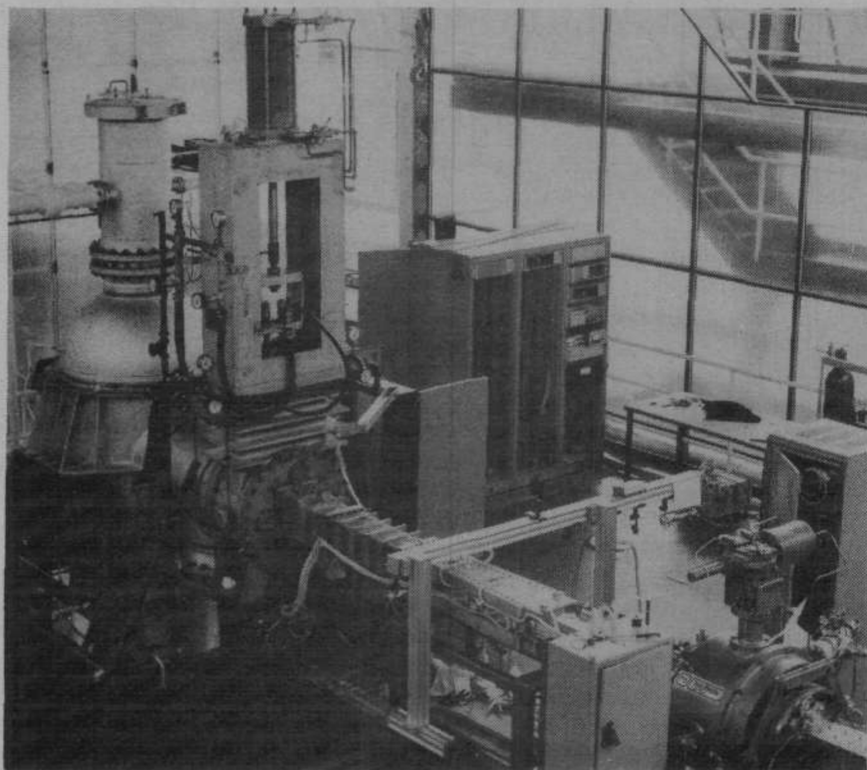
The Indian program, which began three years ago and works very closely with the Institute for High Temperature in Moscow, is divided into two phases. The first will culminate in 1982 when a 5-MW-thermal experimental plant will begin operation.

This first large-scale experiment will then be scaled-up to a 15-MW-thermal plant to give Indian scientists experience and develop competence in all area of MHD technology. The program now involves 45 scientists at a yearly expenditure of about $15 million. The second stage will be design and construction of a pilot commercial plant.

Recently the Indians successfully tested an MHD generator channel on the Soviet U-02 facility in Moscow and have so far had three exchanges of scientists with the Soviet Institute. MHD is important for India, Rohatgi explained, because of its large reserves of low-grade coal that will be burned much more economically using this advanced process.

Closed-Cycle MHD

In October 1979, the Netherlands signed a cooperative agreement with the U.S. Department of Energy for joint work in closed-cycle MHD. In closed-cycle systems, the working fluid is not the combustion products of fossil fuels but a nonreactive gas that is heated externally and ionized,



Courtesy of Eindhoven University of Technology

Closed-cycle MHD experimental system at Eindhoven University of Technology's Direct Energy Conversion division in the Netherlands.

pushed through the MHD generator, and then recycled. Closed-cycle systems have been developed mainly for use with high-temperature nuclear reactors.

At the conference Dr. L.H. Rietjins, the chairman of the division of Direct Energy Conversion at the Eindhoven University of Technology, explained that most closed-cycle MHD work in Western Europe stopped in 1972, when the future of the high-temperature nuclear reactor began to look uncertain. At this point, the Eindhoven program in the Netherlands is the largest MHD program in Western Europe. However, Rietjins predicted that the European countries will reenter MHD work as the technology gets closer to commercialization.

The joint work with the United States has focused on experimentation on a 5-MW-thermal facility in the Netherlands that uses argon seeded with cesium as the working fluid. The aim is to produce electricity for 1 minute with fossil fuels on a similarly sized facility in a closed cycle. The United States will supply a channel and preheat loop for tests and analysis in addition to sharing information on other aspects of MHD research.

The joint testing is scheduled for mid-1981 with a channel being fabricated by General Electric, which has pursued closed-cycle work in the United States. The 5-MW facility at Eindhoven will be outfitted with a superconducting magnet system later this year.

The U.S., Soviet, Japanese, and Polish fossil-fuel-based MHD programs all reported significant progress in research and experimentation. All four countries have plans to make the technology commercial before the end of this century.

The most advanced is the program in the Soviet Union, where the 25-MW-electric U-25 has been running since the mid-1970s. The Soviets have broken ground on the world's first commercial demonstration plant, the U-500, which will be operational in 1985 at an electric-power-generating plant at Ryazan. The U-500, like the other MHD facilities, will run on clean natural gas as a stepping stone to develop the technology that will eventually be converted to coal.

The smaller U-02 has already been converted to burn coal, and work is progressing on converting a by-pass loop on the U-25 as well. Dr. E. Shelkov, the deputy director of the Institue for High Temperature (IVTAN), which is in charge of MHD research, reported that by 1990 the Soviets plan to have three commercial MHD generators operating on gas. After 1990 all plants constructed for utility use will use coal.

During this decade of commercializing MHD technology, the Soviets plan to build up the industrial construction base and components manufacturing required to produce MHD power plants. The operation of the coal-burning U-02 plant at IVTAN has been transferred to the Energy Ministry to train the personnel that will be needed to run commercial plants in the future.

In Japan there are numerous industry-run institutes and laboratories doing MHD research. Professor Y. Ozawa predicted that Japanese utilities will become interested in MHD especially as they see fuel prices rise. In 1976 Japan opened phase two of their program, which began in the 1960s. The main experiment will be construction and operation by March 1981 of the Mark VII MHD generator. This will be a 10-MW electric generator, which is the smallest size that can be used to simulate a commercial-scale plant, according to estimates from experiments in the first phase of the Japanese program. The program in Japan is concentrating on solving the potential problems of nitrogen oxide pollutants from MHD and on materials development for the electrodes and insulation.

Poland has made the commitment to bring the technology to the commercial stage using coal. Professor W.S. Brzozowsi of the Institute of Nuclear Research in Swierk reported that tests were done in 1979 on a 5-MW-thermal coal-fired MHD facility. They have recently added an air heater and are also investigating optimal seedinjection methods and coal particle size.

Some of the Polish MHD research is conducted jointly with the U.S. Department of Energy and is sponsored by the Marie Sklodowska-Curie Fund, in which the U.S. and Polish governments both hold shares. Only the United States and Poland are doing large-scale experimental work with coal.

In the United States, progress was reported in all research areas. Here the major question among conference participants was: when will the U.S. government get serious enough about the development of MHD to fund it at a level consonant with commercialization before the turn of the century? Industry representatives discussed in private the possibility of forming an industry-based association to lobby and educate the population about the potential of MHD technology.

The one MHD program that conference participants knew existed but never before had very much information about was China's. A large delegation of Chinese scientists presented a paper that summarized their MHD work, indicating experimentation on a series of small (less than 1-MW) devices throughout the 1970s. They have done work on variations of MHD designs and used clean liquid fuels until now. The Chinese reported they expect to use coal-based MHD in the future, but did not indicate specific plans for a national program in commercial MHD. U.S. scientists estimated that the scale of the Chinese program puts it at the same point as the U.S. program in the late 1960s.

Most of the information in the conference documents had been published previously, and this relatively small community of scientists was by and large familiar with the progress in each program before arriving at the conference. Perhaps the most important aspect of the international meeting, therefore, was the opportunity for the world's leading thinkers and experimenters in MHD to exchange ideas more informally and jointly evaluate the future of their research.

—Marsha Freeman

AAAS Conference on R&D, Washington, D.C., June 19-20

Scientific Research Under Budget Gun

"The synfuels program will be mobilized like the space program."

John C. Sawhill
Deputy Secretary
U.S. Department of Energy

Two contradictory themes symptomatic of muddled thinking on the U.S. economic and strategic situation: On the one hand, "innovation"; on the other, restricting such innovation to sectors like synfuels while cutting funding for the basic research that will improve overall productivity.

Long-term basic scientific research and education of U.S. scientific personnel will be the most severe casualties of the current research and development funding crunch, speakers at the June 19-20 annual American Association for the Advancement of Science conference on R&D policy announced.

The message for scientists and researchers was clear: Nonscience agencies headed by the Office of Management and Budget and FEMA, the Federal Emergency Management Agency, are centralizing R&D guidelines and mandating short-term concentration on applied research in such fields as synthetic fuels (see *Fusion*, Sept. 1980, p. 60).

The audience of 300 heard Willis H. Shapley, AAAS consultant for R&D Budget Analysis, give a conference overview on "learning to operate under conditions determined by the budget" and "new ways to control the R&D work of state and local governments."

The first session was on federal R&D and featured Dr. Frank Press, White House director of science and technology policy. Press reported that the National Science Foundation will give multiyear rather than long-term grants, stressing "defense, energy, and agriculture," including automobile retooling, oil drilling, hydrocarbons, and satellite communications.

Press reiterated that OMB will gain funding oversight of state and local government R&D, and added that "We're going to be experimenting with cooperative generic technology centers" in the industrial sphere.

Other themes noted by Press and iterated throughout the conference were the need to "establish the scientific basis for regulatory affairs" and a concentration on joint work with China.

The chairman of the House Budget Committee, Rep. Robert Giaimo (D-Conn.), next cited school lunch programs and benefits for the elderly as examples of competition for federal funds, reporting on the $6.5 billion "Savings Bill," which consolidates budget cuts as an all-or-nothing package legislation. "No long-term R&D payoff activity makes sense now," Giaimo stated, because of inflation and capital drains into alternative energy systems.

'Uncertain Returns'

OMB associate executive director H.B. Cutter repeated that basic research has "uncertain returns" and concluded, "In the short run, R&D won't get supported, but in the long run it will." He was followed by Joseph Pechman, economic studies director of the Brookings Institution, who commented, "I think Mr. Cutter and his OMB gang should decide R&D expenditures and not the IRS [through tax credits]."

The luncheon keynote address was delivered by John C. Sawhill of the Department of Energy. The deputy secretary listed oil shale, magnetohydrodynamics, photovoltaics, coal gasification, and other synthetic fuels as R&D priorities, announcing that with banking and scientific support, "the synfuels program will be mobilized like the space program." His speech drew a challenge from *Fusion's* correspondent on the scene, Mary Gilbertson, regarding the high-cost economics of synfuels as opposed to nuclear energy. Sawhill declined to reply.

The session on industrial R&D included renewed emphasis from Senate Science and Technology Committee counsel Ronald Konkel and General Motors vice-president Betsy Ancker-Johnson on the necessity of confining R&D to short-term projects. Utah Innovation Center director William Brown called for an increase in the NSF Small Business Innovation Program and development of "regional innovative centers," while Commerce Department Office of Strategy and Evaluation deputy director Ted Schlie emphasized that the U.S. manufacturing sector has been overtaken by the service sector.

During the session on intergovernmental science and technology, Rep. Thomas J. Anderson of Michigan described the effort to extend federal R&D control to cities, counties, and

FEF-EIR Seminar, Washington, D.C., June 25

Can the U.S. Avoid Strategic Disaster?

"The United States is currently arming itself for a war it will lose," Dr. Steven Bardwell told an audience of 30 diplomats, Pentagon officials, and other U.S. government representatives in Washington, D.C. June 25. Speaking at a seminar titled "Can the U.S. Avoid Strategic Disaster," Bardwell documented the erosion of U.S. military strength in recent years and the gains achieved by the Soviet Union. The cause in both cases, he concluded, is the opposite investment policies pursued by the two. While the American economy has sunk into industrial obsolescence, the Soviet Union has poured resources into basic industry and high technologies, gaining a fundamental strategic advantage combined with the superiority of its manpower.

Bardwell, who is plasma physics director of the Fusion Energy Foundation, described his own visits last year to Soviet R&D facilities and went on to discuss the current debate in the United States over a military buildup. Under the present circumstances, he said, America's industrial capacity has deteriorated to such an extent that efforts to divert substantial resources to the military will run into basic bottlenecks, such as steel shortages for transport equipment to move the military hardware! "Even a modest $30 billion annual increase in military spending—a widely discussed proposal—would, after an initial spurt of growth, precipitate a depression collapse by 1983," he said.

Leadership Erosion

Bardwell was followed by *Executive Intelligence Review (EIR)* contributing editor Criton Zoakos, who analyzed the strategic thinking that has fostered industrial and military erosion in the United States. "The United States has not had an elite" committed to the continual development of the nation since John Quincy Adams's presidency, Zoakos said, noting that it was American patricians like McGeorge Bundy who created the environmentalist movement.

Two representatives of the U.S. Joint Chiefs of Staff walked out of the seminar when Zoakos derided the Joint Chiefs for introducing analyses of Soviet leaders' "biorhythms" as part of the Pentagon's daily strategic estimate. Later the two said defensively, "Well, the Soviets do research into ESP!"

The Washington seminar was one of a series being held around the United States to present the method and results of strategic economics studies utilizing the computerized LaRouche-Riemann model codeveloped by the foundation and the *EIR*, which sponsored the Washington event.

—*Vin Berg*

Suzanne Klebe/NSIPS

EIR Contributing Editor Criton Zoakos: "The United States has not had an elite committed to the continual development of the nation since John Quincy Adams's presidency."

regions. Anderson reported that the Federal Emergency Management Agency (FEMA) is involved on all levels of R&D work.

The Chinese Model

The dinner address came from Dale E. Hathaway, Undersecretary for International Affairs and Commodity Programs, U.S. Agriculture Department. With a nod to the People's Republic of China representatives at the head table, Hathaway stated, "The Chinese have been able to feed one billion people with their methods, so we're interested in looking to what they have done." Predicting food shortages, he argued that, by analogy with energy, high commodity prices are needed to spur R&D.

Ending the conference, the dinner session featured Congressional Office of Technology Assessment director John H. Gibbons and AAAS Executive Officer William Carey.

Gibbons outlined a switch from capital investment and physical resources to "innovation, knowledge, and wisdom, and conflict resolution." Carey commended the conference for promoting dialogue, and concluded, "We have to think about the risk of science investment. We are going to have to go to competitive policies. If we want basic research, we will have to prove its utility."

Reporting on the conference in its July 11 issue, *Science* magazine, published by the AAAS, continued the obfuscation of the basic policy questions by conference participants. "The old system of congressional committee territoriality, under which science was protected, has broken down," *Science* wrote:

"Some seasoned observers felt that the [conference] analysis was accurate in holding that science is more exposed to competition than at any time within memory, but that R&D will do relatively well under the new dispensation as it did under the old. . . . This year, at any rate, it is too late for any rush to activism to have much effect on the new budget. . . . Scientists must hope that R&D gets some help from its friends in Congress and that ex-Navy man Carter and his crew are effective at damage control."

—*Susan Johnson*

Advanced Technology

Robotics: Gearing Up for Production

Although the United States pioneered automation and robotic development, it has lagged in the manufacture of robots. Now experts are predicting a boom in the immediate future as U.S. manufacturers scramble to recoup U.S. industrial strength and to meet the challenge of foreign robot suppliers.

Why is robotics essential to a growing industrial economy? As the Japanese have demonstrated, productivity in Japan's pilot machine-tool manufacturing plants using robotics increased by 350 percent. Equally important, with robots taking over certain noxious tasks such as welding, spraying, and grinding, as well as machining, drilling, and assembly tasks, human labor is freed up for more complex and creative work.

There are now about 2,500 "working" robots in U.S. industry. A small number of manufacturers—such as Hughes Aircraft, Avco, International Harvester, General Electric, and Westinghouse—have installed efficient, automated machine tool systems; and according to suppliers, the demand for new robots is exceeding the current U.S. capacity to supply them.

Most industrial managers and engineers recognize that a manifold increase in the manufacture of machine tools is a prime requisite for industrial growth, and all the evidence supports robotics as the most efficient way to increase machine tool production. The U.S. companies that have automated their machine tool production have retrieved their automation capital investments within two years on average, compared to the six or seven years that is average for ordinary machine tools. At the same time, these companies have increased their production by a factor of 3 or 4.

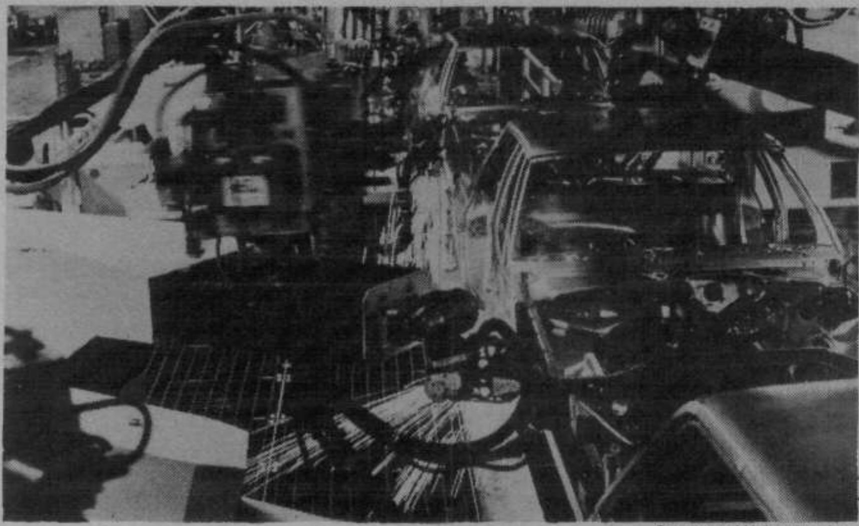
This increase in productivity is largely a result of the increased up-time—the time a machine tool is actually being used in a given machining process—and the number of hours of the day that a machine tool is manned and ready for operation. The up-time for human machinists is somewhere between 30 and 40 percent, with the rest of the time spent in various adjustments of tools and work materials. The equivalent up-time for a numerically controlled robot is approximately 80 percent.

More advanced automation techniques, including computer-aided manufacture (CAM) and robot sensory inputs—eyes and the equivalent of touch—will further increase productivity as well as profoundly affect

What Is a Robot?

A **robot** is a mechanical machine with a movable arm that either has a built-in program or can be remotely controlled by electrical or hydraulic power. The utility of the robot is evaluated by

- the degrees of freedom of the arm; that is, the number of axes along which the arm can move or around which the arm can turn
- the number of discrete points that the arm's extension can position itself within the volume of its activity
- the accuracy and speed with which the arm can reach these points
- the structure of the "fingers" and number of different tools the robot can handle
- the weight that the arm can support
- the programmability of the robot



Courtesy of Unimation, Inc.

A robot welding auto bodies at Chrysler's Newark Delaware plant

the design of products and the methods of their manufacture. These changes, which are on the near horizon, will also yield precision that is presently unattainable.

U.S. Robotics Capacity

The U.S. robot industry is now dominated by two firms, Unimation in Danbury, Conn. and the machine tool manufacturer Cincinnati Milicron in Ohio. But the industry could expand rapidly if firms such as Texas Instruments, IBM, Westinghouse, General Electric, and General Motors bring their laboratory robot hardware and software into the industrial market. Today the estimated yearly value of U.S. manufactured robots is just $90 million. How small this is can be seen by the fact that it would take several billion dollars to replace just 1 percent of the U.S. blue collar workforce.

An important government resource for studying a large complex of automated manufacturing plants is the U.S. Air Force Integrated Computer-Aided Manufacture Program, ICAM. ICAM, which evolved in part from the now lapsed NASA Integrated Program for Aerospace Vehicle Design, is budgeted at $20 million per year through 1984 with substantial pieces of its overall program subcontracted to leading industrial and university laboratories. The ICAM funding is more than matched by the subcontractors' investments in robotics, considerably stimulating the U.S. automation research and development.

ICAM envisions a large integrated manufacturing complex composed of individual factories or CELLS whose input raw materials, manufacturing processes, and output products would proceed under central computer control. The output of each factory or CELL would become the "raw materials" for the next automated factory or CELL, until eventually the completed end product would be boxed and shipped from the complex.

ICAM plans to demonstrate an automated factory (or CELL) in 1985. But can the U.S. economy wait that long?

Robotics Abroad

Japan and Eastern Europe, especially East Germany, have had active factory automation programs for at least a decade.

According to one report, the Japanese conceive of their automation program as the "core of future industry." In 1977, the Japanese had somewhere between 30,000 and 50,000 robots, and this year's robot count is estimated to be near 70,000. (It should be noted, however, that many U.S. observers discount the Japanese robots in terms of the number of axes and the low-level tasks that are assigned to them.)

The Japanese government pays for a good part of the robotics program and has encouraged a national effort behind a projected unmanned factory under the rubric of what is called the National Big Project, or NBP. In addition, the Japanese are discussing a "mother machine" that rebuilds itself. The NBP project is similar to the ICAM program, although the ICAM is more carefully constructed in theory, but of course the NBP has the advantage of an ongoing automation of industry that leads the United States.

The East Germans, who lead the world in the manufacture of accurate machine tools, began their automation program in 1970 and have developed two separate automated machine tool systems. One of these, PRISMA, is directed toward automating planar and curved surface machining and the other, ROTA, automates rotational machining.

The kind of gearup necessary to prepare for the era of automated factories is part of the American tradition. At the end of World War II, U.S. scientists and mathematicians at the war-related research centers (most notably Jay Forrester, John von Neumann, and Norbert Weiner) turned their attention to the reindustrialization of the United States and the world.

MIT published a multivolume series of heretofore classified electronics work (*Microwave Electronics*), so that graduate students beginning their advanced engineering studies at this time were treated to a wealth of instruments and ideas—"servomechanisms," "feedback control," "analog computers," and, of course, the burgeoning digital computer—all pointed toward an early automation of manufacture with concomitant increases in the standards of living of the world population. And as the growth of the computer industry has since demonstrated, far from narrowing the job market, automation, like other advanced technology, will create a great net increase in jobs.

The United States has demonstrated what can be done with computers when there is sufficient capital investment. It's time to carry these advances in computation and communication directly into production by commercializing robotics.

—Michael Tobin

The MIRV Concept And the Neutron Bomb

by Dr. Friedwardt Winterberg

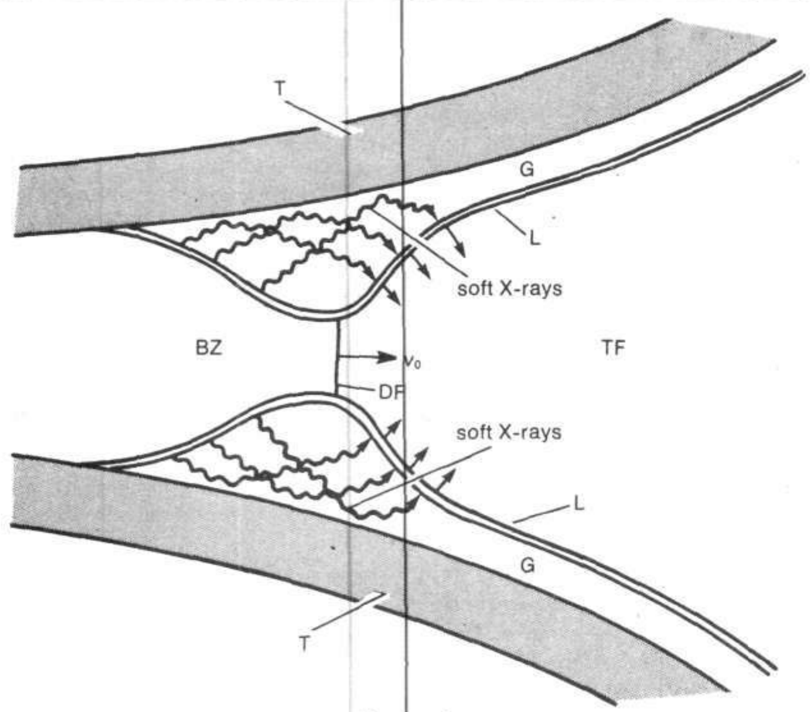


Figure 1
AUTOCATALYTIC DETONATION PRINCIPLE
In an autocatalytic thermonuclear detonation wave, soft X-rays travel through the gap G between the dense metal liner L and the outer tamp T, ahead of the thermonuclear burn zone BZ. TF is the thermonuclear fuel and DF is the detonation front, which moves with velocity v_0.

Some time ago I described the principle underlying the ignition of a fission-triggered thermonuclear explosive device (*Fusion,* Nov. 1979, p. 41). The purpose of that article was not to be sensational but, rather, to help demystify the alleged "secret" surrounding the hydrogen bomb as an example of ordinary textbook physics.

In this field there are secrets only for the layman, not the professional scientist. Secrecy is often imposed by a government to generate a false feeling of security by spreading the belief that it is in the possession of secret knowledge. I have never believed that it can serve any purpose to keep physics facts that can be obtained from any college textbook a "secret." I have never been exposed to any scientific "secrets" and reject any claims that there are such secrets known only to a few chosen people. The public should know the basic principles underlying these concepts without which a rational disarmament discussion is impossible.

There are two concepts that are at the focus of these disarmament discussions. One is the MIRV concept, and the other is the neutron bomb. Let us discuss both.

In the MIRV concept not only one but a whole cluster of thermonuclear bombs is put on top of an intercontinental rocket. This fact by itself suggests that for space-saving reasons the bombs have the shape of long, hexagonal rods. Each of these deadly pencil-like rods is equipped with its own inertial guidance system and small, solid-fuel rockets for trajectory control, enabling it to find its separate predetermined target. However, the special design of slender H-bombs makes a large thermonuclear yield possible only if the H-bomb employs the autocatalytic detonation principle.

Autocatalytic Detonation

I discussed this principle in the context of thermonuclear microexplosions some time ago (F. Winterberg, *Atomkernenergie,* 32:2, 1978, p. 85). In this concept, a precursor of soft X-rays is set free behind the thermonuclear detonation front and moves ahead of this front along a cylindrical channel in between the still unignited fuel and some outer tamp. This photon precursor precompresses the thermonuclear fuel by ablative implosion prior to its ignition in passing through the front of the detonation wave. The principle is explained in Figure 1, which is taken from my above-mentioned paper.

The energy that is set free inside a thermonuclear detonation wave propagating along a rodlike H-bomb is proportional to three factors: the mass M of the rod, its density ρ, and the rod radius r.

This dependence can be easily understood: Because the thermonuclear reaction rate is proportional to ρ^2, the energy set free in a rod of length l is proportional to $\rho^2 r^2 l \tau$, where $\tau \simeq r/v$ is the disassembly time, with v the radial thermal-expansion velocity. The yield is thus proportional to ρrM. For a fixed rod length l, M is proportional to ρr^2 and thus $\rho rM \propto \rho^{1/2}M^{3/2}$. If now the thermonuclear explosive is precompressed, for example to about 20 times its solid-state density, it follows from the $\rho^{1/2}$ dependence that for the same yield the amount of the explosive can be reduced by the factor $\sqrt{(20)} = 4.5$, and the radius of the rod by the factor $\sqrt{(4.5)} \simeq 2.2$. The principle of such an autocatalytic H-bomb is shown in Figure 2.

In the *Progressive* magazine (Nov. 1979) a similar H-bomb design was published, which, however, was deficient in one important respect. It ignored the need to focus the energy from the fission explosive onto the thermonuclear fuse by a prolate ellipsoid, wherein the atomic bomb and fuse are positioned in the two foci of the ellipsoid.

The Neutron Bomb

The neutron bomb is a small thermonuclear weapon. The ignition here, of course, is also accomplished by an exploding fission bomb positioned within a prolate ellipsoid, but the main goal of the neutron bomb is to release as much energy as possible in the form of neutrons. Since a neutron burst alone does not lead to a shock wave, a perfect neutron bomb would leave almost all physical structures undamaged. The reason for this is that neutrons are absorbed in matter only after traveling a relatively long distance. All living matter, however, is most sensitive to this kind of radiation, since in being finally absorbed by any nuclear reactions, the neutrons thereby release intense γ-radiation at their site of absorption.

Because of the requirement to release as much energy as possible in the form of neutrons, the usual ^6LiD bomb explosive is unsuitable for the neutron bomb since a thermonuclear detonation propagating in lithium deuteride requires all the neutrons set free for tritium breeding. A better neutron bomb explosive would be liquid deuterium-tritium (DT). Here, about 80 percent of the energy released goes into neutrons. But since DT is in the liquid state only at very low temperatures, it is unsuitable for a field weapon.

A possible combination, however, is a mixture of 1/3 ^6LiT with 2/3 ^7LiD. Here, first a D-T reaction takes place, burning one-third of the deuterium with one-third of the tritium, leading to just the right number of neutrons to breed from the 1/3 ^6Li—1/3 T, which then can burn with the remaining one-third of deuterium from the ^7LiD. The total neutron yield here, though, is less than 80 percent because one-third of the reaction energy of

$$n + {}^6Li \rightarrow T + {}^4He + 4.8 \text{ MeV},$$

that is, $1/3 \times 4.8$ MeV = 1.6 MeV, goes into charged fusion products, reducing the relative neutron yield from 80 percent down to 74.4 percent. In reality, though, the actual neutron yield is even smaller, because some of the neutrons that should breed tritium are lost from the assembly by diffusion.

These losses can be largely compensated for if one surrounds the assembly with a neutron-multiplying reflector. U-238, however, is unsuitable for this purpose since it has a large nonneutron fission yield and thus could substantially reduce the relative neutron yield. A substance better suited for this purpose is ^9Be, undergoing the reaction

$$^9Be + n \rightarrow {}^8Be + 2n - 1.666 \text{ MeV},$$

with ^8Be spontaneously decaying into two α-particles under the delivery of 0.096 MeV. The reaction is thus endothermic. Figure 3 shows the principle of such a neutron bomb.

In neither the MIRV nor the neutron bomb have I shown how the fission trigger is assembled into a supercritical state. This is done by special *conventional* high-explosive techniques, on which I shall report sometime in the future.

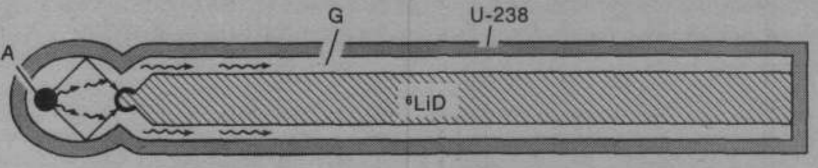


Figure 2
AUTOCATALYTIC H-BOMB PRINCIPLE
The atomic bomb A generates a thermonuclear detonation shock wave with a soft X-ray precursor that travels through the gap G between the uranium-238 and the lithium deuteride.

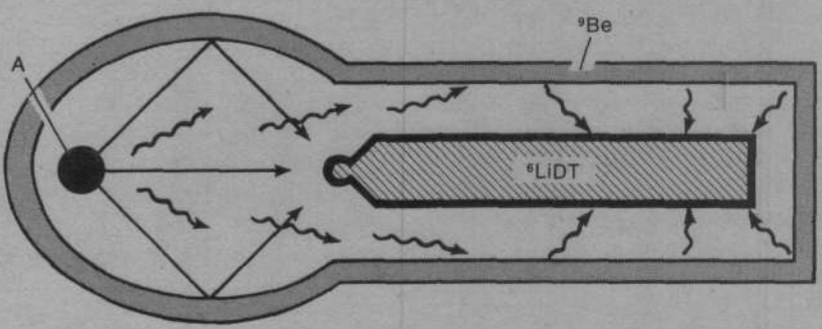
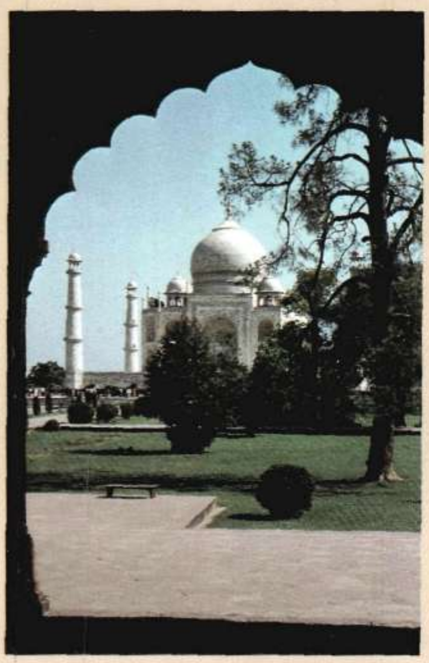


Figure 3
NEUTRON BOMB PRINCIPLE
In the neutron bomb, a neutron-multiplying reflector ^9Be surrounds the chamber in which the atomic bomb A ignites the mixture of lithium deuteride and lithium tritide.

Dr. Winterberg, professor of physics at the Desert Research Institute of the University of Nevada in Reno, is a pioneer in fusion research. In 1978 he received the Hermann Oberth gold medal for his work in thermonuclear propulsion.

The Great Reindustrialization Debate

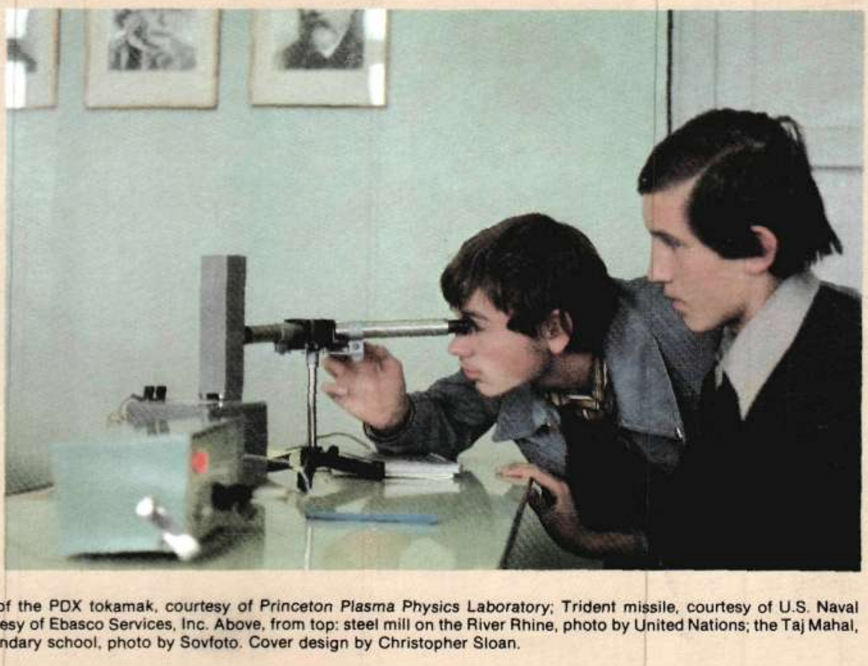


As the U.S. economy sinks farther *into the hole, worried government* officials, think tanks, and business experts have proposed a variety of plans for reindustrializing. In this special issue, *Fusion* reports on why these schemes won't work: The only permanent cure for the economy is investment in the frontier areas of technology—the high technology that will *increase* U.S. industrial productivity.

The keystone of the necessary R&D effort is fusion research. The readiness of the U.S. fusion program to move into the engineering phase is amply documented in the draft report of the Department of Energy's Fusion Review Panel, the Buchsbaum Report, reprinted here in full.

INDIA:
PARADIGM FOR DEVELOPMENT

The development of the Third World is essential for a successful policy of reindustrialization. The paradigm for this is India, and in this issue Fusion Energy Foundation research director Uwe Parpart discusses his recent tour of India and the prospects for the 40-year program to industrialize India proposed by the FEF. Included in this section is one of the first commentaries on the 40-year plan, an article by Colonel R. Rama Rao on developing India's water resources.



MEETING THE
SOVIET CHALLENGE IN EDUCATION

The most often-mentioned motivation for the reindustrialization schemes is some version of "the Soviet threat." The Soviet science curriculum is far more rigorous than ours, as we spell out in detail. Yet, the Soviet curriculum is flawed and is not an adequate model for the United States. To develop a generation of youth capable of running a fusion economy means a return to the Platonic epistemological tradition that produced modern science.

Front cover, from left: technician working on the inside of the PDX tokamak, courtesy of *Princeton Plasma Physics Laboratory*; Trident missile, courtesy of U.S. Naval Photographic Center; nuclear plant construction site, courtesy of Ebasco Services, Inc. Above, from top: steel mill on the River Rhine, photo by United Nations; the Taj Mahal, photo by Uwe Parpart; physics laboratory in a Soviet secondary school, photo by Sovfoto. Cover design by Christopher Sloan.