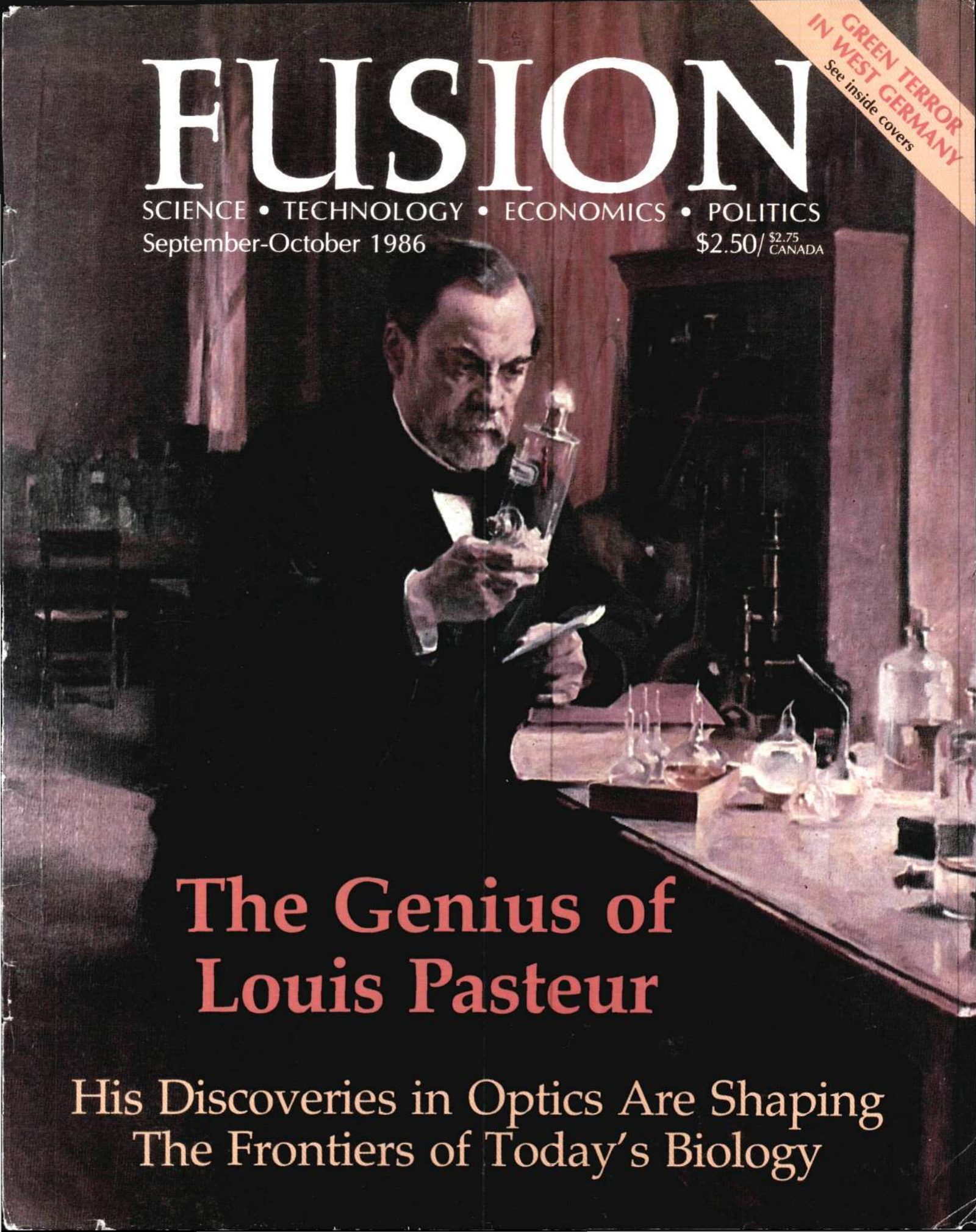


FUSION

SCIENCE • TECHNOLOGY • ECONOMICS • POLITICS

September-October 1986

$2.50/ $2.75 CANADA

GREEN TERROR IN WEST GERMANY

See inside covers

The Genius of Louis Pasteur

His Discoveries in Optics Are Shaping The Frontiers of Today's Biology

Green Terrorists at War

Hanover, June 10

Above: Police form a wall between bottle-wielding "punkers" and a pronuclear election rally.

Right: Two-hundred people braved a line of punkers to attend a campaign meeting, addressed by Renate Muller (standing), who headed the Lower Saxony election slate.

The terror tactics of the Communists and Greens after the Soviet nuclear accident at Chernobyl in late April remind many West Germans of the way the Nazis came to power in the 1920s and 1930s. This fascist violence is coordinated and funded by the Soviets. The Green Party, the Social Democratic Party youth group, and the Communist Party in West Germany are officially supporting the violence, claiming that any kinds of protest against nuclear plants "are not criminal acts." The official Green Party platform calls for bringing down the Bonn government and initiating a Red-Green coalition that would shut down the nuclear industry, pull West Germany out of NATO, and stop collaboration with the United States on the SDI.

Soon after the new Patriots for Germany party began its pronuclear and pro-American election campaign for the June 15 state elections in Lower Saxony, which borders on East Germany, the Greens and Communists directed their violence against the Patriots. They defaced election posters, overturned literature tables, blew whistles to drown out speakers, threw stones at campaign sound trucks, slashed tires, physically attacked campaign organizers (especially women), and scrawled death threats and swastikas near the homes of the candidates.

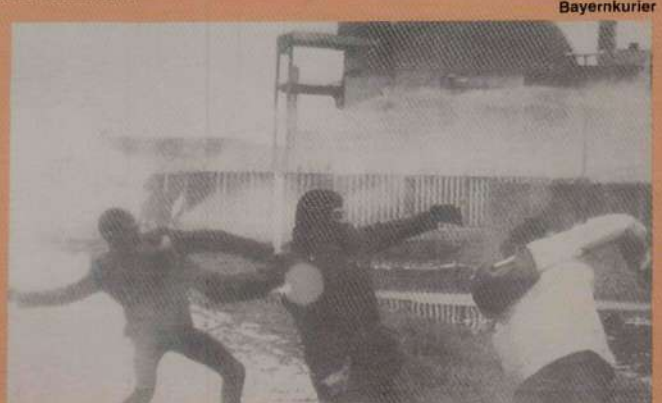
These photos of the terrorist actions were provided by the Patriots.

(Continued on inside back cover)

Left: Punkers line up outside a restaurant where there was a campaign meeting. They taunted and harassed those who went inside. The photo was taken from inside the restaurant.

Below left: Campaign workers pose in front of a nuclear plant before holding an election rally there. Right: Masked terrorists assault a nuclear plant.

Bayernkurier



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

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On the cover: Portrait of Pasteur in his laboratory, by M. Edelfelt, in the Pasteur Museum of the Pasteur Institute in Paris.

Editorial

The Greens and West Germany's Future

We Americans have suffered the systematic and deliberate destruction of our nuclear industry. We have been the victims of a cynical environmentalist movement, which mocks the starvation of the millions who would have benefited from a flourishing U.S. industry, fueled by cheap and plentiful nuclear energy. As a result, the United States has been reduced to a debtor nation that must import goods, its industry strangled by regulations against pollution, regulations supposedly conserving energy, and the like.

The environmentalist movement is best understood as a cult, worshiping a pagan "Mother Nature" and rejecting the traditional values of Judeo-Christian culture that are exemplified by the verse from Genesis: "Be fruitful and multiply, and dominate the earth and subdue it." The character of environmentalism is demonstrated by the extent to which it overlaps the drug culture, the gay rights movement, and terrorist groups.

Warfare Against the State

Nonetheless, disgusting as the environmentalist movement here has been, nothing in the experience of Americans prepares us to understand the situation today in Europe, and particularly in West Germany. The Soviet nuclear accident at Chernobyl has provided a "Green" umbrella in West Germany for a range of so-called protest actions that can only be described as warfare against the state. There, the "Green" movement can be understood only as a cover for Soviet low-intensity military operations, whose aim is to terrorize the Federal Republic into leaving the Western Alliance and becoming neutral—and to unify Germany by force.

Understanding the scale of what is actually going on in West Germany is made more difficult by the lack of coverage of this antinuclear violence in the U.S. media. From demonstrations against nuclear plants and against police, to acts of sabotage against power plants, the violence has now escalated to assassination. A leader of the nuclear industry, Karl-Heinz Beckurts, was assassinated by the detonation of a remote-controlled bomb July 9. Beckurts, an executive at Siemens, was also an important figure for German participation in the U.S. Strategic Defense Initiative. German intelligence experts believe his murder was the coordinated work of Soviet-directed professionals. Similar conclusions are drawn from the destruction of high tension electrical power lines: This is the work of professionals.

Unlike antinuclear demonstrations in the past, the West German protest actions taken since Chernobyl have the character of military deployments aimed at creating conditions of civil war. At the nuclear reprocessing site in Wackersdorf, Bavaria, for example, on the weekend of May 17-18, among the thousands of demonstrators were a hard-core group of about 1,200 trained and armed provocateurs. Their attacks on the police were carried out in a military fashion with intent to kill. They used slingshots, steel bolts and splinters, stones, firecrackers, and Molotov cocktails against the police, injuring 183 of them. The police forces were caught off guard by the violence and were not numerous enough to contain it. Only the massive use of tear gas dropped from police helicopters prevented more injuries—and even deaths—from occurring.

While demonstrators paraded near the site carrying placards that read "Nuclear power means war to the people," small groups of armed protesters on motorbikes conducted acts of sabotage in the area, from ambushing vans of policemen and burning police vehicles, to blocking railroad tracks, smashing police station windows, decoupling and demolishing a freight train, and knocking out electrical towers and telephone lines. The protesters were masked and were in radio communication with one another, to report on their offensive and the police movements.

For many West Germans, the present climate of terror is only too vivid a reminder of the tactics successfully used by the Nazis in the 1920s and 1930s to come to power. Alfred Dregger, the federal parliamentary faction chief of the Christian Democratic Union and the Christian Social Union parties, commented after Wackersdorf: "For the first time after the Hitler dictatorship, the threat is not coming from the outside, but from within." Under Red-Green alliances, he said, democratic rule would be abolished, and "the right of the fist would take over more and more, as it did under the rule of the brown power."

Given such terror tactics, how does one stop the Greens and their Soviet backers? For the Social Democratic Party of Willy Brandt and its friends in the U.S. State Department, this is not a problem; they have made it clear that they do not intend to stop either the Greens or the Soviets. They want a Red-Green coalition, and they want U.S. troops out of West Germany!

What is at stake is not merely the nuclear industry. At issue is the fate of Western civilization. Those with longer memories—and more morality—know that the way to fight fascism is not through appeasement.

Letters

Put *Fusion* in Every School!

To the Editor:

The Konawaena High and Intermediate School students and staff are definitely very appreciative of your generous contribution of 180 copies to our aerospace classes and 20 subscriptions for our library and teacher staff rooms.

The magazines possess added meaning because they were donated in the memory of Lt. Col. Ellison S. Onizuka. Ellison Onizuka holds a very special place in each of our hearts. He was the pride of Kona. He was and still is a symbol of hope. He showed Kona students, by example, what hard work and dedication could achieve.

Ellison Onizuka is missed very much. Thank you for helping to keep his memory alive. Thank you for your support of a school that Ellison Onizuka cared about very much. Thank you for helping us in our pursuit for educational excellence.

Claire L. Yoshida, Vice Principal
Konawaena High
& Intermediate School
Kealakekua, Hawaii

The Editor Replies

We are pleased to report that supporters of the Fusion Energy Foundation have now donated more than 12,000 gift subscriptions to high schools and libraries around the country, in memory of the Challenger crew. Contributions dedicated to bulk gift subscriptions are welcome and are tax deductible. Contributors may select the recipient schools, or leave the selection to us.

Librarians, teachers, and principals interested in receiving gift subscriptions should contact the foundation.

Correction

There was a mix-up of meters and mirrors in the article "Air Force Demonstrates Phased-Array Laser" (July-August, p. 25), for which we apologize. The text should have read: Mirrors with diameters in the range of 10 to 100 meters are extremely difficult to manufacture and deploy. . . . The range of a laser fighting mirror configuration is directly proportional to its effective diameter. Thus, for example 100 1-meter mirrors in a phased array could attain the same effective range as 1 100-meter-diameter mirror.

Viewpoint

Magnetic Resonance Imaging: Lessons in Several Directions


Stuart K. Lewis

by James W. Frazer, Ph.D.

The first proton magnetic resonance representations of living human cross-section were formed at Brooklyn, New York, July 17, 1977. The event was reported in the first issue of *Fusion* magazine, July 1977, and in many other scientific journals. Recently, the story of this achievement was the subject of the book *A Machine Called Indomitable*.

Only five years earlier, in 1972, a learned panel of government-sponsored peers had called the principle of imaging using proton magnetic resonance and radio frequency fields a "physical impossibility." Had Dr. Ray Damadian, the originator of the concept, been less persistent or Dr. Paul Lauterbur been less imaginative, the whole concept could have ended right there. Fortunately, Damadian was able to build a practical machine. Within months of publication of this momentous accomplishment, nearly every major manufacturer of health care equipment had research and development teams developing manufacturers' models of this new technology. Ray Damadian's persistence very nearly got buried in the thunderous competition.

Many radiologists sturdily refused to be involved in research with this dramatic new imaging modality. But now many traditionally X-ray-imaging companies are producing Magnetic Resonance Imaging instruments (MRI). More radiologists are familiarizing themselves with the machine's clinical potential now that the Food and Drug Administration has allowed institutions to charge for clinical use. Use is increasing as it becomes more familiar.

The circumstances that led to the continuing difficulties with the introduction of this new technology are somewhat instructive for those who think basic science should be a self-supporting entity. The originator of the concept, Dr. Damadian, and the originator of much of the computer representation, Dr. Lauterbur, have not really profited much from the products of their labor when one considers their time investment of more than 17 years each (more that 34 man-years) of private investment for research and development. Very little federal money is involved, except health and safety aspects and efficacy studies, which did not redound to the benefit of the originators. Major medical centers are just beginning to tap the potential of the instrumentation, and these are using suppliers other that those of the originators.

James Frazer is a pioneer in many areas of biophysics and biochemistry and their applications to curing disease. He works at the University of Texas Health Science System, M.D. Anderson Hospital and Tumor Institute, Houston, Texas.

Suspicion of Electronic 'Gadgetry'

Suspicion of electronic "gadgetry" has been prevalent in U.S. medicine for a long time, partly due to the number of quack products sold in the early 20th century that had little to do with curing human ills, but that capitalized on prevalent public attitudes toward new electrification networks. Great enthusiasm for various forms of diathermy during the 1920s and 1930s justified some of the suspicion of such instruments, though they have found a use, on a vastly reduced scale, in producing palliative warmth at depth for treatment of bone and joint pain. The introduction of antibiotics, first the sulfa drugs in the 1930s, then penicillin in the early 1940s, proved much more efficacious in the treatment of infectious disease.

As recently as the 1940s, electrocardiograms were still obtained with a string galvanometer with optical recording. The whole instrument was on a wood table and operated by an automobile battery. Clinical correlation between waveforms and findings at autopsy were still being performed.

Just after World War II, the electronics based on World War II developments became available to persons graduating from the most massive educational effort in world history. The recipients of the "GI Bill," which kept many returning servicemen out of the job market for three to six years, formed one of the best educated work forces the world has ever seen. Many of these people had also benefited from service training in almost every imaginable aspect of physical science, but with a heavy emphasis on electronics. The core curricula of many electronics courses for engineers or technicians still feature some principles taught in those early service courses.

Into this educated stage setting were injected the new mechanisms for research support—the Atomic Energy Commission and Office of Naval Research at first—then the National Institutes of Health, and a virtual explosion resulted, building on scientific developments of the years before World War II. One of these developments was phase detection of electronic signals, which led to maser, later laser development, and also to commercial introduction of the magnetic resonance spectroscopies. These later instruments saw almost immediate use in chemistry laboratories in industry, so that industrial development money was employed yielding excellent computer-controlled pulsed, Fourier transform instruments by the mid-1970s. These instruments form an intersection of developments in solid state electronics: computers; theory of molecular field interactions; superconducting materials used to generate

strong, stable, homogenous magnetic fields; and the development of highly purified structural metals and fluoroplastics, most of those developments occurring within the past 30 years.

Less visible than these physical developments, but no less important, were the developments in theory of electromagnetic waves and scattering phenomena stemming from work in inverse scattering by Bojarski at the National Bureau of Standards, but continued to fruition by Weston and Kreuger at the University of Kansas, from which came the mathematical developments allowing field imaging. This area of intellectual pursuit is very likely to lead to yet another type of medical imaging that will add to the chemical information obtainable with the resonance spectroscopies. The ability to focus radio frequency fields deep within biological structures also opens up a plethora of treatment possibilities that are largely unexplored.

Federal Help

One of the circumstances that helped the introduction of magnetic resonance spectroscopy, albeit indirectly and unintentionally, was the institution of a fairly large federal program in 1968 to investigate the biological effects of radio frequencies from 20-70 hertz (extra-low frequencies or ELF) through 300 megahertz and up to 300 gigahertz (top of the millimeter wave band). A great many federal agencies participated in this program, including the Office of Telecommunication Policy in the Executive Office as coordinator, Defense Advanced Research Project Agency, Department of State, Department of Defense (all the services), Federal Aviation Administration, Bureau of Radiological Health, and later the Food and Drug Administration, Environmental Protection Agency, National Institute of Environmental Safety and Health, Occupational Safety and Health Administration, National Institute for Occupational Safety and Health, National Aeronautics and Space Administration, and the Department of Commerce with the National Bureau of Standards.

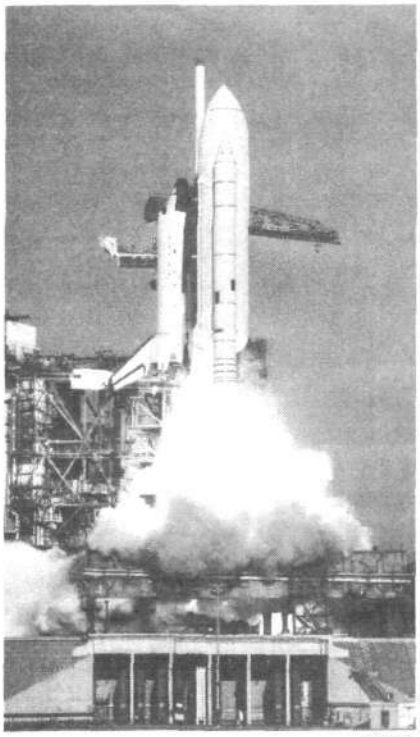
One of the reasons for the large-scale investigation was the intentional aiming of microwave beams at the U.S. embassy in Moscow, with fairly widespread fear of health consequences and effects on mental abilities. One result of the investigation was to show there were health peculiarities at the embassy, but they were more closely associated with intestinal protozoa than with the microwave beams. Some of the results of that program were in frequency ranges and field strengths directly appropriate to Magnetic Resonance Imaging, so that part of the health-effects work was already done when the first images were produced. Alas, each agency must make its own pronouncements, so some of the work was repeated again.

The investigation of the bioeffects of electromagnetic radiation had a few other outputs, again unintentional, but useful. The first truly systematic modeling of the interaction of the electromagnetic fields with man was performed under this program, involving several federal agencies and universities. Several improvements were made in network analysis, primarily at the National Bureau of Standards, but also at some universities. There was quite a development in NOR (nuclear Overhauser effect—direct magnetic coupling between nuclei) or minimal field-perturbing temperature measurement, and there came an increased appreciation of precise mechanisms by which fields could interact with molecular systems. Some of the important work on mathematical modeling and inverse scattering was supported by this program.

As it turns out, some of the same individuals in this federal program became involved with hyperthermal treatment of tumors, analysis of the cardiovascular system, and other offshoots of this program, including magnetic resonance imaging, though the invention and initiation of the latter were not supported in any way by the federal program.

Continued on page 16

News Briefs



NASA

Without the Shuttle, the U.S. space program is grounded.

THE U.S. NEEDS THE SHUTTLE FLYING AGAIN!

As we go to press in July, President Reagan has not yet made a decision on the fourth Shuttle orbiter, the Shuttle is on standby until the beginning of 1988, and the commitment to put a manned space station in orbit by 1994 is in jeopardy because of budget cuts.

Fusion urges readers to support the U.S. space effort by sending the postcard-insert in this issue to the President and writing your senators and congressman. We also recommend that you read the full report of the National Commission on Space, *Pioneering the Space Frontier*, featured in the article on page 32.

U.S. ARCTIC TESTS DEMONSTRATE LASER COMMUNICATION WITH SUBS

The U.S. Navy has demonstrated the use of blue-green lasers for rapid and secure communications with submarines operating beneath the Arctic ice pack. The Navy test, conducted by Lockheed with lasers carried on aircraft, used a frequency-doubled yttrium-aluminum-garnet glass laser with a .53 micron output carried on a P-3C aircraft. The test was overseen by Lockheed and demonstrated that the laser light could penetrate snow and ice to communicate with the submarine below. The high accuracy of the detector permits the system to operate not only at night but even in the daytime when sunlight creates large background noise.

NEW MISSILE DETECTOR DEVELOPED THAT 'SEES' IN UV WAVELENGTH

In order to kill missiles, one must see them, and researchers at the University of California at Berkeley have succeeded in developing a new detector that will prove accurate for "seeing" radiation emitted by missiles in the ultraviolet wavelength (UV). Working under contracts for both the U.S. Air Force and NASA, the Berkeley scientists are building UV detectors with up to 1 million detection cells (1,000 × 1,000 pixels), that can record up to 1 million UV photons per second. Originally designed for making astronomical observations of faint stars and distant galaxies, the detector is an ideal method of finding missiles during their boost phase, when they have long rocket plumes that emit radiation, chiefly in the infrared wavelength region. The large infrared output makes it easy to detect, but difficult to track and point at accurately. The smaller UV signature of the missile, on the other hand, makes an ideal locator for precision tracking and pointing.

Jim Duree

AIDS has no civil rights: Los Angeles residents sign the PANIC petition to put the AIDS initiative on the ballot.

CALIFORNIA AIDS INITIATIVE CERTIFIED FOR NOVEMBER 3 BALLOT

A citizens' initiative mandating the application of traditional public health measures to the disease AIDS was officially certified for the Nov. 3 California ballot on June 25, after more than one-half million petition signatures for the initiative were validated by the state. The initiative mandates that AIDS be "placed and maintained by the director of the Department of Health Services on the list of reportable diseases and conditions mandated by Health and Safety Code Section 3123." The initiative is now the hottest political item in California since Proposition 13, and has widespread support from those who are outraged that a deadly disease is being treated as a question of civil rights rather than public health. The Prevent AIDS Now Initiative Committee (PANIC) was headed up by Khushro Ghandhi, a political associate of Lyndon H. LaRouche, Jr. "It should be obvious that the only reason for the unusual way in which AIDS has been handled by public health officials is pure, naked political pressure," Ghandhi said.

SDI OPPONENTS PRESENT PETITION TO U.S. CONGRESS

A group of scientists currently or formerly at government and industrial laboratories held a press conference in Washington, D.C., June 19 to present to Congress a petition with 1,600 signatures stating that realization of the SDI "dream is not feasible in the foreseeable future." Present to receive the petitions were Senators Daniel Evans and Bennett Johnston. Scientists supporting the SDI were quick to note that the media coverage of the event was larger than its importance. "After more than a year of vigorously soliciting scientists and engineers to oppose SDI, opponents have only been able to gain the signatures of one-half of 1 percent—including today's 1,600 names" of the more than a million U.S. scientists and engineers working in technical fields, noted Dr. Lowell Wood, a leading researcher in the SDI program at Lawrence Livermore National Laboratory. Wood said that in the national labs alone, there are about 30,000 scientists and technicians employed, including some 3,500 at Livermore. Dr. Edward Teller added, "I doubt there are many causes for which you could not get 1,600 signatures" from among the pool of those tens of thousands solicited.

Stuart Lewis

The anti-SDI line-up at the June 19 press conference: (from left) Daniel Fisher, AT&T Bell Labs; Sen. Daniel Evans; Robert Wilson, AT&T Bell Labs; Sen. Bennett Johnston; John Backus, IBM; J. Carson Mark, formerly from Los Alamos National Laboratory.

NATIONAL BUREAU OF STANDARD NIXES NEWMAN'S ENERGY MACHINE

Mississippi inventor Joseph Newman has long argued that he had devised a machine that produced more power than it used, and he sued the U.S. Patent and Trademark Office in 1984 when it did not grant him a patent because it said that his device did not work. As part of that suit, the National Bureau of Standards tested Newman's machine this spring, concluding that the device's efficiency ranged from 27 to 67 percent, nowhere near the claimed 100 percent or more. "Our results are clear and unequivocal," the Bureau said.

CFR JOURNAL CONFIRMS 'NUCLEAR WINTER' IS A HOAX

After four years of propaganda from the nuclear freeze movement and the Soviets that full-scale nuclear war would produce a "nuclear winter" and send the world into a new Ice Age, two climate scientists have substantiated what the Fusion Energy Foundation concluded in 1982: The nuclear winter scenario is a scientific hoax. Writing in the summer 1986 issue of *Foreign Affairs*, the journal of the liberal N.Y. Council on Foreign Relations, Starley L. Thompson and Stephen H. Schneider of the National Center for Atmospheric Research in Boulder, Colo., take apart the initial studies used to back up the nuclear winter scenario. "We intend to show," they write, "that on scientific grounds the global apocalyptic conclusions of the initial nuclear winter hypothesis can now be relegated to a vanishingly low level of probability. Thus the argument that nuclear winter provides the sole basis for drastic strategic arms reductions has been greatly weakened."

LOUSEWORT LAURELS TO MIT AND SMITHSONIAN INSTITUTION

This issue's Lousewort Laurels award goes to the Massachusetts Institute of Technology and the Smithsonian Institution for their joint $74,000 project to design a human-powered aircraft to complete the mythological voyage of Daedalus from Crete to mainland Greece. The project is billed as a way of "making people think about the advances that have been made in aerodynamics and the connections between science and art," and will require a well-trained athlete-pilot to pedal nonstop for the equivalent of four hours at 25 miles per hour. "It's the idea of man working with the elements and nature to accomplish what had previously been only in his imagination," said the director of the project. Perhaps next the project will apply advanced technology to the myth of Sisyphus.

Chernobyl and the 'Big Lie' About U.S. Nuclear Safety

by Marjorie Mazel Hecht

As U.S. nuclear experts emphasized during the hysteria that followed the Soviet nuclear accident, a Chernobyl disaster could not happen in a U.S. nuclear plant, because the Chernobyl reactor could not be licensed to operate here. It is an archaic design rejected for commercial development in the West in the early 1950s because of its inherent safety problems. (See accompanying interviews.)

Although updated by the Soviets, the design goes back to the world's first reactor, the "Chicago Pile" created by the Manhattan Project in 1942. It is a graphite-moderated water-cooled reactor that has a dual purpose: production of weapons plutonium, and production of electrical power. In a word, as one safety expert at the Nuclear Regulatory Commission put it, the safety system for this dual-purpose design is a "nightmare."

The most significant characteristic of the Chernobyl-type reactor is that it has no containment structure of the sort that every Western light water reactor has. Yet, despite the fact that the Chernobyl reactor and its safety systems were known to be different from any reactor used commercially in the West, within three weeks, the antinuclear movement had launched the "Big Lie" campaign that Chernobyl and U.S. plants had similar safety systems, and therefore U.S. plants should be shut down.

'Big Lie' Surfaced in N.Y. Times

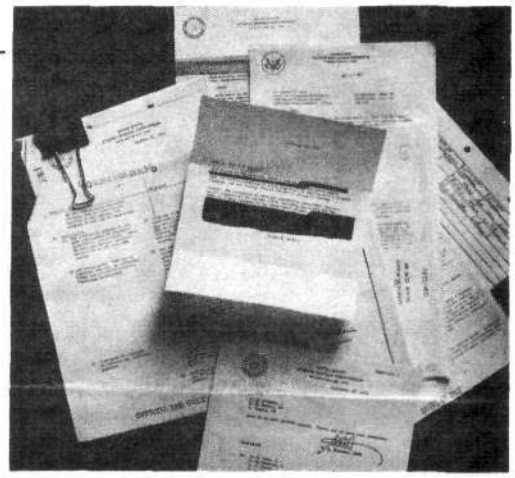
The "Big Lie" first surfaced in the *New York Times*. Stuart Diamond, a *New York Times* reporter who has been an antinuclear activist since the 1970s, alleged in a front-page May 19 article that "new" information about Soviet plant designs was discovered showing that the Chernobyl plant had safety systems and a containment structure like U.S. plants. The headline on Diamond's article was "Chernobyl Design Found to Include New Safety Plans: U.S. Experts Say Construction Is Similar in Some Ways to Plants in America."

Most incredible, Diamond took the words of respected U.S. nuclear experts and twisted them to imply that they supported his "Big Lie." (Long-time *Fusion* readers may remember Stuart Diamond from the days after Three Mile Island when he took the antinuclear side in debates on U.S. college campuses with former Fusion Energy Foundation executive director Morris Levitt.)

The "experts" Diamond quoted by name, at least those that this writer spoke to personally, were very angry that Diamond had twisted their words to convey his own meaning, and three of them sent a letter to the editor of the *New York Times* in protest. "We would like to make it clear that we are not among the experts who have changed our minds about the structure of the Chernobyl reactor," said Dr. Richard Wilson, professor of physics at Harvard University and chairman of a Nuclear Regulatory Commission sponsored study on nuclear accidents. "We have had accurate information all the time and have been attempting to square it with the public and the press. The Chernobyl reactor has no containment in the sense that we and other safety analysts in the United States use the word."

Dr. Ed Zebroski, head of the Nuclear Safety Analysis Center and chief nuclear scientist at the Electric Power Research Institute, said bluntly that his comments to Diamond were distorted with "clearly malicious intent."

Why would Diamond write such a lying article? Wilson put it this way: "Some Russians want to attack the United States economically. It would be an irony if unreasonable fear caused us to cripple our nuclear electric capability as a result of this Russian accident, which has done us no harm and which would not occur here."



IN CASE YOU THINK THE RUSSIANS ARE THE ONLY ONES COVERING UP NUCLEAR DANGERS, JUST READ THESE MEMOS.

Public Citizen's full-page ad appeared in the New York Times *May 19, the same day Stuart Diamond's front-page article made the same lying charges.*

Soviet Nuclear Safety

That the Chernobyl reactor has no overall containment structure was a fact known before the accident and was still a fact 25 days later when Diamond wrote his article, despite his attempt to convince his readers that "experts" had found a containment structure after they "translated from Russian" more of the technical specifications.

It is true that the Soviets "Westernized" their safety procedures in the late 1970s, but U.S. nuclear experts familiar with the Soviet nuclear program hold that the Soviets are willing to take more risks than the United States. For example, Gordon Hurlbert, former president of Westinghouse Power Systems, who had visited Soviet nuclear installations in July 1983, described a three-level safety system at the Chernobyl plant. However, he noted, the system was not up to U.S. standards and could not be licensed here.

Hurlbert commented in an interview May 20 that the Chernobyl plant was not designed, as American plants are, to withstand an explosion, just a steam break, and that it had no containment. The fabled "containment building" that Diamond described in his *New York Times* article is actually

just a containment structure around the steam collectors and headers, not around the entire reactor. (This is like putting the hood of your car over the radiator part only.)

The Soviets went with this design in the early 1970s because it was easier for them than mass producing the more technologically sophisticated light water reactors used in the West. In particular, their scaled-up graphite reactor avoided the problem of producing large pressure vessels. In addition, of course, the graphite-moderated reactor can produce weapons-grade plutonium, a fact about which the Soviets have remained silent.

The Soviets put their first two 1,000-megawatt graphite reactors at a site near Leningrad in 1973 and 1975, and by 1982, they built eight more, which produced at the time 64.5 percent of all electric power produced by nuclear plants in the Soviet Union. Today, there are 17 graphite reactors, known as RBMK-1000, and the Soviets have plans for a 1,500 megawatt version.

From a safety standpoint, the Chernobyl reactor is a "nightmarish problem," according to Robert Bernaro, director of boiling water reactor licensing at the Nuclear Regulatory Commission. The engineering difficulties are inherent in the use of the graphite as a moderator, among other things. U.S. reactors have what is called a negative coefficient, which means that when the coolant temperature goes up, the reactor shuts down. In the graphite reactor, if the coolant temperature goes up, the reactivity goes up, which requires the Soviets to have a variety of special emergency measures to ensure that the graphite does not ignite.

Bernaro, who was also quoted by Diamond, commented on the question of safety: "I'm unwilling to hinge the acceptability or unacceptability of U.S. reactors on what the Russians do or do not do. If we can learn something from what the Russians have done or have not done, fine. . . . But in the meanwhile, I think that our primary attention ought to be on our own reactors."

Antinuclear Advertising

That the *New York Times*'s Diamond crafted his article solely to make the antinuclear case is amply demonstrated by the accompanying full-page ad

Continued on page 60

WHAT THE EXPERTS SAY

An Interview with Dr. Joseph M. Hendrie

Joseph M. Hendrie, former chairman of the U.S. Nuclear Regulatory Commission, is now a consulting engineer. He served on the NRC from 1977 through mid-1981. He was interviewed May 5.

Question: How would you assess the state of U.S. nuclear safety, compared to Soviet safety systems?

The U.S. water reactors are simply incapable of producing the sort of gross release that has occurred in Russia. We don't have the flammables in core that would provide the kind of driving force they had there in the fire. Our systems are engineered with more extensive safety provisions and we then encapsulate the whole reactor system in a very strong and tight containment structure.

Another point is that after Three Mile Island we made a very extensive reassessment of the safety of U.S. plants from all kinds of standpoints and all kinds of accidents and found it appropriate to upgrade a number of areas. We have concentrated attention on operator training and expertise and on a drive to achieve real excellence in operation at all U.S. plants. This is reflected in the industry efforts as well as in the regulatory incentives.

Furthermore, we undertook after Three Mile Island, a very extensive upgrading of the ability both on-site and off-site to take emergency measures in the event of accidents. I think those provisions are particularly notable against the background of the Russian accident.

Question: Most of the material written in the 1970s on the Soviet safety question indicates that their attitude toward safety is very different from that of the United States. They are very scornful of the Americans for spending so much money on what they consider unnecessarily redundant safety systems.

I think that may have been the attitude in some quarters earlier on. My impression is that in the last five, six, or seven years there has been a move in the Soviet Union toward safety standards and arrays of safety systems in the plants more like the Western standards. Those are reflected, for instance, in the designs of the new PWR [pressurized water reactor] line, 1,000-megawatt line, which does have emergency core cooling systems similar to U.S. designs and does have containment. Or at least the outline drawings I've seen for what they were regarding as their standard 1,000-megawatt PWR did have a containment that looked very much like a standard U.S. reinforced concrete prestressed containment. So I think there's been a move in the Soviet Union in the last few years for reactor safety standards more nearly like those in the Western world.

But, of course, these graphite machines are in many ways a design and reactor concept from an earlier time. I think they have a number of features about them which are not desirable from a safety standpoint.

Question: It's curious, given this, that the Soviets claimed in some of their publications that the graphite reactor was actually safer than the PWR.

I think in part that grew out of a concern on the part of the Soviets that was really one of the bases for the effort they put into the graphite machines: it was a long time before the Soviets were confident about their ability to fabricate large pressure vessels of the necessary quality for a large reactor. That's really a central reason why they went into that pressure tube design—to avoid having to fabricate very large size reactor vessels.

Remember that the 440-megawatt PWR, which has a substantially smaller pressure vessel, and which has been

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An Interview with Dr. Richard Wilson

Richard Wilson is Malinckrodt Professor of Physics at Harvard University. He chaired the Nuclear Regulatory Commission-sponsored study group of the American Physical Society on "Radiological Consequences of Severe Nuclear Accidents," which released a report in February 1985. He was interviewed May 6.

Question: What do you see as the major differences between the U.S. nuclear safety system and the Soviet approach to safety?

There are two things one should comment on. Firstly, a crucial thing is the different type of reactor the Soviets have. They have a pressure tube reactor with 1,100 or so independent pressure tubes inside a big 5,000-or-so-ton charcoal matrix. They regarded that as fairly good from the point of view of safety, becuase they can't get the whole thing out of control at one time. However, their pressure tubes have a very large amount of zirconium on them, and they have a very large amount of graphite. Now, if they get out of control, and if they are starved of coolant, then they get too two very important exothermic chemical reactions that are worse than any we get in our plants by quite a bit.

First is the zirconium-water reaction, meaning hydrogen and zirconium oxide. This also happened with us at Three Mile Island, but Chernobyl has more than five times as much. The second reaction is the uranium oxide and carbon reaction, meaning uranium-carbon, carbon monoxide, which is also exothermic. So both of those would heat the thing up and then the hydrogen gas and carbon monoxide gas would put pressure that might explode further up in the system. Then, having done that, this would break open the individual fuel channels, with about 14 pounds per square inch of pressure. That would very quickly blow up the roof of the building.

Something did blow up the roof of the building, so you know that something like this must have happened at one o'clock in the morning on Saturday. That probably could not have happened, according to very rough calculations, with one fuel channel alone going, and that is one of the things the Russians must have felt gave them safety. About 10 of these fuel channels have to go; the hydrogen/carbon monoxide from 10 fuel channels would be enough to cause the roof to blow, by my rough calculations. They presumably thought it was very unlikely that you would get that at any one time. I suspect there was some operator error allowing that to happen.

The main difference here is that we have the big pressure vessel that contains the hydrogen. At one time our pressure vessels were heavily criticized; the question was, would the pressure vessel fail catastrophically. The people who 15 years ago were arguing that it could—like Sir Alan Cottrell, formerly of the Department of Energy of England and now a Cambridge professor—are now arguing that it can't, having seen the new information on vessel tests. . . .

But the second thing that we have, surrounding the whole reactor vessel, is a containment vessel, which will handle 200 pounds pressure per square inch. It is sufficiently large, unlike the 14 pounds per square inch talked about in the Russian reactor, a huge volume, so that the pressure [from the chemical reaction] will already be reduced and diluted from the volume. That can hopefully contain everything. And if a fire begins, you would soon exhaust all the oxygen so that it would self-extinguish.

The crucial thing about our reactors then, is will that containment vessel hold in an accident, and for how long. The "how long" gives you time to do all sorts of things—for example, finding a way of boiling water inside to cool things down, to reduce the pressure, and to get some standard things going. The worst moment, according to all the things we calculate, is if you have a meltdown of the reactor and it melts through the reactor vessel at the time that it's still at high pressure. You get all this molten fuel, 400 tons of it, and some molten iron and whatnot, all dumped into the containment vessel at the same time. And that is much more pressure than the 200 pounds per square inch; we're talking about several hundred pounds. It will heat up the air very rapidly, and the question is how high.

Fortunately, we don't have as many energy sources as the Russians do. We don't have the uranium-carbon reaction and not as much zirconium. The maximum we think that could possibly go is about 60 or 70 pounds per square inch, and our containment vessels will hold 150 to 200 pounds per square inch. That means that at the critical moment—when all the fuel is molten, when all the aerosols are being released—that the containment vessel will hold. There will be several tons of aerosols released in the vessel, some of them radioactive. They will all be initially produced at the smallest size, a tenth of a micron. If they were produced in a dilute area, out in the air, they would immediately float with the air, because the settling velocity of these aerosols is lower than ordinary wind speed.

The point is that if the containment vessel is not broken, the aerosols inside, including the radioactive ones, will collide with each other, coagulate, and then settle out. So, if you wait 5 hours, most of those aerosols will be deposited all over surface inside the containment vessel and are no longer available for release.

However, if you do nothing, the heat will still go up in that reactor. The uranium will be interacting with the concrete and liberating hydrogen from it and raising the pressure. Therefore, at some unknown time, maybe 8 hours, maybe 16 hours, maybe four days, or possibly never, the containment vessel may crack open. Some critics will then say, "but you don't have containment." But, yes you have: you have it for the crucial period for forcing the settling of the aerosols.

Question: So, if there is a crack in containment after that crucial point, you are saying that the radioactivity released would be greatly lessened?

A lot of the radioactivity will be un-

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Fusion at the 'Breakout' Point

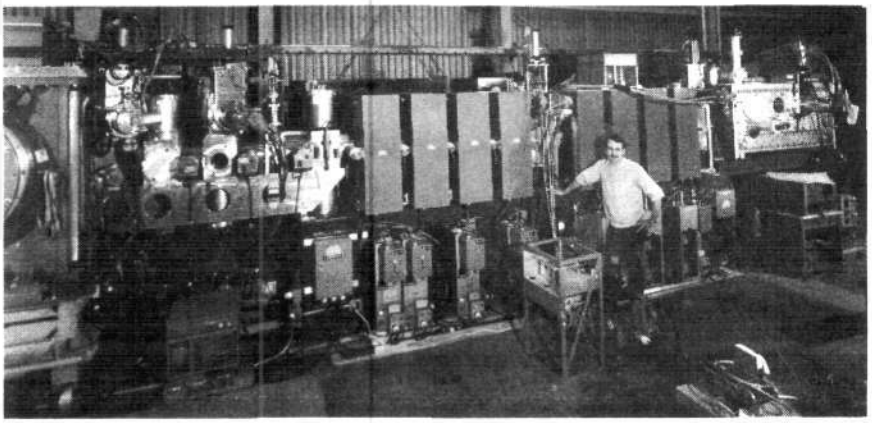
by Charles B. Stevens

Fusion research is at the "breakout" point in both magnetic and inertial confinement. Scientists at the Princeton Plasma Physics Laboratory in New Jersey and at the Lawrence Livermore National Laboratory in California have now reached and surpassed the confinement criterion for net fusion energy production in magnetic and laser fusion, respectively. Actual net energy production with the Princeton TFTR tokamak—requiring simultaneous achievement of confinement and temperature criteria—is expected next year. In other words, the goal of achieving a clean, cheap, and virtually unlimited energy source is within our reach.

In 1978, the Princeton PLT tokamak made headlines around the world when it demonstrated that the temperatures required for net energy-producing nuclear fusion could be attained in a stably confined magnetic plasma. This year's advances, far more significant than those reported in 1978, have scarcely been covered in the daily press.

Furthermore, at the same time that these experiments are demonstrating that the conditions for fusion energy generation can be attained, the Reagan administration is butchering the U.S. fusion research effort, making major budget cuts in magnetic fusion and "zeroing out" the program for inertial confinement fusion. There is no little irony in the fact that just as these experiments are reaching the breakeven point for harnessing the virtually unlimited resources of fusion energy, the political will to get the job done is lagging.

As fusion scientist Marshall N. Rosenbluth recently posed the question upon receiving the 1985 Department of Energy Fermi Award for his work on fusion plasmas: "Can we be a proud and successful nation 20 years from now if we abandon the struggle? I doubt it. This is not an era for standing still."



Lawrence Berkeley Laboratory

A new approach to inertial confinement (impact) fusion is studied in this heavy ion beam linear accelerator at Lawrence Berkeley Laboratory in California. Four beams are simultaneously accelerated by induction.

The unit at the far left (partly off picture) is the 200 kilovolt cesium ion injector with four cesium sources. To its right is the beam-matching section, equipped with diagnostics (monitors). Experimental physicist Tony Warwick poses in front of two sets of four boxes each, containing the ferromagnetic toroids (coils) that provide induction acceleration to the beams. When the machine is complete, there will be 24 boxes in this section. Induction acceleration is interrupted after every four boxes to allow access for beam diagnostics. The tank at the far right contains an electrostatic energy analyzer for precise measurement of the beam energy profile.

The Advances

Current fusion experiments are even beginning to show that there may be a clear path to igniting heavier elements such as helium. These more advanced fusion reactions—though involving far more strenuous conditions of higher temperatures, densities, and energy confinement times than required for hydrogen—could provide the basis for a stupendous leap forward in human technology: the first realization of coherent forms of nuclear energy. Recent studies at the University of Wisconsin and Lawrence Livermore National Laboratory have shown that helium-3 can be readily and economically obtained from the lunar surface.

The Princeton Tokamak Fusion Test Reactor (TFTR) was the first of the major tokamaks currently in operation in the world today, ranking with the JT-60 in Japan and the JET device built in England as a joint project of the European Communities.

The TFTR was originally designed to demonstrate fusion energy production from a burning, pulsed deuterium-tritium plasma, which is stably confined by a toroidal magnetic field. At the same time, the TFTR would provide the facility for continuing studies of the plasma physics of large tokamaks. Building the TFTR provided unique experience in the solution of engineering problems associated with large fusion systems that approach the size and complexity of experimental power reactors.

The current schedule for achieving these goals is given in the TFTR Research Plan (Figure 1).

The TFTR has already exceeded its original projected operating parameters. And while the TFTR was not designed to achieve a reactor-level confinement product of 10^{14} nuclei-sec/cm^3 at the fusion burn temperature of 10

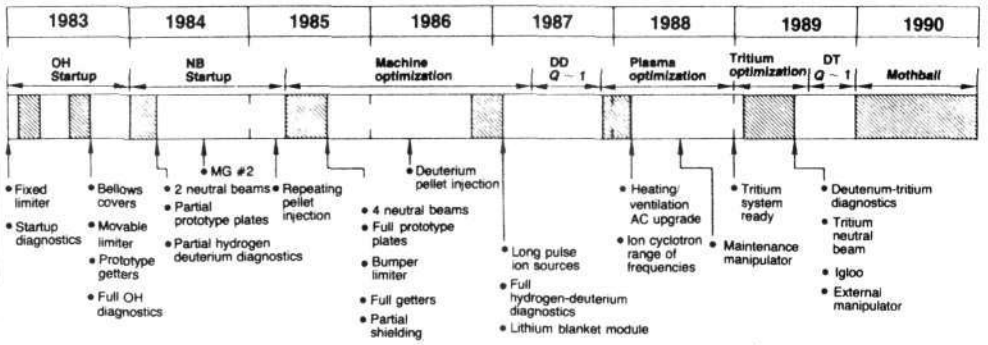


Figure 1
TFTR RESEARCH PLAN
This plan, issued March 1986, calls for achieving breakeven with deuterium-deuterium fuel in April 1987, and with deuterium-tritium (DT) fuel in late 1989. Breakeven is indicated by Q ~ 1. New funding cuts will endanger these and other targets. The cross-hatched periods are down time for accomplishing the hardware improvements.

keV, its performance has now demonstrated that it can reach this goal.

Confinement, expressed as $n\tau$, is the product of the plasma density (n = nuclei per cubic centimeter) and the confinement time (τ, in seconds). (See x-axis, Figure 2.) It is a measure of the efficiency of fusion energy production.

High Density Regime

As predicted by Professor Bruno Coppi in 1974, when his small, high-field tokamak at the Massachusetts Institute of Technology, the Alcator, reached extremely high confinement products, the TFTR has now demonstrated that extremely high densities can be readily achieved in large tokamaks too. This result was achieved with the use of the Oak Ridge National Laboratory pellet injector.

The pellet injector acts as a gun to shoot frozen pellets of hydrogen into the TFTR tokamak plasma during its operation. The hydrogen in the pellets is rapidly boiled off in the hot plasma, and significant amounts of fuel can be added to the plasma in this way. The injector accelerates the pellets to velocities up to 2 kilometers per second before injection. In this way, the pellets can penetrate to the center of the TFTR plasma column before being vaporized.

Peaked plasma densities on the order of 4×10^{14} nuclei per cubic centimeter were achieved. This vast increase in density, achieved with a three-pellet multiple-injection plasma discharge on the TFTR, prevents the neutral beams, utilized for plasma heating, from penetrating through to the center of the plasma column. Princeton is now planning to add radio frequency heaters, capable of penetrating dense plasmas, to the TFTR by 1988.

Another significant aspect of this peaked high density regime is that it greatly increases the prospects for achieving full thermonuclear ignition in the larger JET tokamak. This follows because plasmas with peaked density profiles are much easier to ignite, and density peaking appears to lead to increased plasma energy confinement.

Two energy confinement regimes have been found in tokamaks to date: 1) the low confinement *L*-mode; and 2) the high confinement *H*-mode. The

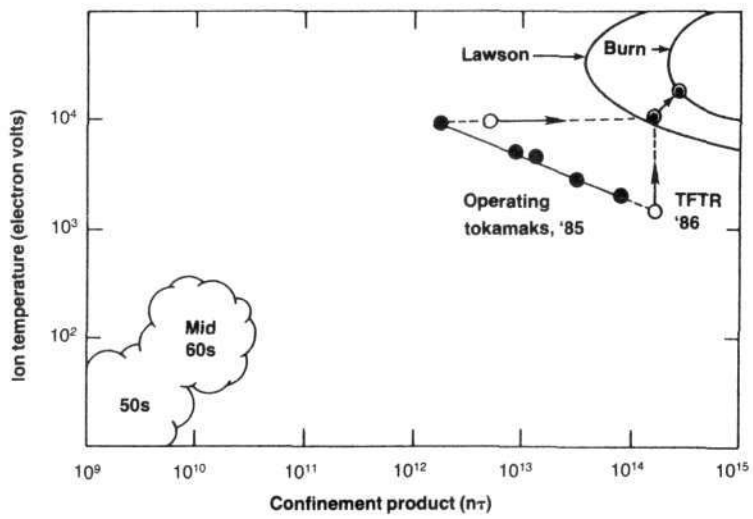


Figure 2
PROGRESS IN TOKAMAK CONFINEMENT
The two new achievements of Princeton's TFTR in 1986 are indicated with the open dots. Along the x-axis is shown the confinement product $n\tau$, where n is the nuclei per cubic centimeter and τ is confinement time in seconds. For fusion breakeven, a sufficiently high confinement product must be achieved at a sufficiently high temperature. Ion temperature is plotted on the y-axis in electron volts. Breakeven will occur in the upper right-hand region marked Lawson (fulfillment of the Lawson criteria for breakeven). Arrows from the open circles point to convergence on this region. Self-sustained fusion will occur in the region marked burn.

H-mode has appeared only in tokamak plasmas that are made with magnetic divertors. A magnetic divertor is like a hole in the magnetic bottle along the outer skin of the plasma, which permits the removal of impurities from the plasma. The divertor also permits the plasma edge parameters, temperature and density, to be readily tailored. In addition, it allows the tokamak to operate without the plasma touching the inside wall of the vacuum chamber, or any other material barrier, such as a limiter.

In experiments until now, the TFTR, which does not have a magnetic divertor and therefore was not expected to obtain the *H*-mode, has exhibited *L*-mode behavior when heated by neutral beams. That is, the energy confinement time decreases. But the peaked high-density regime appears to be exhibiting good energy confinement times. This may indicate that the high-density peak may duplicate the conditions needed to obtain the good *H*-mode energy confinement time scaling.

Heavy Ion Beam Breakthrough

As announced by Dr. Denis Keefe at the 1986 International Symposium on Heavy Ion Fusion, held in Washington, D.C., May 27-29, researchers at the University of California, Berkeley have attained a major technological breakthrough with the first demonstration of simultaneous, multiple-beam acceleration in an induction linear accelerator. This technique had originally been proposed by heavy ion beam fusion proponents like Dr. Al Maschke, who is currently working on the Strategic Defense Initiative at TRW.

Inertial confinement fusion pioneers, such as Dr. John Nuckolls of Lawrence Livermore National Laboratory, have continuously emphasized that heavy ion beams hold great promise for economic production of fusion energy. The primary reason is that the accelerator technology upon which it is based has already demonstrated high operating efficiencies, repetition rates, and reliability.

The induction linear heavy ion beam accelerator, for example, utilizes transformers, a technology that has been at the heart of modern electrical machinery for almost a century. The result is that the induction linear accelerator has a much greater efficiency, repetition rate, and reliability than other types of potential inertial confinement fusion drivers, like lasers and light ion beam accelerators—systems that are at a much earlier stage of their maturation.

LLNL

Lawrence Livermore National Laboratory's Nova, the world's most powerful laser, used X-rays to implode a tiny high-density fusion target for the first time in April, with "extremely encouraging" results. The component shown here is a crystal array frequency converter, which shifts the laser pulses that pass through it to shorter, more energetic wavelengths.

The technique demonstrated in the experiments reported by Keefe can reduce the size and cost of a heavy ion beam accelerator needed for inertial confinement fusion power plants by more than one half. The economic potentials of this development have already been incorporated into a detailed study, *Heavy-Ion Fusion Assessment*, carried out by the major U.S. national labs and McDonnell Douglas Corp. The conclusion of the study is that electricity costs that are competitive today could conservatively be projected for power reactors based on heavy ion beam fusion.

As emphasized by Keefe, the high energy accelerator community is well known for its conservatism and follow-through on technological projections. The multiple beam acceleration, therefore, represents a major development.

It was achieved by accelerating four space-charge-dominated cesium ion beams in the Berkeley induction linear accelerator. The experiment demonstrated that more efficient multiple beam acceleration could be achieved. The result is that the length of accelerator needed to obtain an overall incremental energy increase can be cut by as much as one half by utilizing multiple beams and higher charge-state ions—ions from which two or more electrons have been removed.

With the additional prospects of polarized fusion and high gain targets, the high ion beam fusion approach could provide the basis for producing electricity at costs far below those currently found in fossil fuel and nuclear fission power plants.

Nova Laser Breakthrough

The Nova laser, located at the Lawrence Livermore National Laboratory in California, has also exceeded the confinement criterion for net fusion energy production. Late in April, Livermore scientists demonstrated a significant advance when they conducted their first experiment with a tiny fuel capsule designed to be compressed to high density when hit by the world's most powerful laser, the solid-state 10-beam Nova.

Dr. Erik Storm, deputy associate director for the inertial confinement fusion program at Livermore, reported: "these results are particularly exciting because they were obtained the first time Nova was used to generate X-rays to implode a high density target. These results are extremely encouraging. During the next few years, as we increase the power Nova puts on the target and optimize the targets, we expect to see improvements on the order of 10 fold" in confinement.

This Nova shot obtained a density of 2×10^{24} nuclei per cubic centimeter with an energy confinement time of 50 trillionths of a second. This gives a confinement product of 10^{14} seconds-nuclei per cc.

This product—adequate for break-even when combined with a higher temperature—was achieved with an average temperature of 18 million degrees Celsius and led to the produc-

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Laser Fusion in Japan

A U.S. Laser Scientist Reports

by Dr. John Cox

Laser physicist John Cox is the president of Future Tech, in Gainesville, Fla. From 1978-1982, he was a research scientist at the University of Florida, and worked for U.S. Army Ballistic Missile Defense and for the National Aeronautics and Space Administration to develop high-energy nuclear-powered lasers. Cox was a speaker at the April 22-23, 1986 conference in Tokyo on the Stratetic Defense Initiative, sponsored by the Fusion Energy Foundation and the Schiller Institute, and while in Japan he toured the Institute of Laser Engineering at Osaka University, the center of the Japanese laser fusion program. He reports here on his impressions of the Japanese laser fusion program.

* * *

Let me preface my report by saying that I have visited the U.S. national laboratories at Los Alamos and Livermore, and I've seen what we have here in the United States, so my observations will be in the context of a comparison.

I fell victim to the familiar prejudicial thoughts that the Japanese were incapable of doing unique or novel research; that their bailiwick was taking what we had pioneered and making it cheaper, faster, better—but not necessarily doing anything new. I went into the Osaka laser fusion laboratory looking to see pretty much a duplicate copy of what we had done.

The first thing that struck me was that although the Japanese philosophy about research was somewhat different, they had accomplished things that we will probably never be able to do, and these accomplishments correlate with their dedication to progress and cooperation with industry.

The connection with industry in Japan is much tighter, as industry takes an active role in the research. With the classification system hanging over U.S. research, there's a lot of wasted and duplicated effort. In Japan there is an open society between research and industry, and the progress they've made is fantastic.

The main thrust of the Osaka laboratory is still basic physics. They were not actively looking at fusion reactors and how to take this fusion energy and convert it to electricity at an economical price; that seemed to be a secondary or tertiary consideration. They were primarily looking at this as a research tool to study the physics of fusion.

The main thrust of the Japanese program is to optimize the coupling between the energy in the laser pulse and the target, and that remains, in my opinion, one of the greatest challenges of laser fusion.

They were working on novel target designs and systems which would automate the procedure, and make the results more reproducible. They had an automatic focusing system that was very impressive. They are bringing something on the order of up to 15 laser beams that are 1 meter in diameter, all coming to bear on a target that is less than a millimeter in diameter, all within a nanosecond—1 billionth of a second. The ability to bring that kind of power to bear with that short a timeframe and spatial dimensions is very impressive.

The laboratory is trying to get a trillion-neutron yield; that is, during a single pulse they would generate a trillion neutrons from a fusion burn. They are able to do that, time and time again, not just occasionally.

One of the most frustrating things I've come across in research is that it is difficult to reproduce something if it is very complex. The Japanese are able to get uniform results, which is very critical in terms of understanding the cause and effect. If you have a spurious effect, there are so many unknowns, you have a very difficult time tracking down what caused this. You want control of your system first, then later on, you actually make power a critical factor as well.

Another feature about the Laser Institute which impressed me, was the fact that they have been in business for 20 years and during that period they have developed between seven and nine laser systems, each successively more powerful and more accurate. In the United States we have had a similar progression of technologies from the 1960s to now, but when we build a better system, we cannibalize and disassemble the old system. The Japanese have all of the laser systems at their laboratory facility completely operational and functioning at the same time. This is very valuable when you are training a new generation of laser or nuclear physicists: They can gain experience on the other machines, and develop along the same way the technology has been brought along.

Stuart K. Lewis

John Cox: "If the Japanese would get involved with defensive-type technology in general, the spinoffs to them would be enormous."

An Incredible Teaching Resource

This is an incredible teaching resource—a learning tool for future scientists—it would be a paradise to me, to conduct classes or teach students in an environment like that.

The Japanese do have some problem areas that they are struggling with now. One of their latest systems is up and running and they're getting a lot of information out of it, making a lot of progress. But, in order to maintain that level of progress, they have an employment crunch—a temporary need for labor. For example, they are just finishing their implosion system, so they need many people to work on the diagnostics. The Institute would like to hire 10 or 15 research scientists or engineers who are very knowledgeable about diagnostics. The problem, however, is that if they hire someone at a

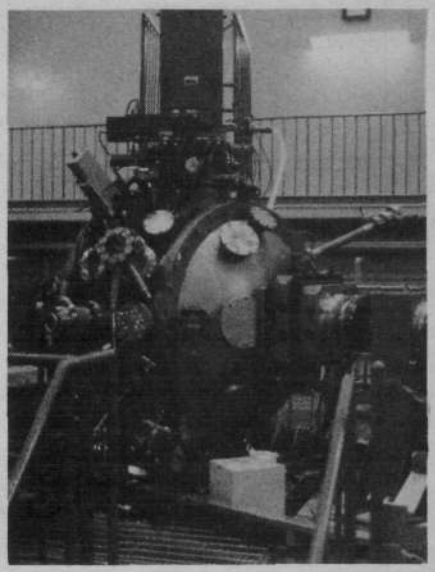
university institute in a government position, that position is normally held for life. Since they only need them for a couple of years, they cannot justify the expense of hiring these extra staff people for a short time.

I asked the head of the laboratory why he didn't hire contractors, as we do in the United States, who have a job to do, and who leave when it's done. He replied that it went beyond the regulations and that he as an administrator could not look the person in the eye three years from now, and tell him he's fired. It wasn't just a question of money; it was also the fact that the tradition affects even the management and the top level staff.

They are making an effort now with the Diet [Japanese Parliament] to open up temporary positions—to create a new position, a temporary worker, who would be moved around. He said that is not a trivial thing; it's a revolution in their way of life. I asked why they don't hire foreign contractors. Personally, I'd love to work on Japanese diagnostics for three years and then leave. He answered that they are considering that, too. Another benefit from hiring foreign contractors would be bringing in new thoughts to invigorate the program. He expects it is going to be a slow process, however.

The Diagnostic Question

The one area of technology where the Japanese are not as current is in the area of diagnostics. However, I can't say that they're any less accurate or reliable in their data because of it.



The newer technology would not make the detectors or systems intrinsically better, per se; it would make them faster and would increase their productivity. They're working on that now.

The Japanese will have to import some of that technology from the United States, for example, sensor technology which is critical to them and on which we have spent billions. We are the leaders in this area. If Japan had a defense budget, they would have an equal array of technology.

The Japanese could become a partner with the United States on the SDI program. There is some talk about spinoffs in the private sector from this technology. What is not discussed is the spinoff for scientific technology. That is even more obvious and straightforward. Our scientific research benefits 100-fold more than the private sector does.

How that could apply in the Japanese situation is not clear. What is clear, however, is that those same scientists who are working on the problems of solving laser fusion, would also be swept up into the military-oriented research, and there are many common goals. They overlap so much, that it's difficult to separate them.

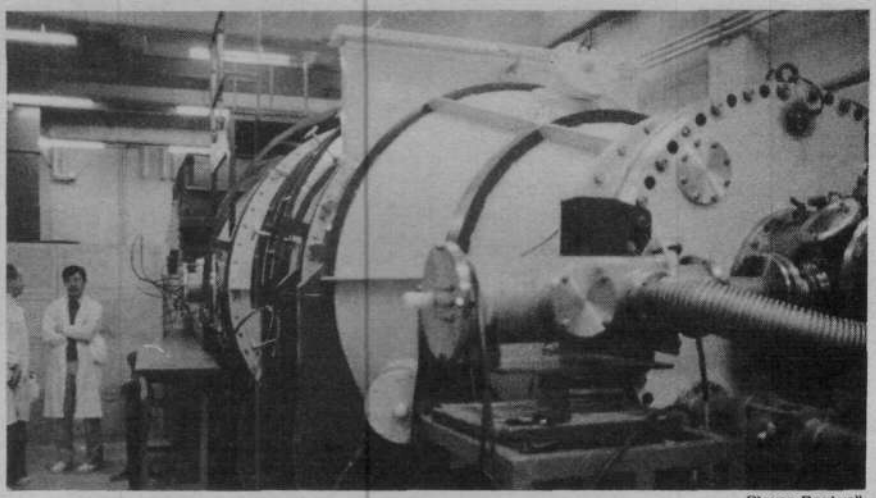
A perfect example is the work I did on a high-energy laser system that was not a military-funded research effort, but where the same work applied to NASA and the military. There was a complete overlap in the basic research, which parts ways as it evolves into technology components and hardware. In basic physics, such as laser fusion physics, the overlaps are enormous. That's why our basic research is so good; we've leaned on military support, which spills over into private research.

The big advantage that the Japanese have is their openness. They're closed to the outsiders, of course, but within the society the contractors in private industry are able to work hand-in-hand with research scientists in a government facility.

What is specifically important is the feedback from the problems generated at the site. Here in the United States there is a classification network that shunts all of this information, and there are isolated pockets of people who do not communicate with each other.

In Japan, everyone knows the same information, and the problems can be solved from within. For instance, at Osaka, they have a complete, total capability in-house: they make the fusion pellets there, and they have a complete facility to rebuild and repair their own laser systems. They do have contractors come in to support that effort, but they do everything there. It is like a complete vertical monopoly.

Here, U.S. fusion fuel pellets are made in Ann Arbor, Mich., by a private company, on contract with the federal



Steven Bardwell

"The Japanese have all of the laser systems at their laboratory facility completely operational and functioning at the same time. This is very valuable when you are training a new generation of laser or nuclear physicist." Here, two of Osaka University's older devices, the Gekko 2M glass laser (left) and the Reiden electron beam device.

government. They are shipped to the labs, and the actual research and data come out classified.

The Classification Factor

In the United States, even within the same laboratory, information is not shared. The absurdity of this really strikes home when you realize that the Japanese are doing reseach in areas that we haven't gotten to yet. They have advanced beyond us, and they have tried to publish the results of their work, but no American publication will accept it. This is because the work is not being done here at all yet, or no one has any feel for this work and can't determine the value of the paper, or the material being done in Japan would be considered classified data here in the United States. It's ridiculous . . . it's a travesty.

The reason for these obstacles on our side is that when the laser fusion program first originated, it started producing data that were relevant to weapons, such as the so-called "EMP effect" or electromagnetic pulse. When they discovered the magnetic fields propagating out from the explosion, they rewrote all the bomb codes. It changed everything. That's where the program took off, and why there are two laser fusion laboratories in this country now, because of the ability to model a mock-up of the explosions. Here was a tool that enabled them to do essentially mock-up explosions of microexplosions, enabled them to improve their models of explosives and design better weapons. That's where it all got classified.

Let me give an illustration of the bane of classification from my own experience. I was working on an optical processor for the Air Force and was funded at the University of Florida. We were trying to develop robotic machine vision using a new principle of optics. It's the same principle that the insect eye uses, a surface processor instead of a volume processor. In other words, our eyeball needs a volume—it has a focal length, and a diameter, and an aperture: It has a certain field of view. An insect eye is basically a skin; it has no volume. We were developing optical sensors based on technology that mother nature invented millions of years ago.

I was to give a paper at a conference in California in 1983, but the Air Force withdrew my paper and classified it. I requested an explanation since this was basic physics. I asked "What good is this going to do the Russians?" They said, "Look, we just paid $100,000 for this data. We don't want the Russians to have it for the cost of a conference seat." So they were classifying my research because they didn't want the Russians to pay for an air fare and a conference fee, and get the same information for which they had just paid $100,000! That totally changed my perception of why things are classified.

They did this twice. The second time, I didn't even leave town. Until four or five years ago, there were aspects of the laser fusion research programs at the University of Rochester, KMS Fusion, and so forth, where there was unclassified work going on. Then that policy was changed at the end of the Carter administration. . . .

I mentioned this to the director at the Osaka lab, Dr. Sadao Nakai, and he said that there was virtually no Japanese effort to speak of in looking at commercialization of the product. He tended to avoid that discussion about commercialization or anything to do with any other application other than basic physics. He did, however, point out that they are trying to spin off this technology in other ways. That's what KMS Fusion has done. The micropellet technology has spilled over to the private sector. They are making micropellets for pharmaceuticals, for cancer therapy research.

Spinoffs

This technology is very fruitful in spinoffs. The Japanese are not as eager or capable of spinning off this technology; that's not what drives them. That requires somebody championing a product; somebody saying, "I'm going to get this company going." That entreprenurial spirit is there, but it is subdued, although it's beginning to be more of a factor.

Perhaps all the Russians will do is learn Japanese and read in the open literature some of the results the Japanese are getting in their experimental work, which they can't get published in the United States. Thus we will help deny ourselves some of what will be available to the Russians.

Because of the difficulty in telling how much is being spent in the United States on laser fusion research, I asked the Japanese if they knew their own expenditures. They said that they had spent $300 million on the facility, and I assume that includes everything they've got up to today. It's difficult to make dollar-for-dollar comparisons. How does a dollar spent in Japan compare to one spent here? So, while I have a number of $300 million, I have to place uncertainty on that number, plus or minus 50 percent.

Certainly, the Japanese are getting a lot of mileage out of their money. Yet $300 million is a sizable investment and I don't think you will find that investment in any one of the two U.S. labs.

If the United States would wise up and at least transfer information back and forth between the two programs, there would be an enormous benefit to us. I am not sure how it would happen. But the SDI could certainly open the door and get the thing rolling.

If the Japanese would get involved with defensive-type technology in general, the spinoffs for them would be enormous.

Viewpoint

Continued from page 5

One wonders what would have happened, if the same level of popular education, enthusiasm, and naiveté prevalent in the early 1950s had been present when the ideas and demonstrations of magnetic resonance imaging occurred in the late 1970s. One can only speculate, of course. But to some of us dinosaurs, survivors of a past time, it seems that the educational depression from the mid-1960s to the present has had a very negative impact on many of the more important developments of the past 10 years.

Note

1. *A Machine Called Indomitable* by Sonny Kleinfield (New York: Times Books, 1986) is reviewed on page 56.

Warren Hamerman

The second panel of the Paris conference. At the podium (from left) are paleontologist Jean-Michel Dutuit, Christine Bierre from the French FEF, and European FEF director Jonathan Tennenbaum.

Pasteur's Method Revived In FEF Paris Conference

"The Importance of the Method of Louis Pasteur for Conquering AIDS and Other Pandemics" was the title of an extraordinary conference in Paris, June 6 and 7, sponsored by the Fusion Energy Foundation of France. Attended by more than 120 scientists, students, and laymen from Europe and the United States, the conference was held at the Société Immobilière du Corps Médical Francais, and it drew international press coverage.

Pasteur himself no doubt would have approved of the fight the conference organizing generated on the question of scientific method. The Pasteur Institute and the University of Paris were in an uproar after the FEF circulated a leaflet on campus before the conference in the form of a humorous "letter" from Pasteur ridiculing the philosophy of Jacques Monod. Nobel Prize winner Monod, a former head of the Pasteur Institute, is best known for his 1971 book *Chance and Necessity*, where he describes man as a "random accident" in the universe.

The president of the university then invoked an archaic campus regulation banning ideas on campus that cause a commotion. As a result of the "ban," several professors, including one of the speakers, were not permitted to participate in the conference on Friday, the first day. However, many attended the Saturday session, and, in fact, all of France's major laboratories were represented at the conference.

A highlight of the conference was a beautifully designed "Pedagogic Museum" on the contributions of Pasteur. A sampling of the exhibits presented in the museum included: an original oil portait of Pasteur (see photo), as well as displays of Pasteur's own highly talented oil paintings of his mother and father, which he did when he was a teenager; a polarimeter and accompanying crystal models through which the conference participants could "redo" Pasteur's principal experiments in molecular dissymmetry; a display of the geometric arrangement and color beam sequences of the Chartres Cathedral windows; and presentation of the contributions of the scientists from the Ecole Polytechnique to the modern understanding of polarized light and rotational action.

Christine Bierre of the French FEF opened the conference reading the greetings for best success from French Prime Minister Jacques Chirac, an ardent supporter of the Strategic Defense Initiative, and from U.S. FEF board member Lyndon H. LaRouche Jr., who called for the revival of the Pasteur method in science: "Let us uplift the spirits and talents of many among today's youth; let an accurate memory of the work of the great Pasteur inspire those youth to abandon cultural pessimism for scientific and cultural optimism; let them understand, that scientific and cultural optimism have a sound practical foundation, only when the mind is disciplined by a rigorous scientific and moral conscience, as we see in the process by which the great Pasteur effected his great contributions," LaRouche said.

Laurent Rosenfeld, president of the French FEF, then reminded the audience that 100 years ago, Pasteur made his famous speech announcing the success of his rabies vaccine and the creation of the Pasteur Institute. Noting the recent gift made by the Duchess of Windsor to the Pasteur Institute, Rosenfeld called for the creation today of an optical biophysics laboratory with those funds.

Warren Hamerman then presented an overview of Pasteur's scientific contributions in a keynote address titled: "Louis Pasteur, the Father of Geometric Optical Biophysics":

"The discovery and elaboration by Louis Pasteur (1822-1895) that optical activity is the unique geometric characteristic of living processes is the foundation upon which the modern scientific frontier known as optical biophysics, or nonlinear biological

The author (left) poses with a portrait of Pasteur painted for the conference by FEF member Karel Vereycken.

spectroscopy, is based," Hamerman said. "Pasteur traced his own heritage to the method of scientific hypothesis-formation associated with the constructive geometry program of the 1794 Ecole Polytechnique of Gaspard Monge and Lazare Carnot and its scientific continuation into the 19th century through the Société D'Arcueil."

The next presentation was given by Dr. David from the Merieux Institute, who described his work as the leader of a "Bioforce," a rapid deployment health strike force specifically designed to intervene in Third World countries. To avoid immediate biological catastrophe, the Bioforce intervenes in critical areas for rapid mass vaccinations, as in Peru now against rabies.

Closing the first morning session, Maurice Valléry-Radot, who was educated by Pasteur's daughter, the historian Marie Louise, spoke on Pasteur as a politician. He insisted that Pasteur detested what today would be called liberalism—that is, anarchic democracy, the worship of mediocrity. Pasteur demanded that anything not susceptible of precise scientific knowledge be excluded from the political domain.

The Concept of Negentropy

The second panel opened with a speech by Dr. Jonathan Tennenbaum, European coordinator of the Fusion Energy Foundation, on Bernhard Riemann and the relevance of his groundbreaking work on geometry to studying living phenomena. Tennenbaum situated the continuation of Riemann's work in the 20th century by American economist Lyndon LaRouche, who developed the concept of "negentropy" based upon his studies of the scientific work of Riemann and Georg Cantor.

Next, Prof. Jean-Michel Dutuit, a paleontologist from the Paris Museum of Natural History, spoke on the theme of "the rise to power of the living process." Dutuit stated that if we are to believe the most current notions, biological evolution would be a strange story, consisting of choices made by successive ecologies over hundreds of millions of years—choices picked up amid innumerable solutions haphazardly "proposed" by living forms.

Dutuit illustrated the problem with such a conception by reviewing the emergence of the very first germs of life, 3.5 to 4.0 billion years ago, the solar system and the Earth having appeared about 5 to 6 billion years ago. Life must be seen as a "process in work"—process, in the sense that life is no mere succession or juxtaposition of animal and vegetal forms, he said. Consequently, Dutuit explained, the object of our reflection is the mode of growth of life conceived as a whole, capturing and transforming universal energy. So conceived, life corresponds to a change in metrics of universal evolution. Life is not juxtaposed, or opposed to the inanimate world, nor is it a parasite on that world, as other conceptions claim, but it represents the carrying out of the history of such an inanimate world, through other more efficient means and the use of different laws.

Dutuit then proposed an attempt to quantify the essential phase-changes in the evolution of the vertebrates. The mode of regularly accelerated negentropic growth, which is that of life, the growing intertwining of the coming into being of the organic and inorganic worlds, and more clearly, the relations of an economic sort between these two worlds, he said, show that there exists between them two-way correlations, and that the programmatic transformations of life are not arbitrary. Life is not a blind process.

Dutuit concluded that it would be criminal if, now that it has become conscious with Man, evolution were bent or reversed, whether the cause be war, economic shortages, or a cocktail of viruses and bacteria.

Optical Biophysics

Dr. Fritz Popp, from the Kaiserslautern University in West Germany, then spoke on the role of DNA in ultraweak photon emission of biological systems. Today, he said, it is an admitted fact that living systems emit a very weak photon radiation that is called "low-level luminescence." Popp and a group of researchers have worked out a model that explains "low-level luminescence" in terms of a nonequilibrium phase transition, including the possibility of a surprisingly high coherence of this radiation. In 1980, researchers at the Max Planck Society in West Germany came out with the notion that the source of the weak photon emission from living tissues could only be chromophores. But Popp believed just the opposite. If the ultraweak photon emission is assigned to a coherent electromagnetic field, which is the most fundamental communication basis for living tissues, then the best candidate for its source would be the biomolecule with the highest potential information density—namely DNA.

In conclusion, Popp said that:

Continued on page 62

Louis Pasteur

After a photograph of M. Dornac, Pasteur Institute Museum

Louis Pasteur in his study at the Pasteur Institute, 1890.

Father of Today's Optical Biophysics

Pasteur's geometric approach to biology—in the tradition of Cusa, Leonardo da Vinci, Kepler, and Leibniz—is the foundation of today's (and tomorrow's) frontier area of optical biophysics.

by Warren J. Hamerman

The discovery and elaboration by Louis Pasteur (1822-1895) that optical activity is the unique geometric characteristic of living processes provides the foundation for the modern scientific frontier known as optical biophysics or nonlinear biological spectroscopy.

Louis Pasteur's method of geometric biological spectroscopy—most explicitly evident in his groundbreaking early studies on molecular dissymmetry and fermentation—stands in refreshing contrast to the otherwise completely pragmatic and reductionist orientation pervasive in biochemistry and molecular biology today. Pasteur traced his own heritage to the method of scientific hypothesis-formation associated with the constructive geometry program of the 1794 Ecole Polytechnique of Gaspard Monge and Lazare Carnot and its scientific continuation into the 19th century through the Société D'Arcueil.

Pasteur established that living processes can be studied, analyzed, and "signatured" by their optical activity—which characteristic optical activity or "rotatory power of polarized light" is geometrically determined by a process involv-

Chronology of the Ecole Polytechnique's Geometric Optical Biology Project

In the 1790s, under the direction of Lazare Carnot and Gaspard Monge, a grouping of international scientists centered in Paris resumed the intensive study of geometry, light propagation, and rotational action that had been the focus of Leibniz and Christian Huygens during their collaboration, also in Paris, a century earlier.

1774 Biot born
1775 Malus born
1783 Monge named examiner of Naval cadets; Lazare Carnot writes his reflections on Leibniz's calculus
1786 Monge investigates double refraction and structure of Iceland Spar; Arago born
1788 Fresnel born
1792 Monge becomes minister of Navy
1794 Ecole Polytechnique founded under jurisdiction of Minister of War; Biot becomes Ecole section leader; Malus begins studies at Ecole; Mitscherlich born
1795 Monge gives descriptive geometry lectures at Ecole
1797 Monge becomes director of Ecole
1799 Monge's *Descriptive Geometry* is published; Biot becomes entrance examiner at Ecole
1802 Biot does basic geometry of ellipsoids
1803 Arago begins studies at Ecole; Biot writes history of science during French Revolution; Carnot writes "Geometry of Position"
1804 Humboldt, Biot, and Gay-Lussac do joint experiments on magnets; Malus becomes president of Société des Sciences, de l'Agriculture et des Arts de Lille; Fresnel begins studies at Ecole
1805 Arago collaborates with Biot on refraction of light passing through Earth's atmosphere; as secretary of Bureau des Longitudes, Arago goes to Spain with Biot; Malus becomes examiner in geometry at Ecole
1807 Malus publishes *Traité d'Optique* based upon Huygens's hypotheses
1808 Malus discovers polarized light; explains polarized light as a verification of Huygens's theory of advancing wave front; Arago begins experiments on polarized light; Biot becomes professor of astronomy, University of Paris
1809 Malus attacks Laplace for trying to deduce Huygens's law from Newton's mechanics; Arago succeeds Monge as professor of descriptive geometry at the Ecole; Malus, Arago, Biot et al. join Société D'Arcueil; Arago elected to Institut de France as an astronomer; Alexander von Humboldt and Arago become roommates in Paris
1810 Malus defeats Laplace for scientific prize on the question of double refraction
1811 Arago invents polariscope and polarimeter; Arago discovers chromatic polarization; Malus publishes *Théorie de la Double Réfraction*
1812 Malus dies; Fresnel works on project of highway from Spain to Italy
1813 Arago becomes director of Paris Observatory; Fresnel, Arago, and Petit begin collaboration in attacking Newton's theory of light particle emission; Biot establishes basic laws of rotatory polarization
1815 Fresnel announces his *Theory of Stellar Aberration*; Fresnel develops geometry of transverse waves; Biot announces discovery that natural organic products deviate the plane of polarized light; Arago builds a cyanometer to measure degree of blueness in atmosphere
1816 Fresnel combines Huygens's wave principle with the principle of interference; Biot publishes *Traité de Physique*
1817 Fresnel discovers circular polarization; Fresnel studies periodic effects of chromatic polarization; Mitscherlich studies at Göttingen University
1818 Gaspard Monge dies; Fresnel elaborates geometry of double refraction and transverse waves; Mitscherlich begins crystallography study in Berlin
1819 Mitscherlich studies with Berzelius in Stockholm; Mitscherlich discovers isomorphism
1820 Arago present at LaRive laboratory in Geneva for Oersted experiments; Ampère and Arago begin collaboration
1822 Louis Pasteur born; A. von Humboldt and Arago conduct experiments on Earth's magnetic field; Lazare Carnot dies in Magdeburg
1823 Mitscherlich and Fresnel collaborate in Paris on fermentation and other questions
1824 Arago writes review of history of polarized light
1827 Fresnel dies; 1830 Arago replaces Fourier as secretary of Académie des Sciences; Arago writes biography of Fresnel
1833 Arago derives from polarimeter the ratio of the amount of polarized light to neutral light; Arago proposes photometer to measure comparative intensities of stellar light
1847 Pasteur submits physics and chemistry dissertations indicating studies of crystallization, optical activity, and so forth
1848 Biot verifies Pasteur's molecular dissymmetry discovery
1853 Arago writes biography of Malus; Arago dies
1862 Biot dies

ing classical geometric "projections." The explicit geometric tradition of Pasteur, who was a highly talented amateur painter in the tradition of Rembrandt, stretches back through the school of Monge, via Leibniz, Huygens, and Euler, to Kepler and Leonardo. This scientific tradition can be most efficiently traced by looking for its characteristic trait of making physical models—actual geometric constructions—to demonstrate the way in which processes *work* in nature.

Pasteur's famous wooden models of left-handed and right-handed tartrate crystals were firmly embedded in this geometric approach and gave birth to the widespread tradition of biomolecular model-building in the 20th century. The mathematical high point of this approach of synthetic or constructive geometry, in fact, was flourishing at the University of Göttingen in Germany through the work of Jakob Steiner and his student, Bernhard Riemann, simultaneously with Pasteur's own work.

Pasteur's method was explicitly derived from Gaspard Monge's "descriptive geometry" as applied to optics by a generation of scientists trained at Monge's Ecole Polytechnique in the late 18th century (Arago, Fresnel, Biot, and Malus) and their close German collaborators (Alexander von Humboldt and Göttingen's Eilhard Mitscherlich). These were Pasteur's immediate scientific teachers and forebears. Their work established the modern scientific understanding of light beam optics and spectroscopy on a firm geometrical and nonempiricist footing. Demonstrating a true Keplerian heritage, most of these scientists were leading geometers and astronomers: Arago was the director of the Paris Observatory from 1813-1846; Biot from 1808 onwards was professor of astronomy at the University of Paris; Fresnel based his discoveries of transverse waves, diffraction, and interference phenomena on observations of stellar aberrations (see chronology).

Pasteur established that there was a direct mapping relationship between the left-handedness or right-handedness of biological products when in their crystal state or in solution and their action on the rotary power of polarized light. There are certain characteristic features of the intrinsic geometries of living space that are directly responsible for its ability to absorb and reorganize light energy (electromagnetic radiation) for its own growth and self-reproduction. Thus, it can be proven geometrically that neither living processes, nor the universe in which living processes exist, obey the Second Law of Thermodynamics. Such processes are inherently negentropic, a term introduced by economist Lyndon H. LaRouche, Jr. to describe the self-developing process in the universe as a whole, which is coherent with the development of living systems.[1]

In Pasteur's terminology, the nature of our nonequilibrium universe to progress in the direction of ever more ordered states—namely, to accomplish work and "grow" away from equilibrium—is its characteristic "dissymmetry." As he wrote in 1874:

> The universe is a dissymmetrical totality, and I am inclined to think that life, such as it is manifested to us, is a function of the dissymmetry of the universe or the consequences which it produces.

Pasteur was conscious of the fact that his approach to science was in total contrast to the prevailing doctrine of Positivism, a philosophical outlook that denies all reality but those "facts" empirically verifiable through sense certainty. During the early 1880s, in fact, Pasteur engaged in open polemical warfare against the champion of Positivism, Auguste Comte. Pasteur focused upon the devastating flaw of the Positivist doctrine in its inability to account for creative discovery:

> Positivism does not take into account the most important of positive notions, that of the Infinite. . . . What is beyond? The human mind, actuated by an invincible force, will never cease to ask itself: what is beyond?. . . He who proclaims the existence of the Infinite—and none can avoid it—accumulates in that affirmation more of the supernatural than is to be found in all the miracles of all the religions; for the notion of the Infinite presents that double character that it forces upon us and yet is incomprehensible.

Today's scientific frontiers are filled with examples of numerous Pasteurian effects. Researchers engaged in energy-dense plasma experiments and high-energy particle physics have repeatedly observed "twisted" structures

Pasteur as a young student.

exhibiting the characteristics of left- and right-handed rotation or spin. Left- and right-handed dissymmetries have been observed in astronomical structures. Laser optics and circularly polarized advanced optics research for rapid microbiological identification—like multiparameter light scattering—are directly based upon similar Pasteurian effects.

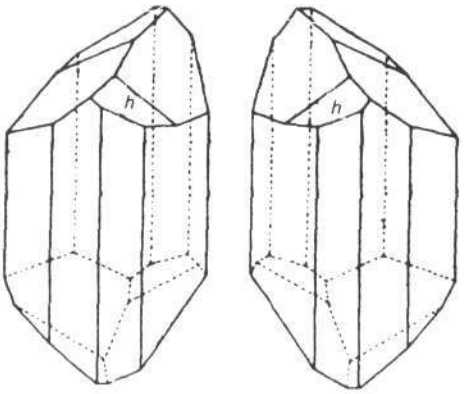
Geometric Biology

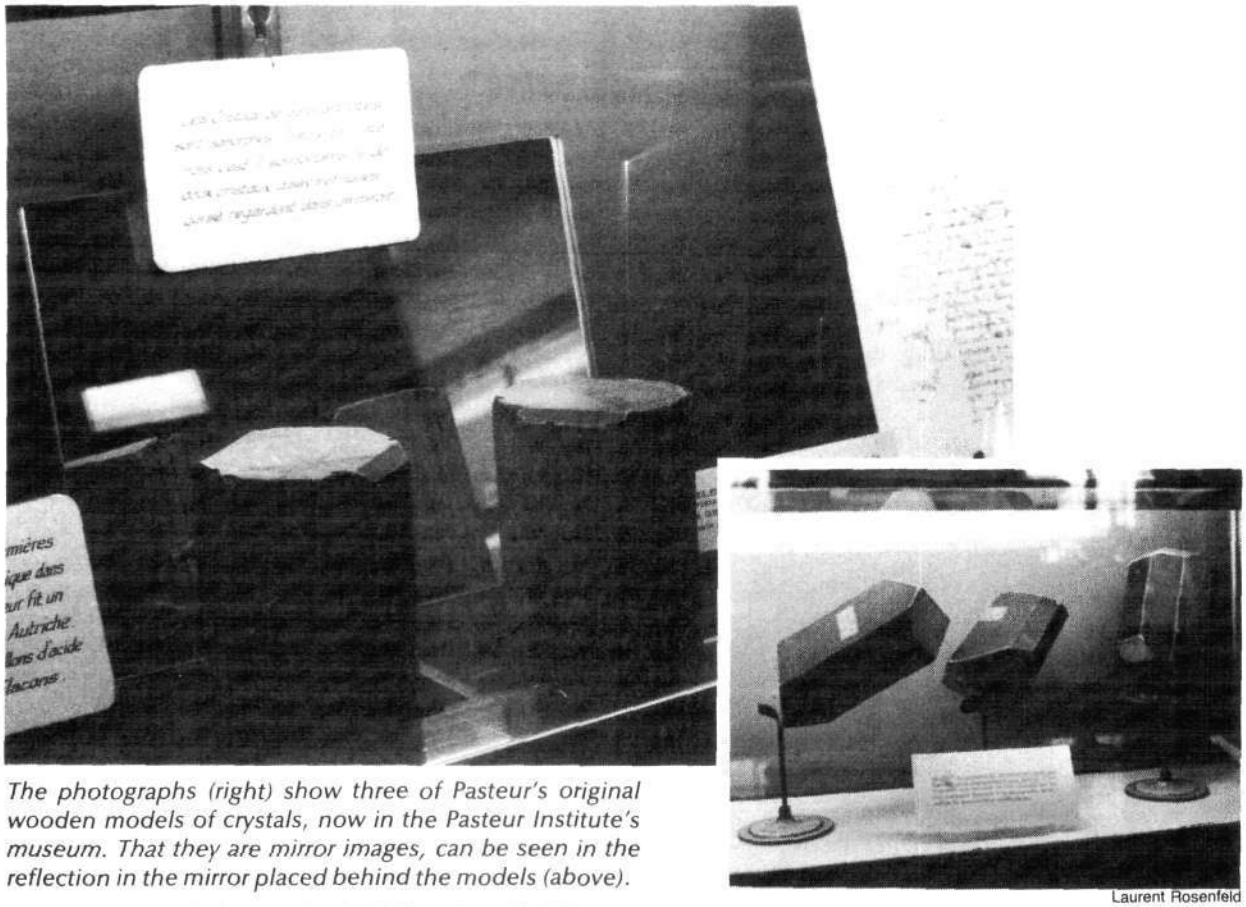
By projecting down to the level of biological molecular action—its optical rotatory power—rather than to the molecule as a fixed thing-in-itself—Pasteur opened the way for the geometrically oriented biologist to advance the spatial organization of the biological molecules themselves. The standpoint is similar to the way in which Kepler unlocked the great "secret" of the planetary orbits by demonstrating that they were geometrically derived from the relationship of the distances between the five Platonic solids.

Pasteur explained the dissymmetric or nonsuperimposable mirror-image characteristic of biological molecules in terms of a basic geometric model not unfamiliar to modern biologists—the helix or twisted staircase. The rotational

Figure 1
PASTEUR'S MODELS AND SKETCHES OF LEFT-HANDED AND RIGHT-HANDED TARTRATE CRYSTALS

Pasteur discovered that crystals of tartrate compounds had hemihedral facets that were inclined in the same direction as the optical activity of the crystals. In the schematic models here, the dissymmetrical hemihedral facet of the tartrate crystal is labeled h. *The right-handed tartrate acid, derived from the right-handed ammonia and sodium, turns the plane of polarized light toward the right. The left-handed tartrate acid, turns this plane toward the left. Sodium-ammonium paratartrates, which have an equal amount of the left- and right-handed crystals, are optically inactive.*





The photographs (right) show three of Pasteur's original wooden models of crystals, now in the Pasteur Institute's museum. That they are mirror images, can be seen in the reflection in the mirror placed behind the models (above).

Laurent Rosenfeld

action of the twisted staircase or helix proceeds either around the left or around the right, even though the internal structure of the helix or twisted staircase itself may not change.

Thus, certain types of knowledge about the geometry of living processes is advanced by interpreting the projections from a higher-ordered process or manifold. The way in which the optical shadows are "cast" depends upon the geometric relationship of the way in which living processes "work" in our unique life-supporting universe.

To quote Pasteur from an 1870 letter to Jules Raulin:

> You know that I believe that there is a cosmic dissymmetric influence which presides constantly and naturally over the molecular organization of principles immediately essential to life; and that, in consequence of this, the species of the three kingdoms, by their structure, by their form, by the disposition of their tissues, have a definite relation to the movements of the universe. For many of those species, if not for all, the Sun is the *primum movens* of nutrition; but I believe in another influence which would affect the whole organization [geometry], for it would be the cause of the molecular dissymmetry proper to the chemical components of life. I want by experiment to grasp a few indications as to the nature of this great cosmic dissymmetrical influence. It must, it may be electricity, magnetism. . . .

Pasteur discovered and proved experimentally that living processes were geometrically *dissymmetric*; namely that the crystalline forms of biological molecules were oriented or "twisted" with a preferred directionality—either right-handed or left-handed. He wrote in 1874:

> All mineral products and all of the numerous organic substances which one obtains in the laboratory lack molecular dissymmetry and the correlative action on polarized light. Both of these properties, on the other hand, are inherent in a great number of natural organic substances most important from the physiological standpoint: such as cellulose, sugars, albumin, fibrin, caseine, certain vegetal acids, etc. . . .

After his basic tartrate/paratartrate studies were completed by the mid-1850s, Pasteur then tried to explore experimentally the broad nature of dissymmetric synthesis. He placed crystals and plants variously in powerful magnetic fields to observe if there were any transformations in their optical activity, structure, or synthesis characteristics. He grew plants under conditions where the light was *reverse polarized* through the use of quartz and mirrors to observe the results in geometric form.

In addition to the helix, Pasteur also proposed a remarkable geometric solution to explaining the organization of what are called optical isomers, stereo isomers, or enantiomorphism. In this situation two or more compounds have the same functional chemical "groups," but merely differ in the arrangement of these "groups" in space; in other words, two compounds with exactly the same structural elements and arrangement, for example, can be mirror images of one another. Pasteur proposed a Keplerian solution in the form of one of the five Platonic solids—the tetrahedron. The asymmetric carbon attaches to four dif-

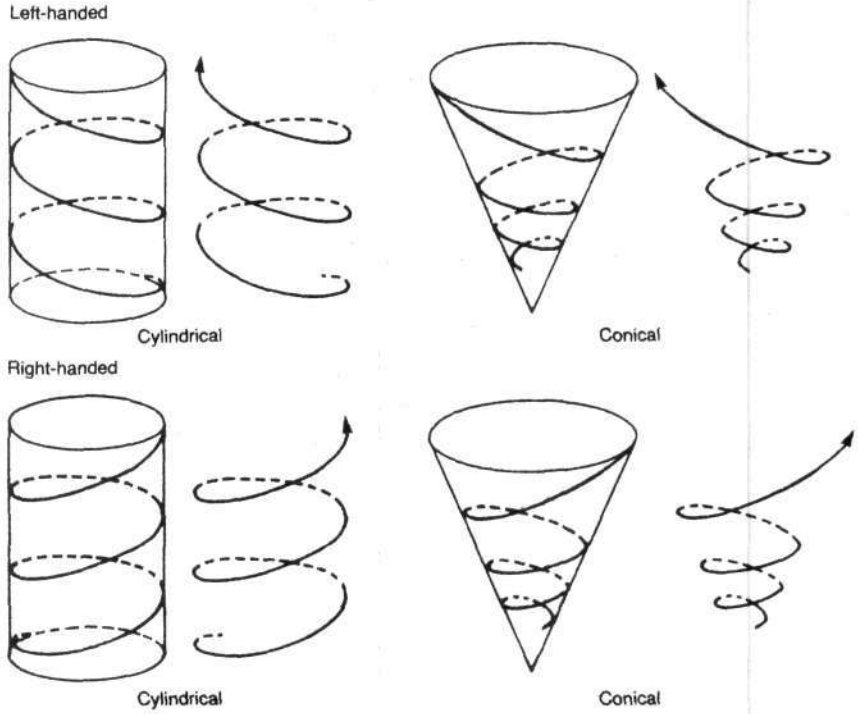
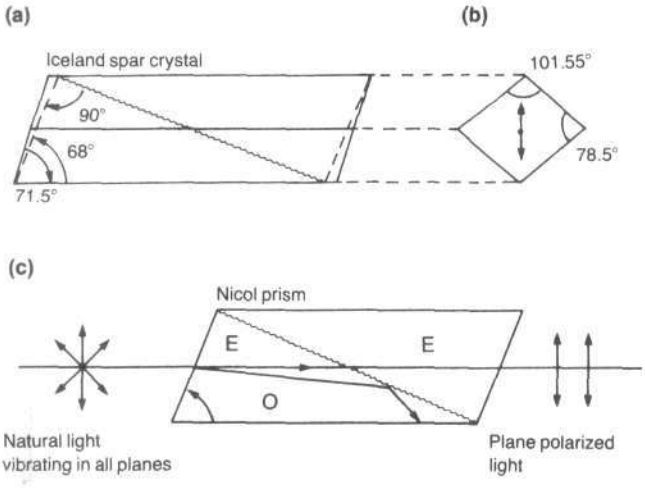


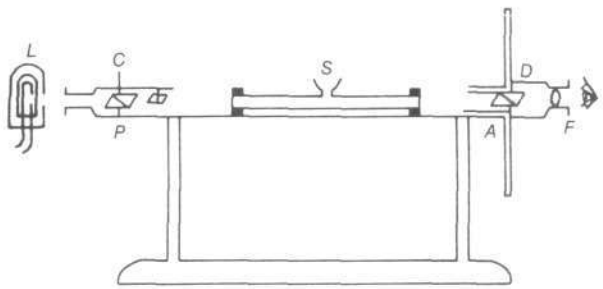
Figure 2
PASTEUR'S MODEL FOR BIOMOLECULAR GEOMETRY: THE LEFT-HANDED AND RIGHT-HANDED HELIX

Pasteur hypothesized that left-handed and right-handed helices are the basic geometric model for biological molecules. The helix is constructed by rotational action—generating a self-similar curve around the surface of a cylinder or a cone. The self-similar spiral (rotational action) proceeds around the cylinder or cone at a constant angle (pitch). Left- and right-handed helices are mirror images of each other. Before Pasteur's work, the prevailing view held that there were totally distinct and fixed chemical species, which arbitrarily combined or "broke up" as a cluster of billiard balls.

Figure 3
ICELAND SPAR AND POLARIZATION

Some crystals, including Iceland spar (known as calcite, $CaCO_3$), have the property of double refraction: a beam of light is split in two when it enters the crystal. These two beams are perpendicularly polarized; one beam, called "ordinary," behaves normally and its wave front is perpendicular to the direction of propagation. The other beam, the "extraordinary," has a wave front that is not perpendicular to the direction of propagation. The ordinary (O) and extraordinary (E) beams in a doubly refracting crystal can be separated in a Nicol prism, a crystal of Iceland spar whose natural shape is shown in (a). To make the Nicol prism, the end faces are cut at a more obtuse angle, as shown along the dotted line in (b). The crystal is then cut along the shorter diagonal, shown by the jagged line, and cemented together with Canada balsam. As depicted in (c), the index of the balsam totally reflects the ordinary ray (O), while transmitting E.





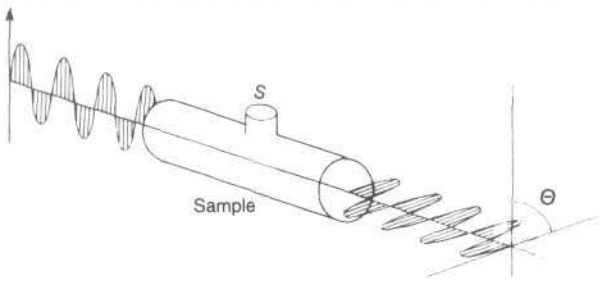
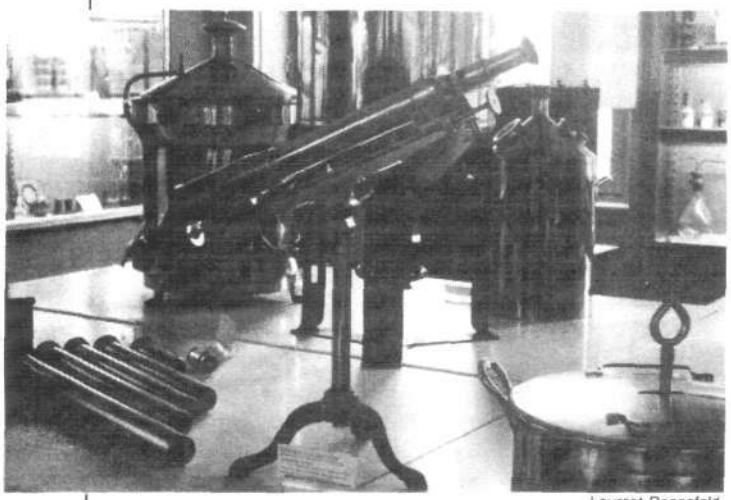


Figure 4
PASTEUR'S POLARIMETER

The polarimeter is used to measure the angular degree (Θ) of optical activity—the power of rotation of plane-polarized light of a substance. A fixed Nicol prism (a crystal of calcite), P, *is the polarizer. Pasteur's light source,* L, *was a flame; today monochromatic light is used. The second Nicol prism,* A, *is called the analyzer, which is attached to a rotating disk,* D, *graduated in degrees and fractions of degrees. The sample is placed in the central cylinder,* S, *which has clear glass ends. A third small Nicol prism at* C *rotates through a small angle to divide the viewed field into halves of unequal brightness through the eyepiece,* F *(as is often done for focusing in a camera view finder). The zero point is where the two fields are brought to equal intensity by means of this rotation.*

Rotation of A *through a certain angle to the left or right, brings the two fields to equal intensity of brightness. The number of degrees through which* A *is rotated measures the degree of polarization (right or left) of the sample.*



Laurent Rosenfeld

Pasteur's polarimeter in the Pasteur Institute museum.

ferent groups tetrahedrally. The scientists credited with discovery of the basic tetrahedral organization of compounds involving carbon—Kekulé, van't Hoff, and le Bel—themselves credit Pasteur's hypothesis of a possible Platonic tetrahedron organization for being the foundation for their own ideas on the tetrahedral geometry of carbon compounds.

Pasteur based his hypotheses about the geometry of biological substances on their degree of optical activity, or ability to rotate the plane of polarization of plane-polarized

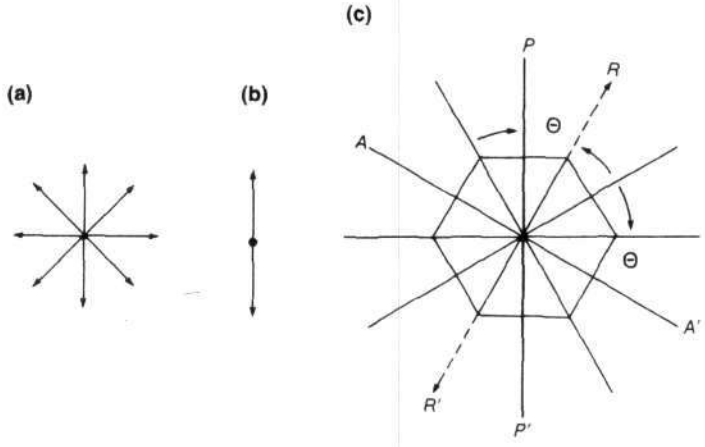


Figure 5
PLANE-POLARIZED LIGHT

Natural light has waves that are linearly polarized in all possible transverse directions. A wave front in a beam of natural light is depicted in (a), advancing toward the reader from the plane of the paper. The point is an end view of the axis of the wave. A linearly polarized light wave is shown plane-polarized in a vertical direction in (b). In (c), light polarized along P-P′ *enters a hexagonal crystal along the optical axis. When the light exits the crystal, it is vibrating in the direction* R-R′*, after having been rotated through angle* Θ. P *is the plane of polarization in the polarizer and* A *is the plane of polarization in the analyzer.*

light. The extent of rotational action depends upon the wavelength of the light, the path length, and the concentration of the material (if it is in solution). The rotational action can be observed and measured in a polarimeter when a polarized beam is passed through liquids, solutions, or vapor. The inherent dissymmetry of the molecules in the substance determines the character of the rotation. Thus, through his work on molecular dissymmetry Pasteur established the method of approach upon which optical biophysics or biological spectroscopy is based.

A significant amount of information about the "structure," "dynamics," and "energetics" of biological molecules can be adduced by focusing a beam of known wavelength from the electromagnetic spectrum upon them and observing the patterns of optical activity—diffraction, emission, absorption, and so forth. The widespread successful use in the 20th century of X-ray diffraction patterns and more modern technologies such as multiparameter light scattering including the more specific circular intensity differential scattering, nuclear magnetic resonance, electron paramagnetic resonance, and forms of fluorescence all rely upon the Pasteurian approach.

When trying to advance knowledge of a biological substance below the levels of observable resolution, one can observe the way in which the substance emits, scatters, diffracts, or absorbs various qualities of light. Thus, a map is made from a higher domain of the characteristics of the molecular action by the way in which it affects the beam. The principle is one of adducing the nature of an object by the shadow it casts. Since the most fundamental aspect of living matter is the way it utilizes or organizes electromagnetic radiation (sunlight) for growth, the procedure established by Pasteur establishes a means of indicating basic knowledge about the biological material in question.

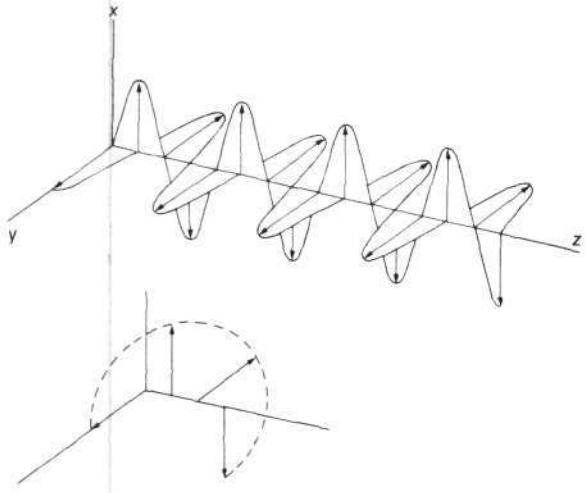


Figure 6
CIRCULAR AND ELLIPTICAL POLARIZATION OF LIGHT

Most biological spectroscopy today does not utilize plane-polarized light, but circularly or elliptically polarized light. If the source emits light polarized in both xz *and* yz *planes, and in the same phase, then the two waves superimpose to produce another plane-polarized wave. If the phase difference is* π/2*, as shown, then the path down the* z *axis is helical. When the amplitudes of the two waves are equal, and if the phase difference is* π/2*, then the resultant wave is said to be circularly polarized. If the two components along* x *and* y *are unequal in amplitude, the resultant path is elliptically polarized.*

Biosynthesis and Synthetic Geometry

Prior to Pasteur's application of this geometric method to biology, there were three nodal points in the explicit modern geometric knowledge of life:

(1) *The discovery and elaboration by Leonardo da Vinci, Luca Pacioli, and their circle, based upon the groundbreaking conceptions of Nicholas of Cusa, that living matter "grows" according to the particular form of self-similar geometries that conform to "golden section" or "divine proportion"* ratios. Cusa had established that the nature of a universe in which life is expressed is the *least action* or *maximum-minimum* principle. Cusa's expression of least

action is known as the *isoperimetric principle*, for which a minimum closed rotational action encompasses a maximum area. From a basic geometric standpoint, an isoperimetric rotational action can either "spin" in a left-handed or a right-handed direction while characterizing the same maximum area. Thus, it is not accidental that plasma physicists have discovered left- and right-handed force-free plasma filaments, that astrophysicists have discovered left- and right-handed astronomical structures, and that biologists have discovered the ubiquitous nature of left- and right-handed biological helices. Light itself, of course, can be circularly polarized left or right. The universal nature of "handedness" in fundamental biological phenomena, astronomical phenomena, and plasma physics phenomena is not caused by some mystical chiral "force" or an epiphenomenon of the reductionist molecule, plasma filament, or astronomical structure in itself. Instead, it is a projection of the fact that the universe, since it was constructed, must be consistent with principles of basic synthetic or constructible geometry established by Cusa as the basis of modern science. Furthermore, Leonardo explored, from the standpoint of his teacher Cusa, the common hydrodynamic or wave features of light, water, air, and sound in the organization of our universe and sought to develop his discoveries as the basis for the unique, particular geometric features of living forms.

(2) *The remarkable presentation in 1611 by Johannes Kepler that "living" forms—flowers, bushes, trees, and so on—are governed by a fivefold or pentagonal symmetry, in contradistinction to nonliving crystalline structures such as snowflakes, which are geometrically "packed" or organized in a sixfold or hexagonal symmetry.* Kepler explained that the fivefold or pentagonal characteristic of life, or what he called the "beauty or special quality of the shape" of living processes, is organized according to the geometric principles of the Platonic solids. He stated that living processes exhibit the geometric "playfulness of Nature":

> Of the two regular [Platonic] solids, the dodecahedron and the icosahedron, the former is made up precisely of pentagons, the latter of triangles but triangles that meet five at a point. Both of these solids, and indeed the structure of the pentagon itself, cannot be formed without the divine proportion [golden section] as modern geometers call it.

(3) *The establishment by the group of Leibniz, Huygens, and their collaborators such as Leeuwenhoeck et al. of the geometric language not only for measuring growth (the Leibnizian calculus), but also for understanding the way in which light moves as an advancing "wave front."* Leibniz put into modern scientific form the principle of *least action* from the standpoint of his predecessors, Cusa and Kepler, as an ordering conception for understanding processes in the universe. Specifically, Leibniz elaborated what he called the *geometry of situation* (analysis situs) as being primary. Huygens and Leibniz also discovered the phenomenon of *double refraction* resulting from Iceland spar crystals, which opened the door for science to unlock, control, and manipulate light beams. Leibniz's circle also perfected the use of the modern light microscope for biological study. The immediate forebears of Pasteur—Fresnel, Biot, Arago, and Malus—all viewed themselves as direct students of the double refraction experiments.

Pasteur's Discoveries

Pasteur submitted his doctoral dissertation in basic physics, *A Study of the Relative Phenomena of Rotatory Polarization of Liquids*, on Aug. 23, 1847, in which he proposed that the rotary polarization of liquids could be applied to solving diverse problems of chemistry. Among the chemical problems he cited was his own scientific jumping-off point: the *isomorphic* problem presented by the German crystallographer Eilhard Mitscherlich (1794-1863), who was trained at Göttingen University. Mitscherlich's problem concerned the sodium-ammonium double salt crystals—the tartrates and paratartrates. In his dissertation, Pasteur states that he will apply the insights of geometric physics, crystallography, and geometric optics to solving certain basic dilemmas confronting chemistry.

Three days later, Pasteur submitted a second dissertation, this one in chemistry, *Researches on the Saturation Capacity of Arsenic Acid: A Study of the Arsenites of Potash, Soda, and Ammonia*. Here he established the particular "Pasteurian" method of precisely measuring the angles of left or right orientation of the crystals of the arsenic compounds of potassium, salt, and ammonia, then comparing the facet angles of the crystal to precise angle computations in the polarimeter of the degree of rotation of the plane-polarized light. His papers of this period contain precise tables of these angular ratios. Based upon this knowledge, he then formulated hypotheses about the chemical and physical properties of the substance. In short, Pasteur operated on the principle that geometry was primary, determining the physical and chemical properties.

The Mitscherlich problem from which Pasteur started involved two crystalline salts of ammonium and soda. Double soda and ammonium tartrate, discovered by Carl Scheele in 1770, is found in wine barrels as a thick crusty material related to fermentation. Paratartrate or racemic had been produced by accident by an Alsatian industrialist named Kestner. Mitscherlich had established that both tartrate and paratartrate have the exact same chemical composition, the same crystalline shape, the same precise angles, the same specific weight, the same double refraction and, therefore, the same angles between the optical axes. When dissolved into water, their refraction is identical. Both substances, in short, manifested the exact same physical and chemical data: specific gravity, index of refraction, melting and boiling points, solubilities; they also had identical crystalline form, with the same nature and number of atoms arranged in the same way at the same distances. In fact, it was this arrangement that was the basis of the prevailing definition of a fixed chemical species. Nonetheless, the tartrate rotated the plane of polarized light, while the paratartrate did not. So the species was not "fixed" with respect to action, only with respect to its structural components.

As Pasteur stated:

> *I could not understand that these two substances*

could be as similar as Mitscherlich said, without being completely identical. To be able to be surprised when needed is the first movement of the mind toward discovery.

In May 1848, Pasteur announced that he had discovered under the microscope small hemihedral facets on the crystals of all 19 tartrate compounds he had studied. In all cases, the hemihedral facets on the crystals were inclined in the same direction as the optical activity: In other words, crystals with a hemihedral facet to the left rotated the plane of polarized light to the left, and there was a relationship as well between the angle of rotation and the angle of deviation of the facet. When equal amounts of crytals were present between those that were hemihedral-left and those that were hemihedral-right, the mixture was optically inactive. The optically inactive crystals, consisting of an equal mixture of left- and right-oriented ones, were the sodium-ammonium paratartrates.

To quote Pasteur:

> I had the happy idea of orienting the crystals [in the same direction under the microscope]. . . . Then I saw in the confused mass of the paratartrate crystals that there were two kinds. Among some, the dissymmetrical facet was oriented to the right, among others, toward the left. In other words, the paratartric was formed of two kinds of crystals; some dissymmetrical to the right, others dissymmetrical to the left. And the crystals that were dissymmetrical to the right were similar to that of the ordinary tartrate. Another idea naturally came to my mind. Right-handed crystals had a complete identity of shapes with tartrate. Following the logic of my preconceived idea, I separated from paratartrate crystals those right-handed crystals.

The right-handed crystals shifted the plane of polarized light to the right, exactly as did tartrate. The left-oriented crystals were optically active to the left. The mixture of the two was optically inactive.

Thus, Pasteur established that the geometric organization of space determined the nature of optical activity! Furthermore, he demonstrated the inadequacy of the then-prevalent notion of a "chemical species" as a fixed form of constituent atoms; instead he oriented the investigator to studying the relationship between the geometric qualities of the molecule and its active interaction with light.

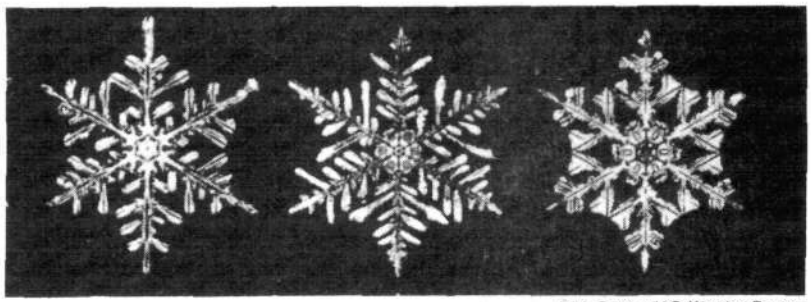
In 1850-1851, Pasteur published similar studies on asparagine and its derivatives (aspartic acid, malic acid), the aspartates, and malates. In 1852, he demonstrated that optical activity is intimately associated with life by establishing that the products of living syntheses (organic products *in vivo*) were optically active, while the products of the same chemical syntheses when performed in the laboratory were optically inactive. He also explained the existence of *mesotartaric acid*, which was optically inactive in what he described as the "untwisted" state of the molecule, while optically active in its "twisted" state.

In the basic crystallographic studies that he pursued through 1856, Pasteur established that there were four tartrates in all: (1) the levorotatory or l-tartrates; (2) the dextrorotatory or d-tartrates; (3) the racemic or mixture of d- and l-tartrates; and (4) the mesotartrates (i-tartrates), which are optically inactive. One of the principal methods Pasteur developed to separate the components was an ingenious application of solubility properties. While the salts of l- and d-tartaric acids with metals or ammonium had identical solubility properties, the salts formed with optically active natural bases such as quinine had very different properties. The differences in the solubility of the d- and l-salts could then be used to separate the mixture.

Pasteur applied his insights to a detailed optical study of the differentiation between living and nonliving syntheses. In a mature assessment of his work presented in 1874 *Observations on Dissymmetrical Forces*, Pasteur described it as follows:

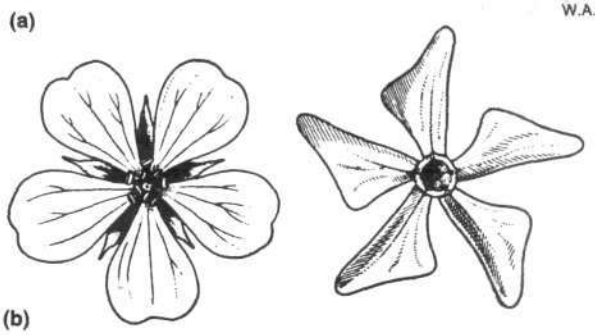
> All mineral products and all of the numerous organic substances which one obtains in the laboratory lack molecular dissymmetry and the correlative action on polarized light. Both of these properties, on the other hand, are inherent in a great number of natural organic substances most important from the physiological standpoint: such as cellulose, sugars, albumin, fibrin, caseine, certain vegetal acids, etc. . . .
>
> The opposition between the existence of chemical actions of symmetrical order and of dissymmetrical order was introduced into science the day when it was recognized that the physical and chemical properties of right and left tartaric acids (identical whenever inactive nondissymmetrical bodies are set going in their presence) became, on the contrary, dissimilar when these acids are under the influence of active, dissymmetrical bodies. The role of molecular dissymmetry was also introduced as a factor to the phenomena of life, the day when it was verified that a living well-ordered ferment takes to fermenting right tartaric acid easily, while not to left tartaric acid.
>
> Living beings take the carbon necessary to their nutrition from right tartaric acid in preference to carbon from left tartaric acid. Hence, since there is dissymmetry in the immediate natural laws—notably in those which can be considered as primary—namely, in the immediate constituent principles of living cells; since vegetables produce simple dissymmetrical substances to the exclusion of their inverses; since, in contrast to what is produced in our laboratory reactions, the vegetable kingdom does not form exclusively paratartrates or simple inactive substances; and since it probably forms these latter substances only through oxidations or secondary reducing actions similar to those of mineral chemistry, as natural oxalic acid or acetic acids show; I conclude that it is absolutely necessary that dissymmetrical actions preside during life over the elaboration of the true, immediate natural dissymmetrical principles.

Furthermore, Pasteur did not rule out the ability of future generations of scientists to leap over the barrier established between the mineral and oganic kingdoms by pursuing the



(a)

W.A. Bentley/U.S. Weather Bureau



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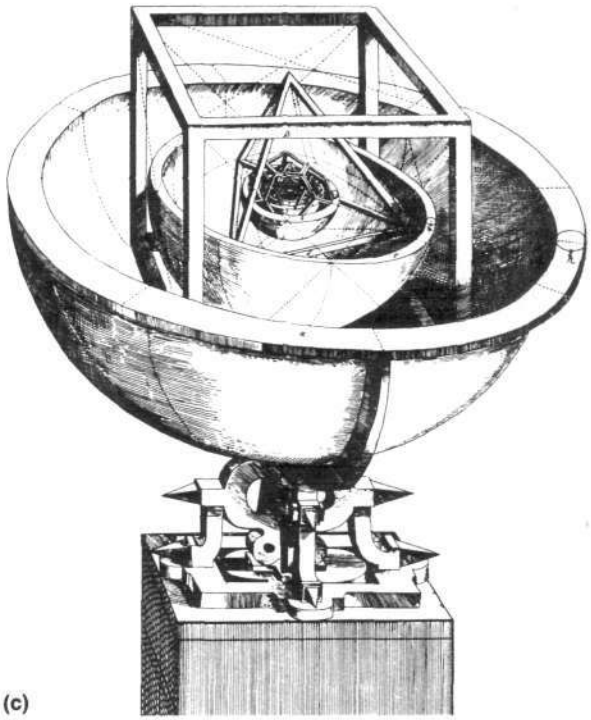


(c)

Figure 7
KEPLER'S GEOMETRIC ORDERING OF NATURE
The sixfold symmetry of inorganic nature can be seen in snowflakes (a), while the fivefold symmetry of living matter is evident in the shape of flowers (b). Kepler's model of planetary orbits (c) was constructed by alternately inscribing and circumscribing the five Platonic solids in six spheres representing the orbits of the six inner planets. The illustration shown here appeared in Kepler's Mysterium Cosmographicum, *published in 1595.*

nature of dissymmetry:

> Success in this avenue will give access to a new world of substances, reactions, and probably as well, to organic transformations. It is at that point, it seems to me, that we should locate the problem not only of the transformation of species but also of the creation of new species. Who could say what would become of plant and animal species if it were possible to replace cellulose, albumin, and their cognates in living cells by their inverses?

Pasteur had reached these provocative ideas by applying his method of geometric optical biophysics to study the process of *fermentation*, through which work he established that certain microorganisms "discriminate" between left- and right-handed forms and selectively metabolize one or the other.

The Biology of Fermentation

Pasteur began his work on fermentation in 1855, shortly after becoming the professor of chemistry and dean of the Faculty of Sciences at Lille. In 1855, he published a paper showing that crude amyl alcohol found in industrial fermentations in the Lille area was composed of two isomeric forms—one optically active and the other not optically active.

When he began his studies, the hegemonic scientific view traced the optical activity of amyl alcohol to the optical activity of the sugar that began as the starting substance; this prevailing view asserted that fermentation was purely a "chemical" process in which fixed chemical properties were transferred unchanged from the starting building blocks to the final product. Pasteur, instead, argued that the molecular structure of amyl alcohol and sugar differed too much from one another for there to exist any transfer of optical activity per se from one to the other. His hypothesis was that fermentation was the result of living organisms.

In 1857, Pasteur published a series of groundbreaking memoirs on fermentation. In his paper on lactic acid fermentation, Pasteur wrote:

> Just as an alcoholic ferment exists—namely, brewer's yeast—which is found wherever sugar breaks down into alcohol and carbonic acid—so too there is a special ferment—a lactic yeast—always present when sugar becomes lactic acid.

In terms of the basic geometry of biological processes, lactic acid was a most interesting case, as Pasteur discov-

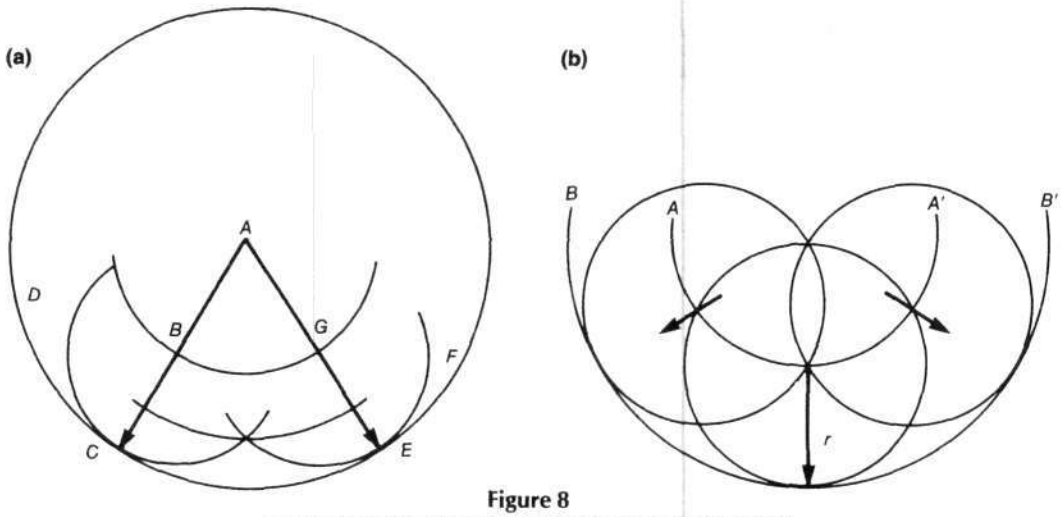


Figure 8
HUYGENS'S PRINCIPLE AND CIRCULAR ACTION

Huygens's principle is a geometric method for constructing the shape of an advancing wave front. According to Huygens, every point in the wave front may be considered the source of a small secondary wavelet, *that spreads out in all directions with a velocity equal to the velocity of propagation of the wave. The new wave front is constructed through a surface tangent to the secondary wavelets—the so-called envelope of the wavelets. Adapted from Huygens's original drawing, (a) shows* DCEF *(the outer circle), a wave emanating from luminous point* A. *The particles* B *and* G *generate secondary wavelets. In (b), the wave front advances from* AA' *to* BB'. *If* v *represents the velocity of propagation, the radius* (r) *of the spherical wavelet is defined as* r = vt.

ered. Lactic acid is a classic example of the way in which four different groups attach *tetrahedrally* to an asymmetric central carbon and one structure is the mirror image of the other.

He established that the "lactic yeast" was a living organism that utilized nitrogenous substances in the fermentation medium as its food. Therefore, the nature of the fermenting medium (its acidity, chemical composition, and so forth) determined the quality of the total fermentation process itself. By 1859, Pasteur had developed a medium, known as "Pasteur's fluid": a solution of sugar, yeast, and ammonium salt that was most conducive for lactic fermentation.

In his study, *On Ammonium Paratartrate Fermentation*, Pasteur established that only the right-handed form was attacked by the microorganism, leaving the left-handed form alone. Thus, the fermenting fluid became more and more optically active to the left as the process unfolded. He linked this "geometric selection" to the nutritional needs of the particular "living organism" responsible for the fermentation. Subsequently, he extended his studies to fermentations involving butyric, acetic, and alcoholic processes.

In 1860, Pasteur published his classic memoir, *On Fermentation*, in which he described the way that alcoholic fermentation produces not only carbonic acid and ethyl alcohol, but also glycerin and sucinic acid, as well as trace amounts of cellulose, "fatty matters," and "indeterminate products." Thus he established that fermentation was not a simplistic "chemical" conversion of sugar into carbonic acid and alcohol from fixed chemical building blocks. The complexity of the process, he explained, was the evidence of the activity of a living organism.

He described, in fact, how he had succeeded in producing yeast and alcoholic fermentation in a medium free of organic nitrogen. He took a pure solution of cane sugar, added an ammonium salt and the minerals obtained by incineration of yeast, and then sprinkled in a trace of pure brewer's yeast. Pasteur concluded that the yeast must *grow and develop* in this medium by assimilating its nitrogen from the ammonium salt, its mineral constituents from the yeast ash, and its carbon from the sugar. He also succeeded in cultivating the specific mold *Penicillium glaucum* in a medium of pure water, cane sugar, phosphates, and ammonium salts.

In 1861, Pasteur isolated a specific butyric ferment with two unique features: first, unlike brewer's yeast and lactic ferment, it was a motile animal; second, microscopically, the liquid from a butyric fermentation had the curious quality that the rodlike infusoria lost their motility and apparently "life" at the margins of the glass slide, but remained active and "alive" in the middle of the slide. Why?

Pasteur hypothesized that the reason had to do with the fact that there was atmospheric air at the edges of the slide. He then passed a current of air through a fermenting solution, and observed the end of all motility. He had established that butyric fermentation results from an infusorium that lives without free oxygen gas; this was the first proven example of an animal capable of living without free oxygen.

Since Pasteur had established that fermentation was a correlative of life and *caused* by living germs, his experimental work led directly into his subsequent famous disproof of spontaneous generation, and eventually to his positive development of the modern germ theory of disease. At a very early point, while in the midst of his fermentation studies, Pasteur foresaw the broadest implications of

this contribution: "What would be most desirable would be to push those studies far enough to prepare the road for a serious research into the origin of various diseases."

Pasteur's Roots

Pasteur was the direct heir of Monge's students from the Ecole Polytechnique and their German colleagues Alexander von Humboldt and Eilhard Mitscherlich, who discovered the phenomenon of polarized light, established the concept of "optical activity," and invented the principal scientific instrument that Pasteur utilized for his optical experiments—the polarimeter.

Dominique Francois Jean Arago (1786-1853), who succeeded Monge as the professor of descriptive geometry at the Ecole Polytechnique, became France's premier astronomer as the director of the Paris Observatory from 1813-1846. During 1805-1806, he collaborated with Biot on experiments on the refraction of light passing through the Earth's atmosphere. He was the roommate of Alexander von Humboldt from 1809-1811 at the very time that he invented the polariscope and polarimeter, which Pasteur later utilized for his spectroscopic work. From 1808 onward, following Malus's discovery of polarized light, Arago engaged in experiments passing beams of polarized light through a variety of gaseous and crystalline substances at various degrees of incidence to study light's properties. In 1811, he discovered chromatic polarization by using thin mica plates. White light polarized by reflection could, in passing through crystals, be split into differently colored beams.

In 1811, Arago also invented the polariscope and polarimeter, and a year later, he observed the special case of rotatory polarization, which Biot used in his general law of optics. From 1813-1815, Arago collaborated with Fresnel on a series of experiments on refraction in liquids and solids, which demonstrated the failure of the Newtonian theory of emission and particle attraction. Along with Fresnel, he became a vocal critic of the Newtonian emission theory of light. The prolific Arago later wrote the principal review article on polarization (1824) as well as biographies on Fresnel (1830), Young (1832), and Malus (1853).

Etienne Louis Malus (1775-1812), also a student of Monge at the Ecole Polytechnique, became the champion of Huygens's theory of light. In 1807, Malus published his *Traité d'optique*, which described the geometrical properties of a system of contiguous rays of light in three directions. In his famous geometric discovery, Malus established that light rays emanating from a point source, after being reflected or refracted from a surface, are all normal to a common surface; however, after a second reflection or refraction, they will no longer have this property. Malus used this geometry to establish the absurdity of Newton's conception of the light particle as a point mass with sides that "moved" like a ball bouncing into other balls. In a series of polemics against LaPlace, among others, Malus argued against the application of Newtonian mechanics to light beams. Instead, he demonstrated that Huygens's conception of the advancing wave "envelope" was correct.

In 1810, the same year that he discovered polarized light, Malus reestablished Huygens's methodology in *The Theory of Double Refraction*, by deducing the law of double refraction from the principle of least action. While working on double refraction, he discovered that a ray of sunlight reflected at a certain angle, from a transparent medium, behaves in exactly the same way as if it had been ordinarily refracted by a double refracting medium. He found that each medium had a characteristic angle of reflection for which this happened. In his subsequent *Memoir on New Phenomena of Optics* (1811), he utilized the term polarization for the first time.

From the standpoint of the internal history of spectroscopy itself, it is also interesting to note that Joseph v. Fraunhofer, in 1814, observed his famous lines of the solar spectrum only a few years after Malus made the modern discovery of polarized light. Later, in 1862, the son of the great German crystallographer Eilhard Mitscherlich (who discovered the phenomena of isomorphic crystals and formulated

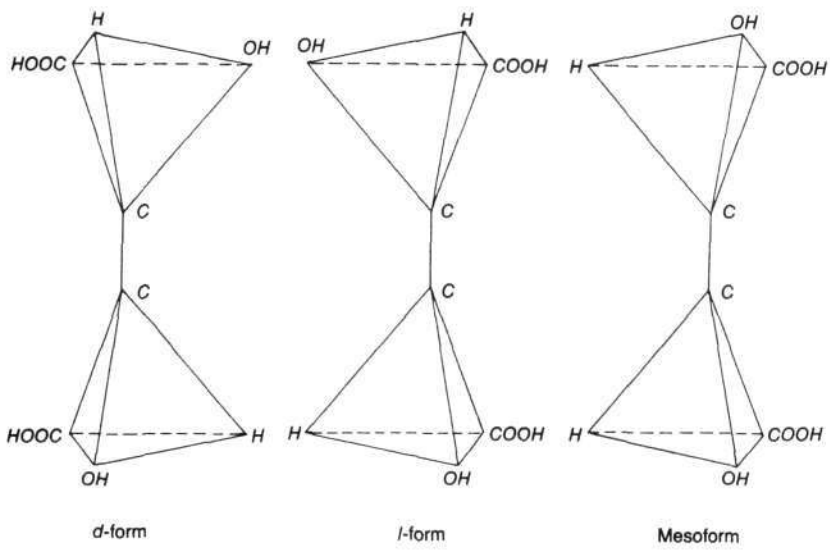


Figure 9
OPTICAL ISOMERS OF TARTARIC ACID AND THE TETRAHEDRON
Pasteur showed how two compounds with exactly the same chemical composition can differ in being mirror images of one another—optical isomers. In tartaric acid, shown here, neither the upper nor lower tetrahedron in the right-handed d *form can be rotated to agree with the corresponding tetrahedron in the left-handed* l *form. They are instead mirror images of each other. Meanwhile, in each of these forms the upper tetrahedron is* not *a mirror image of the lower. In addition to the mirror image forms, there is a third mesoform which is optically inactive, because the upper tetrahedron is the mirror image of the lower.*

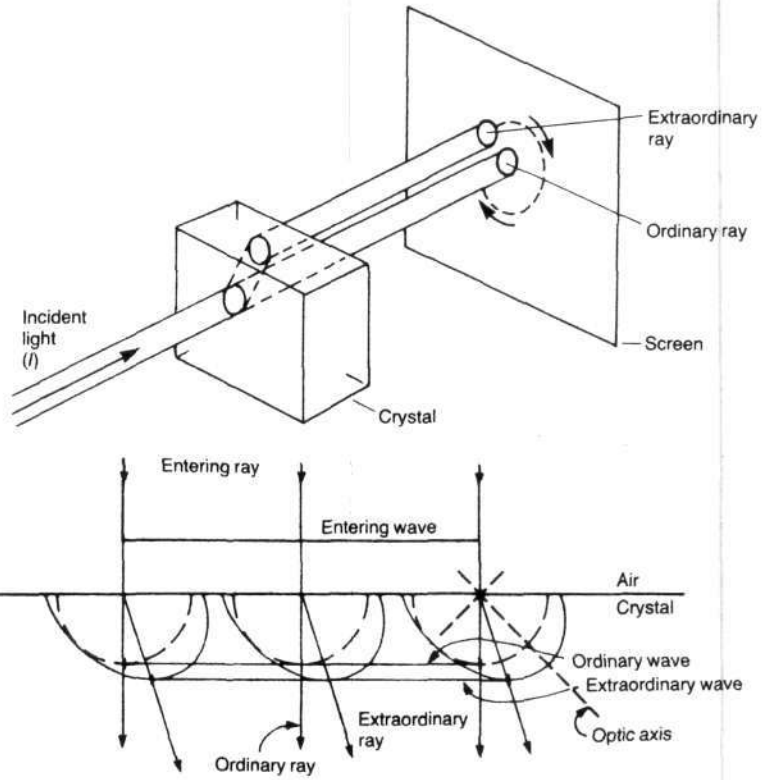


Figure 10
DOUBLE REFRACTION AND POLARIZATION

In (a), a focused beam of natural light is split into two beams by a doubly refracting crystal (see Figure 3). Huygens showed that one ray (the ordinary ray) obeys the normal law of refraction. The other ray (the extraordinary ray) has a refractive index that depends on the rotation of the crystal. The two rays are plane-polarized at right angles to each other. The light propagates at different velocities in different directions: The ordinary ray propagates with a classic Huygens spherical wave front; the extraordinary ray, with an ellipsoidal wave front, as depicted in (b).

Crystals have an optic axis; that is, one or two directions along which the light is not doubly refracted.

the tartrate/paratartrate problem that Pasteur solved) made one of the critical discoveries for spectral analysis. Alexander Mitscherlich established that chemical compounds, like metals and gases, have characteristic spectra that differ from the metallic element.

Augustin Jean Fresnel (1788-1827), also a student of Monge, began his work on geometric optics in 1814 when he articulated the "pulse wave" hypothesis as a devastating challenge to Newton. By studying the aberrations in starlight transmissions, Fresnel developed an explanation of diffraction phenomena and fully developed the mathematics of *transverse waves*.

On Method

Pasteur, who in fact was trained as a physicist at a time that living processes were viewed as the most appropriate field of study for physics, demonstrated the ability of biological syntheses to generate products that rotate the plane of polarized light. In contrast, he demonstrated that the exact same "chemical combination" in the laboratory outside of living systems generated products of the same precise chemical structure and physical properties as the biological products. However, they differed absolutely in one fundamental property: they were *not* optically active.

The geometric distinction between living processes and nonliving processes from the standpoint of their ability to reorganize light, or electromagnetic action, is the fundamental question of optical biophysics.

Pasteur's work constituted one of the precious few handfuls of knowledge in our understanding of the true fundamentals of life.

There is no better way to summarize the depth of Pasteur's overall scientific contribution than by recalling his own explicit ideas about the nature of fruitful scientific method. In his innaugural speech as dean of the new Faculty of Sciences at Lille on Dec. 7, 1854, Pasteur declared:

> Without theory, practice is but routine born of habit. Theory alone can bring forth and develop the spirit of invention. It is to you specially that it will belong not to share the opinion of those narrow minds who disdain everything in science which has not an immediate application. You know Franklin's charming saying? He was witnessing the first demonstration of a purely scientific discovery, and people round him said: "But what is the use of it?" Franklin answered them: "What is the use of a newborn child?"

Warren Hamerman, a founding member of the Fusion Energy Foundation, has a background in basic immunological research.

Notes

1. Most biologists readily accept that living systems do not obey the Second Law of Thermodynamics. However, they accommodate themselves to a compromise formulation elaborated by Ernest Schrödinger in the 1940s in his lecture series called "What Is Life?" in which he said that living systems have "negative entropy." By this he meant that although they do not obey the Second Law, living systems are a net drain on the universe, sucking negative entropy from the universe as a whole and thereby accelerating the process of entropy in the universe. More recently, the Belgian theorist Prigogine has reified the concept of negative entropy. In contrast, LaRouche's concept of negentropy grew out of his study of economic processes in the early 1950s,which he then applied to the history of the biosphere as a whole. For a fuller discussion of this, see LaRouche's textbook, *So, You Wish to Learn All About Economics?* (New York: New Benjamin Franklin House, 1984).

Commission on Space Sets a National Goal

A 50-year mission to colonize the Moon and Mars—and in the process revitalize the economy and restore the nation's cultural optimism.

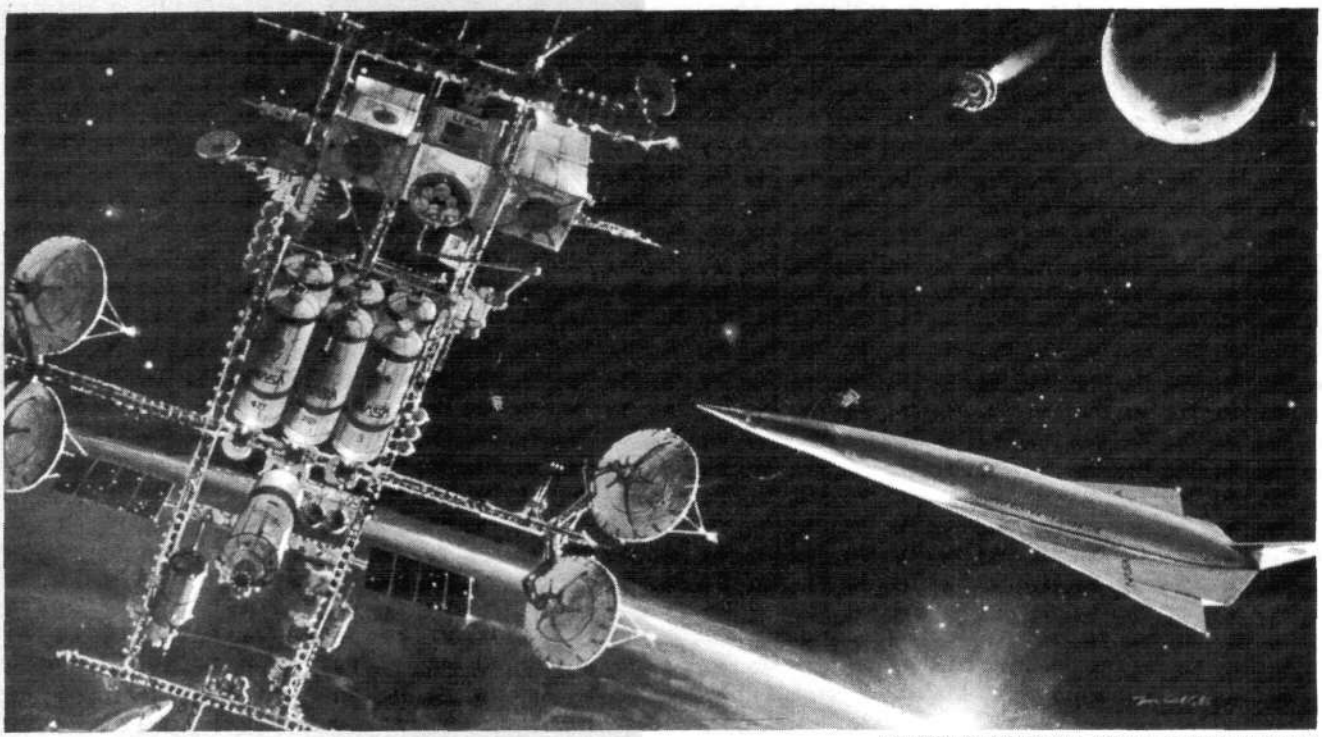


Illustration by Robert McCall, courtesy of Bantam Books, Inc.

An aerospace plane (foreground) heads toward an Earth Spaceport (left), which is in low-Earth orbit. A cargo transport vehicle (lower left) delivers goods, while a two-stage transfer vehicle (upper right) returns to the Spaceport.

Back to The Moon And On to Mars!

by Marsha Freeman

What better memorial to the Challenger crew than the report of the National Commission on Space, setting as a national goal a return to the Moon and a manned mission to Mars! The report, issued on the 25th anniversary of President Kennedy's speech launching the Apollo Project, gives the nation a 50-year plan for moving into space. As Kennedy did 25 years ago with his mission to the Moon, the mission proposed by this report has the potential to revitalize the nation's culture and economy, and uplift our youth and their education.

Pushing aside the media attacks on NASA, White House policy paralysis, and questions on whether the manned space program will get back on its feet and flying again, the National Commission on Space released its report May 23, outlining an exciting and optimistic future for the United States in space. Titled *Pioneering the Space Frontier,* the report states that "through vigorous leadership" this nation can begin to colonize our solar system at the turn of the century.[1]

The report assumes that the nation will not abdicate its

responsbility to maintain leadership in space, and will rebuild a robust Shuttle fleet. The time line proposal for the Moon-Mars mission has a tight schedule, each step depending upon the completion of the previous task. Any loss of time now, will set back the entire program.

The Commission also warns that:

> . . .it is imperative that the United States maintain a continuous capability to put both humans and cargo into orbit; never again should the country experience the hiatus we endured from 1975 to 1981, when we were unable to launch astronauts into space.

At a press conference in Washington to release the report, Commission chairman Tom Paine, a former Apollo-era NASA administrator, stated:

> Stronger leadership and greater vision will be needed, but the expected benefits to America and the world will greatly outweigh the costs. Our report recognizes that the final decision will be made by the American people through its leaders in Washington. The Commission is therefore not prophesying, but describing what the United States can make happen through vigorous leadership in pioneering the space frontier.

The report lays out the milestones for NASA to reach toward: initial operation of the space station, on time, by 1994; a manned outpost on the Moon by the year 2005; a first manned mission to Mars by the year 2015.

To accomplish these goals, the report outlines how the nation will have to push forward the frontiers in space transportation, new propulsion systems, life support technologies for living away from Earth, and new sources of energy. To accomplish these tasks requires long-range planning at NASA, in addition to a commitment for a steadily increasing level of funding indexed to the Gross National Product.

The benefits to the United States of pushing mankind to live in space will be seen in technology revolutions in energy, manufacturing, medicine, the life sciences, and the space sciences. Without the combined challenges of developing and deploying technologies based on lasers, plasmas, and new physical principles for the Strategic Defense Initiative and the Moon-Mars mission, the nation will not be ready for the 21st century.

Declaration for Space

In the report's introduction, the Commission states that its "vision is to make the solar system the home of humanity." It is not simply a question of doing long-term planning, the Commission indicates, but a renaissance in education and an orientation toward the future. "Our leadership role should challenge the vision, talents, and energies of young and old alike, and inspire other nations to contribute their best talents to expand humanity's future."

From the outset, the report makes the Commission's stand clear on the necessity for a national commitment to accomplish its goals, giving no quarter to the current mad push toward trying to commercialize or "privatize" the space program out of existence:

> As formerly on the Western frontier, now similarly on the space frontier, government should support exploration and science, advance critical technologies, and provide transportation systems and administration required to open broad access to new lands. The investment will again generate in value many times its cost, to the benefit of all.

The Commission also takes a clear position on the need for *both* an aggressive manned space effort and a strong program for space science. An "aggressive space science program" which is recommended, includes studying the structure and evolution of the universe, our galaxy, and our solar system, as well as the emergence and spread of life. Space science research should include astronomical facilities in Earth orbit and on the Moon; unmanned sample return missions from planets, moons, comets, and asteroids; a global study of the Earth; studies of the Sun; the search for planets around other stars; and the study of long-duration effects of microgravity on life.

The report formulates a program for "exploring, prospecting, and settling the solar system," starting with a return to the Moon in the year 2005 and the first manned expedition to Mars by 2015. The reason for going this time will be to settle human civilization in space, not just to visit.

The specific technologies that must be advanced for the overall program to be possible include the development of both the aerospace plane and advanced rockets, aerobraking for orbital transfer vehicles, closed ecosystems for living in space, electric launch and propulsion systems, nuclear electric space power, and tethers and artifical gravity facilities in space.

Included among the major milestones for the next 50 years are the development of new cargo and passenger transport vehicles by the year 2000 and extended use of the space station, which should be well in use by then. Five years later, robotic lunar surface operations should have completed detailed surveys of the Moon, and the first permanent outpost for astronauts would be started. During the next decade, detailed unmanned exploration of Mars would be completed, with samples returned to be examined and evaluated. By the year 2015, the first human outpost on Mars would be established, followed by colonization.

The report has "value only to the extent that its recommended space goals for 21st century America are adopted and acted upon," the Commission states. The report recommends that the President and Congress "direct the administrator of NASA to review the Commission's findings and proposed space agenda, and by Dec. 31, 1986, recommend a long-range implementation plan, including a specific agenda for the next five years."

Economic Benefits

The Commission no doubt could imagine the reaction of budget-balancing congressmen and accountants in the Office of Management and Budget to this "exciting vision of our next 50 years in space." Therefore the introduction specifies the important economic benefits to be derived from challenging the space frontiers:

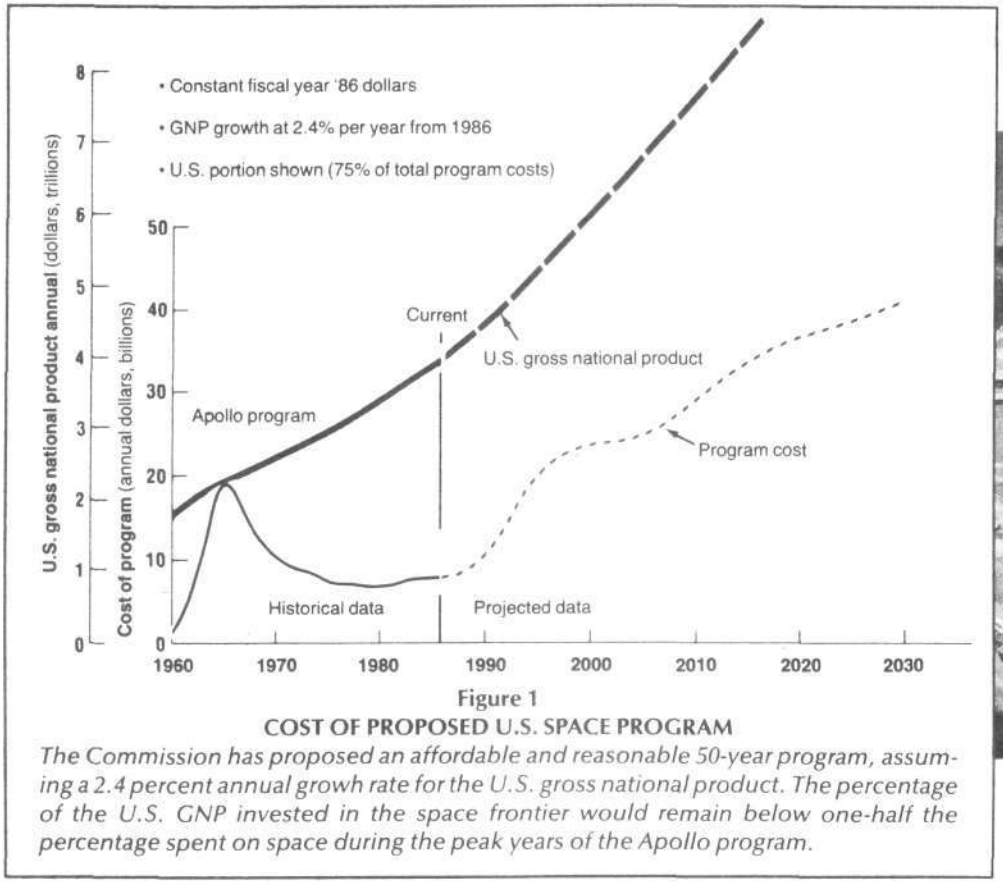
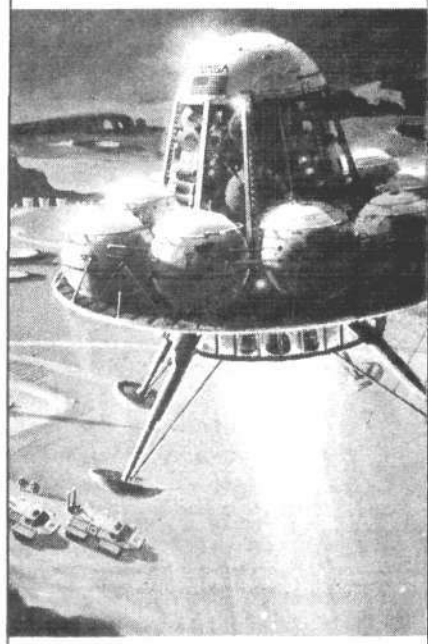


Figure 1
COST OF PROPOSED U.S. SPACE PROGRAM
The Commission has proposed an affordable and reasonable 50-year program, assuming a 2.4 percent annual growh rate for the U.S. gross national product. The percentage of the U.S. GNP invested in the space frontier would remain below one-half the percentage spent on space during the peak years of the Apollo program.



As we learned in World War II, government-academic-industry teams mobilized to accelerate advances in science and technology can build the foundations for new growth industries even though the original objectives were narrowly focused on military requirements. Wartime breakthroughs in jet propulsion, antibiotics, synthetic rubber, oil pipelines, nuclear energy, microwave radar, liquid-fueled rockets, radio guidance, electronic computers, and other systems led to America's high growth industries of the 1960s and 1970s.

The programs we recommend will motivate people, provide new standards of excellence, and stimulate many fields of science and technology. . . . Specific examples include artificial intelligence, robotics, teleoperation, process automation, hypersonic flight, low-cost global and orbital transport, optical communications and data processing systems, ultra-high-strength and high-temperature materials, supercomputers, wireless power transmission, pollution-free vehicles (electric and hydrogen-oxygen fueled), orbital antenna farms, closed-cycle ecology biosphere operations (which could revolutionize intensive agriculture), and myriad others.

The report continues that "in the last 50 years, government-sponsored research and development created 'enabling technology' in aeronautics and in communication satellites." During the next 50 years, it suggests, the government should provide the "enabling technology" for entire orbiting industrial parks.

To open up the Moon for industrial development and a new economic base of activity, the enabling technology will be transfer vehicles from low-Earth orbiting space stations. "When that second link in our space transport system is completed," the report says, "the event will compare in significance to the driving of the Golden Spike in Utah more than a century ago, that marked the completion of the transcontinental railroad."

Will we have to put the country in hock to achieve these ambitious space goals? The Commission projects that the rate of growth of the nation's Gross National Product (GNP) in the next 50 years, will average the same 2.4 percent that it did in the past 25 years. They recommend that the amount of money spent by NASA each year be a fixed percentage of the GNP, and that that percentage need be only half of what it was during the years of peak Apollo funding. This would mean that the NASA budget would be about 2 percent of the GNP, rather than the 4 percent it was during Apollo, or the 1 percent it is now. (See Figure 1.)

In a speech in summer 1985, Commission chairman Paine remarked that the most cost-effective space programs were done on a "crash basis," like Apollo. He described the capabilities available from a modestly growing NASA budget over the next 50 years, as "seven Apollo programs in the 20-50 year period."

The Highway to Space

Before we can even think of going back to the Moon, or sending our children off to Mars, this nation will have to extend and upgrade its space transportation capabilities. (See Figure 2.) Today, the United States has no way to take

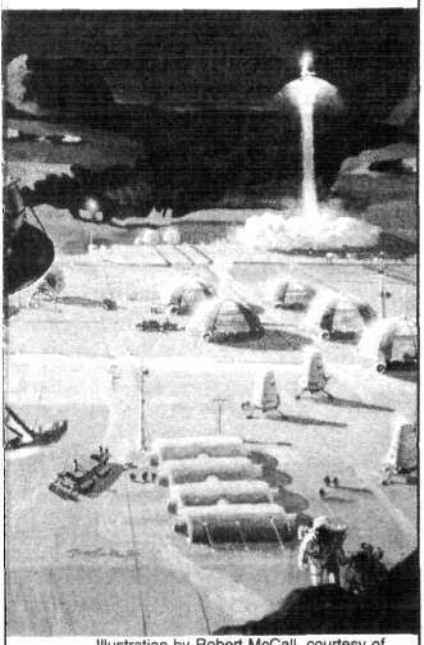


Illustration by Robert McCall, courtesy of Bantam Books, Inc.

A Mars lander arrives at a Mars settlement from the Mars Spaceport, while another lander (in the background) departs.

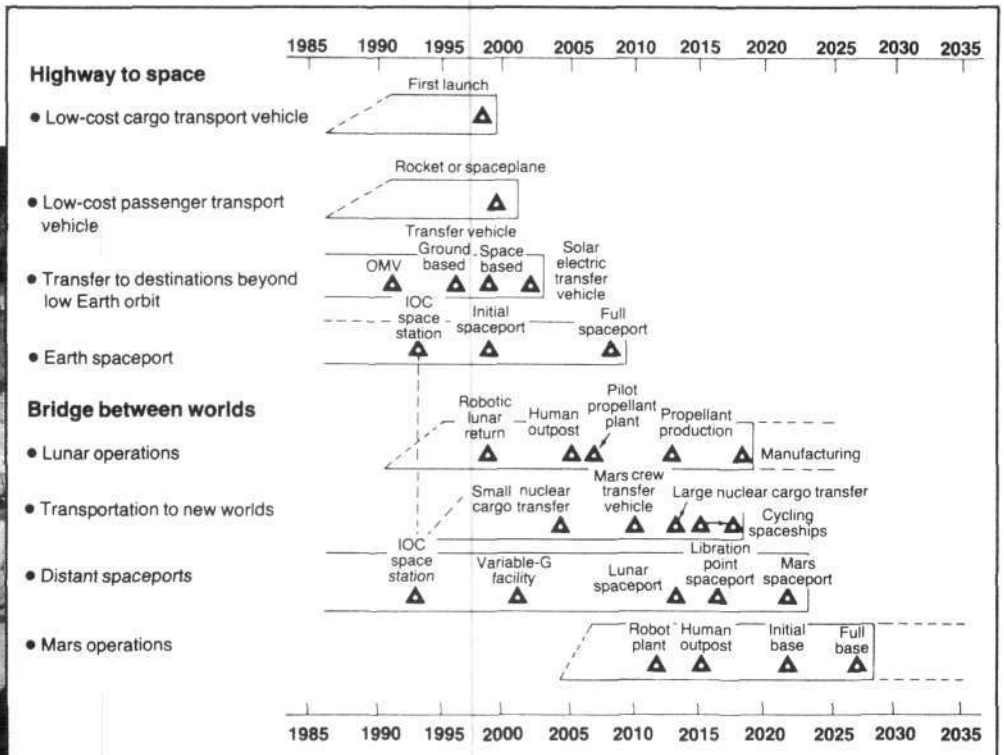


Figure 2

A PHASED APPROACH TO BUILDING THE HIGHWAY TO SPACE

The Commission's plan for a low-cost highway to space starts with economical new cargo and passenger transport vehicles, adding a transfer vehicle for destinations beyond low-Earth orbit, in conjunction with an orbital spaceport within 15 years. In the next 5 years, there would be initial robotic lunar surface operations, followed by a permanent outpost to support astronaut operations. In the next 10 years, robotic operations would begin on Mars, followed by a Mars outpost for human activity.

people to the Moon—the Space Shuttle can only orbit the Earth at up to 300 miles. But the Space Shuttle will be our railroad to a space station, and from there, other space transport vehicles will be designed for the lunar trip.

The Commission report is dedicated to the seven astronauts who lost their lives in the Jan. 28 Challenger mission. The report takes a strong stand on the need for the Shuttle, and explains the difficulties in the current shuttle as follows:

> The Shuttle represents an effort to build one vehicle to serve many roles. Meeting the diverse requirements for human transport to and from orbit, for orbital stay times of a week, and for transport of large and heavy cargoes to and from orbit, placed heavy demands on the technology available at the time the shuttle was designed. The inevitable result was a very complex and somewhat fragile vehicle. A long and difficult development program has resulted in an orbital transport system that is both expensive and technologically demanding to operate.
>
> Nevertheless, the Space Shuttle is a technological triumph and a magnificent achievement both in pioneering winged flight into space and in providing a reusable vehicle for spaceflight. . . . It has opened the Highway to Space.

By the turn of the century, our current Space Shuttles will be obsolete and at the end of their operational lives. The Commission states that the Shuttle "should be replaced by a new vehicle designed to meet all requirements for the transport of passengers and high-value cargo to and from orbiting spaceports. . . . This vehicle, optimized for passenger transport, may be smaller than the Shuttle. Since the space station will have been operating five or more years before passenger transport vehicles (PTVs) become operational, they will not need the capability for extended, independent stay times in orbit. . . . PTVs must be designed for reliable low-cost operations, even if this means increased development costs."

The report recommends that research into two "essentially different but complementary means to cost reduction" for passenger flight be conducted in parallel, to develop the next-generation Earth-to-orbit transport system. The first is the air-breathing aerospace plane, which the Air Force and NASA are now examining. The second line of research is to develop more advanced rocket systems for orbital travel, possibly using various kinds of hybrid engines and both liquid hydrogen and petroleum-based fuels. By 1992, both programs should provide enough data for the nation to make a policy decision on which technology should be developed to replace the Space Shuttle.

In addition, a specially designed cargo transport vehicle

should be developed, to separate the freight requirements from the passenger requirements. The goal would be to reduce the cost of getting a pound of cargo to orbit to about $200. These would likely be one-way only, similar to the Progress cargo ships the Soviets have used to resupply their space stations.

Once the space station is operational, it will provide the technology base and infrastructure to build additional, more specialized orbiting facilities. The Commission recommends the construction of a series of Spaceports as transportation hubs in space. These facilities will be used for the storage, repair, supply, maintenance, and launch of orbital transfer and other space-based vehicles.

From the Earth-orbiting Spaceport, new orbital transfer vehicles (OTVs) will depart to higher Earth orbits and the Moon. They could be chemically propelled, based on a modular design, where more fuel tanks could be added for longer journeys. The most energy-efficient way to bring this OTV back to the Earth Spaceport is to use aerobraking. This technique uses the upper atmosphere of the Earth to slow down the vehicle so it can dock with the Spaceport, conserving its onboard fuel.

The OTV would make use of in-orbit maintenance, refueling, testing, and repair at the Spaceport. The first OTVs could be unmanned, followed by passenger transports. The report warns that for this schedule to be maintained—OTVs operational by the turn of the century for returning to the Moon—the "United States space station must be kept on schedule for an operational capability by 1994, without a crippling and expensive 'stretch-out.'"

Going the at-least 35 million miles to Mars, however, requires a completely different generation of spacecraft from those that can go the quarter of a million miles to the Moon. Using the most advanced technologies based on today's propulsion, a Mars trip will require minimally *six months* of travel, as compared to the two days to the Moon. As Paine remarked at his press conference, the Commission report did not assume any breakthoughs in basic science for their projections, and more advanced technologies, such as fusion propulsion, could certainly shorten the trip time.

It is possible, however, that more conventional transport will have to be relied upon for the first Mars trips, in the second decade of the next century, to be followed by later advances. The report suggests the development of "cycling spaceships" which go only from Earth's Spaceport to a similar orbiting Spaceport at Mars. Similar in concept to the Mars delivery vehicles proposed by space scientist Krafft A. Ehricke in 1968, these spaceships could save time and energy by not slowing down at either planet, but transferring its passengers to space "taxis, which would go to the Spaceports." The cycling spaceships are actually moving space stations, with "substantial research facilities" and the other things passengers would want to have on board to make life comfortable throughout the six-month journey.

Bridge Between Worlds

The Moon is so close to the Earth that running "home" in case of emergency is still possible; but this is not so on Mars. When humans go there, they will have to take with them initially all of the food, water, air, other consumables, and equipment they need. For example, they will have to be able to perform semimajor surgery and take care of any other emergencies. No one would think of sending the first Mars crew out with technologies they are trying for the first time, so the Commission report wisely recommends that, *"many of the systems needed for reaching outward to the* planet Mars will be proven in the course of work in the Earth-Moon region."

Before full-scale lunar development can begin, a Lunar Spaceport will be in orbit, to "handle incoming and departing transfer vehicles. . . . The Spaceport will become a hub of activity as tons of habitation modules, cranes, scientific devices, lunar rovers, and processing and manufacturing equipment descend upon the Moon's surface. . . . Return

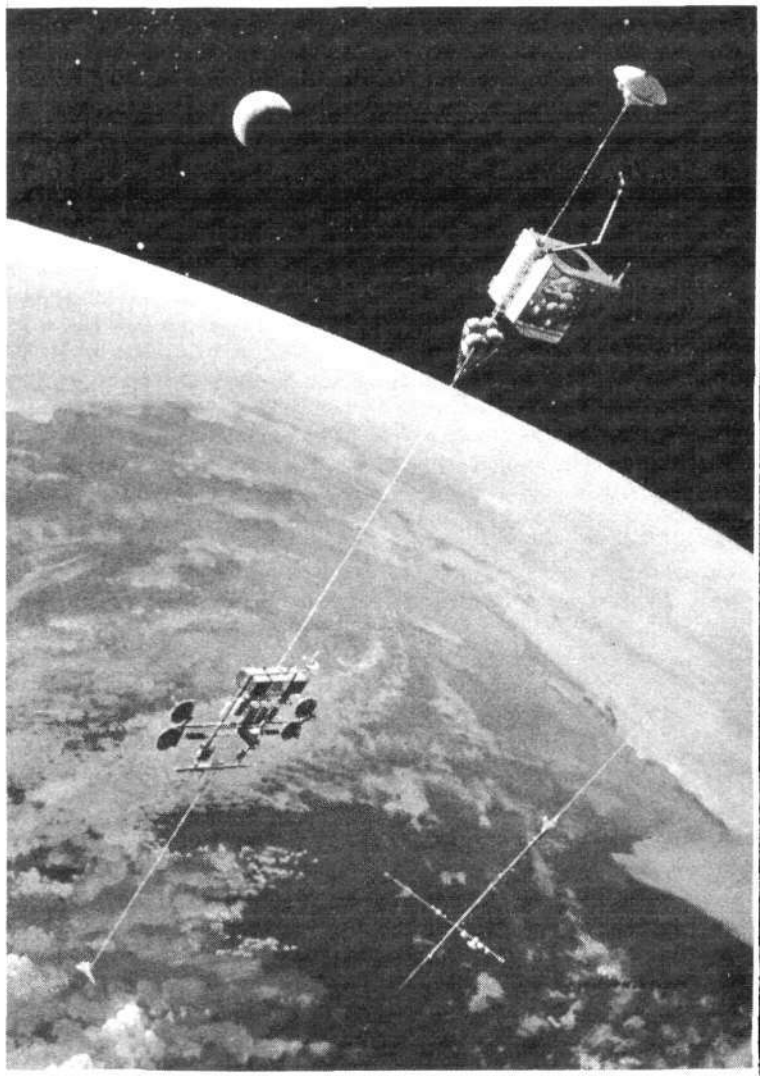


Illustration by Robert McCall, courtesy of Bantam Books, Inc.

In this scene from the early 21st century, an Earth Spaceport is in the foreground, with a transfer vehicle tethered at one end and a passenger vehicle tethered at the other. In the background is the proposed Variable Gravity Research Facility that will be used to determine the long-term effects of weightlessness and radiation on human beings in space.

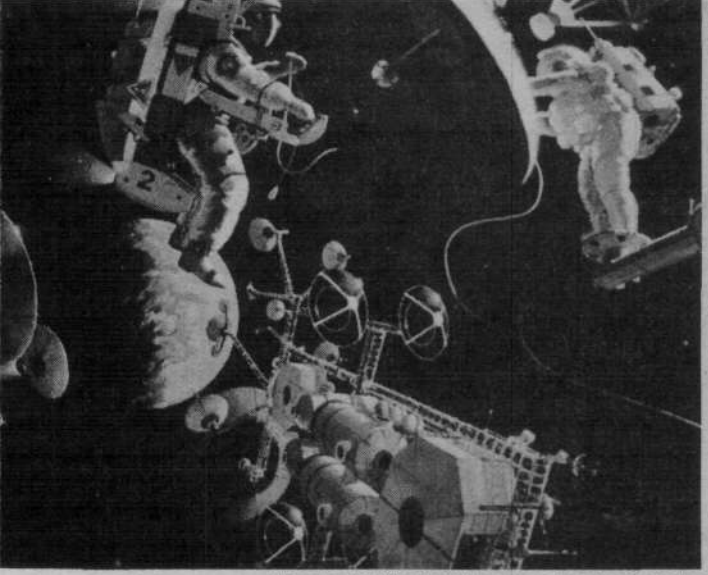


Illustration by Robert McCall, courtesy of Bantam Books, Inc.

Two astronauts installing a new dish antenna to improve the capability of a large communications platform. Below them is a commercial space station in geostationary orbit.

traffic from the Moon will provide lunar soil for shielding and processing," at the Spaceport itself, "thus providing oxygen, lunar metals, and possibly hydrogen," the report postulates. Because lifting material from the Moon requires only 5 percent of the energy it takes to lift the same mass from the surface of the Earth, it will eventually be much cheaper to bring materials to the Earth space stations from the Moon, rather than from the Earth, although the Earth is nearer.

Once lunar operations are in place, work to lay the basis for the Mars mission will include the development of self-sustaining biospheres, where virtually all waste is recycled and reused, and where food is grown for "local" consumption. Robotic industrial processing techniques and automated factories that will be needed on Mars will be "debugged" in orbital factories and on the Moon. Full lunar industrializiation—including mining, propellant production from the Moon's abundant oxygen, the processing of metals and other raw materials, and manufacturing and fabrication—will be the "growth industries" of the next century.

Operations on Mars

A Mars-orbiting Spaceport will "serve as a base for scientific investigations of the Martian surface, and will be a node for incoming and outgoing crews and equipment," the report states. In terms of a Mars outpost, the report poses the possibility that the tiny Martian moon, Phobos, could be used virtually as a space station, as it orbits only 6,000 miles above the Martian surface. Because Phobos is so small, it will require very little energy to land there. It is also possible that Phobos may be rich in volatile elements, like oxygen and hydrogen, and that a processing plant could be established there. "The propellants obtained from this plant will support future Mars operations, and greatly reduce the necessary cargoes transported over the long supply line from Earth," the report suggests. It also explains that:

> The great distance of Mars will dictate not only the development of complete and fully redundant biospheres for operation there, but also the establishment of two or more bases, for example, both on the planetary surface and in orbit, so that a serious problem occurring in one of the bases can be overcome by quickly transferring personnel from the affected base to another.

The Commission members also examined the kinds of surface transport required for operations on Mars. "There is a logical sequence of experience for the design of land-roving vehicles both for the Moon and for Mars. . . . For long-distance traverses of the surfaces, there will be enclosed vehicles, equipped with full life support systems, in which people can live and work in shirt-sleeve environments for many days."

"For short trips in the vicinity of outposts and bases, vehicles roughly similar to the lunar rovers of the Apollo era will be used," the report continues. In these, the colonists will have to don space suits. "For observation, surveys, and checkout of changing conditions, remotely piloted Mars airplanes are likely to be useful," because, unlike our Moon, Mars has a thin atmosphere.

"We project the growth of an initial Mars outpost to a Mars Base in about the third decade of the next century," the report states. "While that seems far away now, many of the people who will live and work at that Mars Base have already been born."

The Commission describes its report as an "economical, phased approach." Each step lays the basis, or provides the "enabling technology," for the next. The goals are clear, and pulling back on any one, delays the completion of the next. By setting such long-term goals, the Commission states one of the most important changes could be in education:

> When Sputnik 1 penetrated the vacuum of space in October 1957, the reverberations shook the technological and educational underpinnings of the United States. A series of science education initiatives, including the National Defense Education Act of 1958, triggered a reformation of America's education system.
>
> This momentum has not been sustained; once again our Nation is confronted with the necessity to revitalize education. . . . A citizenry able to understand and appreciate our Nation's space program is a key ingredient to the future of the program. The Commission believes that current weaknesses in our educational system must be corrected to ensure a vital 21st-century America.

After reviewing some of the most disturbing statistics dealing with the decline in the quality and quantity of science education, the report makes some specific recommendations. The disciplines of science that are already represented in the space program, including nearly every branch of physics, chemistry, life sciences, medicine, and biology, will be joined in the future by experts in even broader technical fields, like agronomy.

The Commission recommends establishing a National Space Laboratory, which would allow students to carry out experiments in orbit as part of their educational program.

They recommend that "Congress authorize NASA to create a fellowship program in space science and engineering. This will help attract the best students to pursue careers in these disciplines and permit access to space careers by highly qualified young people regardless of their financial situation." They also suggest that "NASA undertake a program to upgrade university space research equipment."

A Question of Leadership

From Sept. 13, 1985 to Jan. 17, 1986, the National Commission on Space held 15 public forums to allow the American public to voice their suggestions and comments on the future of the U.S. space program. Thousands of citizens participated directly in these meetings or sent their ideas to the Commission in writing.

Rather than issuing a technical government document with a limited printing, the Commission has had its report commercially published in paperback, available in bookstores for the American public to read. Last month Paine announced the Commission's plan to get a copy of the report into every high school in the nation. A half-hour videotape film on the 50-year program is available free of charge from the Commission for use by schools and others.[2]

This was not Paine's first experience in trying to project long-range goals for the space program. As the head of NASA during the time of the first Apollo lunar landing, he was involved in the September 1969 study titled, "America's Next Decades in Space," which presented four possible scenarios for the post-Apollo future of the United States space program. At the fastest rate, NASA projected that the first manned expedition to Mars could take place in 1981. This would have been preceded by a space station in 1975, which by 1980, could have housed 50 astronauts and crew. An Earth-to-orbit shuttle would be operational by 1975, the report suggested, and a space tug to go to the Moon would be ready a year later.

Needless to say, this program plan was never implemented. The program was aborted because of the same fallacious budget-cutting economic policies that the Reagan administration is trying to foist on the space program today. This time, Paine and the other members of the Commission have decided to take their plan to the American people, to garner broad-based support for an aggressive series of space goals.

If policymakers in Washington had enough vision to look 50, or even 20 years into the future, they would see how the decisions they make today—to replace the Challenger orbiter, to build the space station on schedule, to upgrade the space science programs—will determine whether the nation can start implementing the necessary Moon-Mars programs outlined in the Commission report in the future. It is simply a question of taking the political leadership.

Marsha Freeman, director of industrial research for the Fusion Energy Foundation, writes frequently on space policy.

Notes

1. *Pioneering the Space Frontier* is published by Bantam Books, Inc. (New York) and sells for $14.95. See order blank on page 58.
2. The videotape is available from Pacific Productions, 1054 31st St., N.W., Washington, D.C. 20007 at $29. See ad, page 63.

Space Commission

An interview with Tom Paine,

Dr. Thomas O. Paine was the administrator of NASA in July 1969 at the time of the first Apollo landing. Paine was president of Northrop Corporation from 1976 to 1982, and is now president of a Los Angeles consulting firm, Thomas Paine Associates. He is interviewed here by Marsha Freeman.

Question: Do you think that the Commission report will be able to influence policy decisions in Washington now, in this time of budget constraint?

I think the report has a very difficult lifetime to get through. Reports of the type we have just produced have a fairly standard reception. That is, the day they're written, they are called a "rosy view of the future," "much too far out," "Oh, my God, those things could never be achieved." But I think if we were to be reviewing our report 10 or 15 years from now, we would probably be getting the opposite criticism—"they failed to foresee a lot of these new things that have been coming along; the report is obsolete; it didn't go far enough." In writing a report like this, you have to face the fact that you're probably not going to be bold enough in the long run, but you're probably going to be too bold in the short run.

Question: I have here a short quote from Joseph Loftus from the Johnson Space Center. "What's been achieved in space is extraordinary. It you laid out a proposal to do in the next 25 years what has been done in the past 25 years, no one would believe you."

That's my favorite quote. I thought that was a terrific observation, and it's true. If we had said in the Space Commission report that 8 years from now we were going to land people on the Moon, we would have been laughed out of Washington. Yet that is precisely what we said in 1962, and it's precisely what we did! In many ways, if we were to propose today to do what we've done for the last 25 years, today's America, today's Washington leadership, in many ways, would say, "Oh that's much too bold. You could never do that." Yet the fact of the matter is, *we've done it.* And I've had people tell me, "let me see those pictures of astronauts riding on the Moon in a vehicle. I can hardly believe it." They've already forgotten that that was all done, 16, 17 years ago.

Question: Looking at launch requirements up to the mid-1990s, including the construction of the space station, the testing and deployment of the Strategic Defense Initiative, and the other

Chairman Talks About America in Space

former NASA administrator and chairman of the National Commission on Space

defense and science payloads, we've found that eight Shuttle-equivalent payload carriers would be needed by that time.

I think that's right. It is quite a formidable launch requirement that we face. I think my second comment would be that you are only looking at things that are visible from 1986. It may be that if you took another look at 1992 or 1994, there will be things that would have come over the horizon by that time, and I don't think there will be anything much that will reduce those estimates of yours. So we really are in a bind.

At the same time, I think it's fair to say that because we have neglected to develop the new technologies that the nation needs to design the next generation launch systems—we've really had 10 years of neglect of advanced rocket propulsion technology development in this country—we simply can't jump immediately in and start designing the post-Shuttle system now. It's going to take us a good 5 years of intensive technology development and that means that you can't be sitting around debating Gramm-Rudman. You've got to get some engineers working on new technology, whether the lawyers and economists are ready or not. If we're going to be developing post-Shuttle transportation by the end of the century, we've got to get started on that technology today. And that's a very important point. Because of 10 years of neglect, it's even more critical than ever.

Question: One question about the Rogers Commission which is investigating the Space Shuttle Challenger accident. You were not the head of NASA during the 1967 Apollo fire investigation. . .

However, I was administrator when we investigated the Apollo 13 accident, but we didn't lose any lives in that. . .

Question: I see a danger that there will many things recommended in their report that will be difficult, if not impossible, to comply with, such as systems having no "criticality 1" items, which could lead to the loss of the orbiter and crew, which would require having redundancy for everything. I'm sure that in the Apollo system there must have been many items where the system simply had to work. What is your idea on how any commission recommendation should be implemented?

You're getting into the area where I think engineering trade-off decisions have to be made. As you start loading redundancy and safety factors into equipment, you reach a point where you're not really increasing the reliability or safety after a while, because you start getting the failures of all the safety systems that shut down engines when they really shouldn't be shut down.

It's really a technical, engineering decision as to what is the optimum balance. And there are, as you point out, areas where you simply cannot have redundancy. When we sent the Apollo spacecraft out to the Moon, we had one rocket engine to bring them back. We just couldn't load two on there; it would not have been possible to carry out the mission. What you try to do then, when you only have one, is make darn sure that you are building the absolute maximum amount of reliability into it, and then you test and test and test and test. It's perfectly feasible to do this. We have demonstrated it time and again. We fly something like 70 million people back and forth across the Atlantic Ocean every year, and the only time we ever dump anybody in the drink is when a terrorist puts a bomb on board.

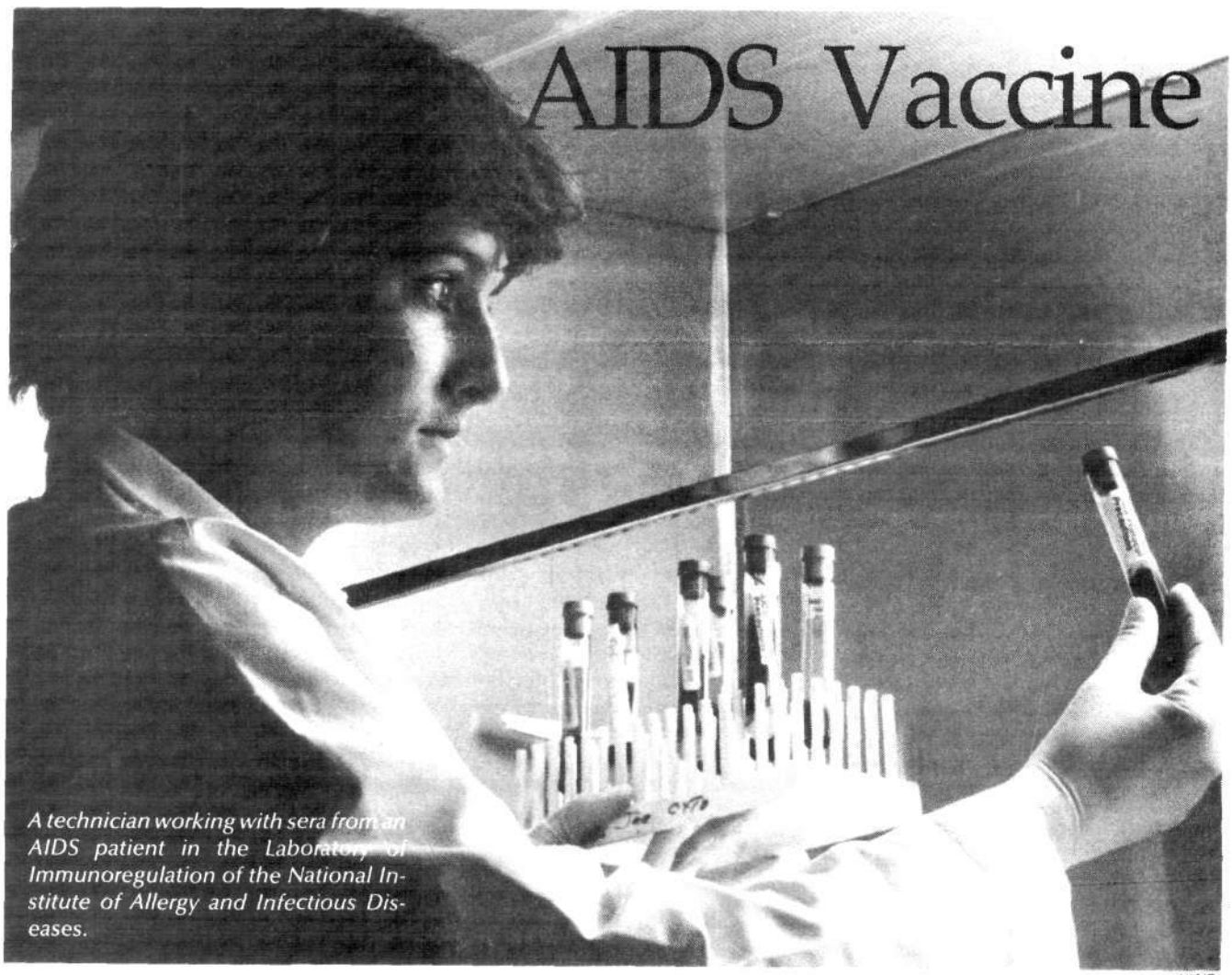
We can design space systems that are both inexpensive, and very safe and reliable to fly, and it's time we got at it. But I think one of the fundamental problems is that you can't do it on too low a budget. I think when we cut NASA from the peak of Apollo down to the present size (we cut it to *one third* of what it was), we cut too deeply.

Unfortunately, the NASA administrators at the time were anxious to keep a bold program going, so they probably accepted too great a commitment. They overpromised; they came out with commitments that couldn't be met; and the net result was a budget crunch. Then they had to take some shortcuts and some economies, that now, with all the benefit of hindsight, any Monday morning quarterback can say: "we cut too deep, we didn't really spend enough. We should have put more emphasis in there on safety."

Question: I see a danger of that happening with the current space station program. . .

I think there's a *real* danger of it happening. I think the space station program at the present time is going right down the Shuttle road. Namely, you start out with a sum of money, and you say, "OK, we're going to build it for $8 billion." Then, as time goes on, you run into difficulties, you don't get any increases . . . that would be an overrun . . . gosh, we can't have an overrun. I think that's the wrong way to fund these advanced projects, where you really don't know all the things you're going to be getting into. I think it's much better to fund them on an annual operating cost, and then go ahead and deploy the thing when you're satisfied you're finished, and it's ready.

Breakthrough Near In Search for AIDS Vaccine



A technician working with sera from an AIDS patient in the Laboratory of Immunoregulation of the National Institute of Allergy and Infectious Diseases.

NIAID

A new medical discovery promises not only to detect carriers of the AIDS virus, but also to prevent these carriers from developing the lethal disease.

by John Grauerholz, M.D.

A major breakthrough that for the first time offers hope to the millions of persons infected with the AIDS virus was announced by Drs. Allan Goldstein and Paul Naylor at a press conference in Washington, D.C., May 22. Researchers at the National Cancer Institute and the George Washington University School of Medicine have discovered that the antibodies they prepared against a thymus hormone, thymosin a-1, were able to neutralize the HTLV-III/LAV (AIDS) virus in tissue culture. This is the first demonstration that antibodies that prevent the entry of the AIDS virus into cells, or the replication of the AIDS virus once inside a cell, can be produced in response to a non-viral protein. In addition to being an effective vaccine, this discovery points the way to a specific test for the virus itself,

and provides a fundamental insight into one mechanism that brings about the profound suppression of the immune system seen in patients with AIDS, acquired immune deficiency syndrome.

The significance of this breakthrough is not simply that it could prevent vaccinated individuals from becoming infected. More important, it could also prevent those who are carrying the virus, but have not yet developed active disease (the asymptomatic carriers), from developing AIDS or one of the other deadly conditions associated with the AIDS virus. These people, once identified in a mass-screening program, could be treated with such a vaccine, thereby preventing them both from developing AIDS and from remaining a carrier of the disease. In other words, this breakthrough makes it possible to stop the spread of AIDS; what is required is a mass-screening to identify infected individuals, combined with a full-scale national mobilization to rapidly exploit the promise of this breakthrough.

Although the possibility of a vaccine against the AIDS killer is a dramatic breakthrough, the importance of this new technology in also providing the capability to quickly develop a screening test for the presence of the AIDS virus should not be underestimated. The present tests used cannot discern the presence of the virus itself; they test for *antibodies* to the virus. A test for the virus itself would eliminate the vexing problem of the antibody negative virus carrier, as well as certain risks involved in growing large quantities of AIDS virus for preparation of the current test kits. Since the antithymosin antibody reacts with a highly conserved region of the virus (one that does not mutate easily), there is almost no problem with failure to detect mutant strains of virus.

The Thymus Clue

Most previous attempts at producing a vaccine for the AIDS virus have concentrated on the external envelope of the virus, on the assumption that this part of the virus would be most accessible to attack by a vaccine (Figure 1). AIDS is a retrovirus, a group of viruses formed by the action of RNA on DNA instead of the usual, reverse process. Unfortunately, the particular part of the AIDS retrovirus genome, the *env gene* (Figure 2), that codes for the external envelope is highly mutable, and a vaccine produced against one form of the virus may be totally ineffective against another form of the same virus, varying only in the envelope. Also, most antibodies produced against the envelope do not appear to be neutralizing antibodies.

The antibodies produced in response to thymosin a-1, however, react with a protein that is coded for by the *gag gene*, whose products form the internal protein capsid surrounding the genetic material of the virus. These genes are highly conserved in retroviruses and do not display the genetic drift characteristic of the env genes. As a result, a vaccine prepared against this protein, known as p17, could be expected to be effective not only against the various AIDS viruses, but also against related retroviruses.

This breakthrough was the product of research by Dr. Allan L. Goldstein of the George Washington University School of Medicine in Washington, D.C. Goldstein had been struck by the clinical similarities between AIDS patients and children with rare primary immunodeficiency

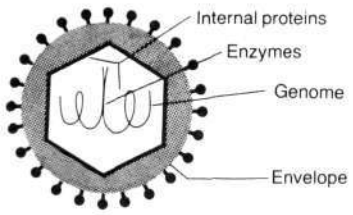


Figure 1
DIAGRAM OF A TYPICAL RETROVIRUS

The AIDS virus is one example of a retrovirus, a term that refers to a group of microorganisms formed by RNA acting on DNA, instead of the usual, reverse process. The retrovirus core consists of the RNA genome of the virus, along with the enzymes for converting the viral RNA to DNA within the cell (the "reverse transcriptase"). Surrounding this are the internal proteins, p24 and p17. Antithymosin a-1 antibodies cross-react with p17 and apparently interfere with assembly of the virus. The internal proteins are in turn surrounded by an envelope derived from the membranes of the host cell. Most attempts to produce a vaccine have centered on trying to produce antibodies to the envelope.

Source: "Retrovirus Vectors for Gene Transfer: Efficient Integration into and Expression of Exogenes DNA in Vertebrate Cell Genomes," to be published in *Gene Transfer*, ed. R. Kucherlapati (New York: Plenum Press).

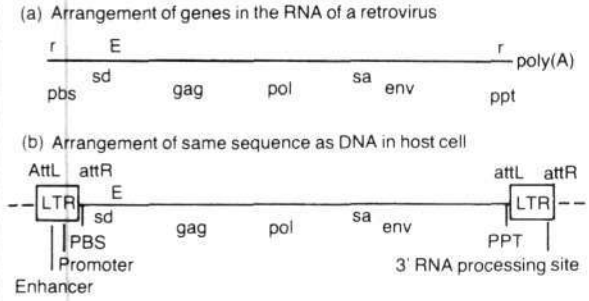
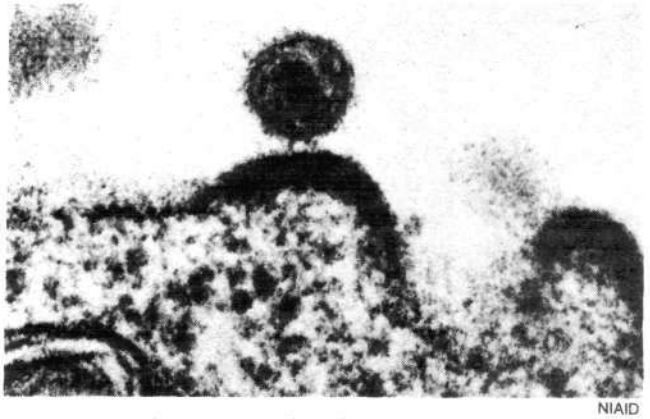


Figure 2
ARRANGEMENT OF GENES IN A RETROVIRUS

The arrangement of genes in the RNA of a retrovirus is shown in (a). The term pbs refers to the primer binding site, where the enzyme for copying the RNA to DNA binds to the RNA to start copying. The term gag is the gene coding for the internal proteins shown in Figure 1, while pol codes for the enzyme that converts virus RNA to DNA within the cell. The gene coding for the envelope is called env.

The same sequence translated into DNA and inserted into the genetic material of the host cell is shown in (b). LTR stands for long terminal repeat, repeated sequences of genetic material that are characteristic for inserted proviral DNA.

Source: "Retrovirus Vectors for Gene Transfer: Efficient Integration into and Expression of Exogenes DNA in Vertebrate Cell Genomes," to be published in *Gene Transfer*, ed. R. Kucherlapati (New York: Plenum Press).



NIAID

The potential vaccine will make it possible to screen for carriers of AIDS—and then kill the virus they are carrying. Here, AIDS virus (HTLVIII/LAV) budding off from a T lymphocyte.

diseases (called PIDs), associated with the absence or marked underdevelopment of the thymus gland. These children show an increased susceptibility to opportunistic infections, including pneumocystis carinii pneumonia, one of the common infections in AIDS victims. Since AIDS affects the T4 lymphocytes, which are thymus-derived cells, Goldstein did studies of thymus function in AIDS patients and in persons considered at risk for AIDS.

These studies revealed that AIDS patients, and members of the then-defined risk groups, had increased concentrations of proteins similar to thymosin a-1 in their blood. Thymosin a-1 was the first hormone to be purified from the thymus gland and is a potent stimulator of immune function, acting primarily on helper T-cells, the cells whose function is destroyed in AIDS. The hormone has been demonstrated to restore T-cell function in a number of conditions, including cancer, and in irradiated animals.

The assay for thymosin is done by injecting rabbits with a synthetically produced thymosin a-1. The rabbits develop antibodies to the thymosin, which are then collected by drawing blood from the rabbits and separating out the antibodies. These antibodies are then combined with a radioactive label. The labeled antibodies will then bind to proteins which are immunologically similar to the original hormone against which they were formed. This particular technique is called radioimmunoassay. The amount of thymosin present is calculated from the amount of radioactivity bound by a given specimen.

Paradoxically, it would have been expected that AIDS patients would have had lower than normal levels of thymosin a-1, but in fact numerous studies showed the opposite. AIDS patients had markedly elevated levels of the hormone by radioimmunoassay, and these elevated hormone levels were the best marker for the disease prior to the discovery of the HTLV-III AIDS virus, and the subsequent development of tests for an antibody to the virus. Ironically, it now appears that scientists had a test for the virus itself and did not know it.

Medical Detective Work

To explain this unexpected finding, Goldstein and his colleagues proposed three hypotheses that might account for the detection of elevated levels of thymosin a-1 in AIDS patients and in persons at risk for the disease.

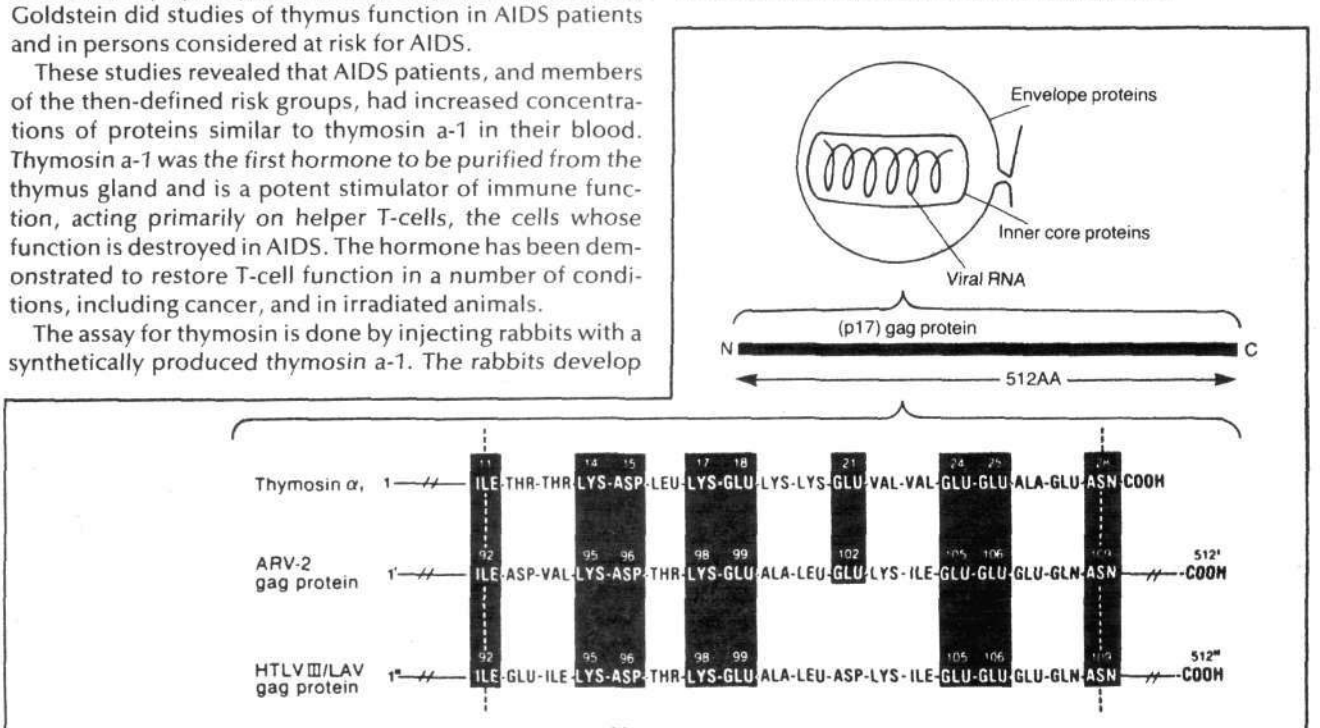


Figure 3

ELECTRON MICROGRAPH AND SCHEMATIC OF AIDS VIRUS ATTACHING TO A CELL

The internal structure of the virus and the location of the p17 protein inside the virus are shown in this electron micrograph. In the diagram, the black horizontal line in the center, below the AIDS virus, represents an enlargement of the p17 gag protein area where the two dotted lines meet above. Below this is a further enlargement of the 18 amino acid sequence of the p17 protein, which shares a number of common amino acids with the AIDS retroviruses. There are three parts to this enlargement—the top showing the sequence of thymosin-a, the middle showing the sequence of AIDS-related virus, and the bottom showing the same sequence for the HTLV III/LAV (AIDS) virus. The black areas mark the amino acids common to the thymus hormone and the virus proteins. As can be seen, the array is very similar.

Source: Viral Technologies Inc.

Courtesy of George Washington University Medical Center

Thymus expert Dr. Allan L. Goldstein, chairman of the Department of Biochemistry at the George Washington University School of Medicine in Washington, D.C., directed the research that led to the AIDS vaccine breakthrough.

(1) End organ failure: the defective T-cells were failing to respond to the thymosin, and the body was producing more and more hormone in an effort to stimulate them.

(2) Production of an abnormal hormone or abnormal amounts of hormone because of an invasion of the thymus by the AIDS virus.

(3) The presence of a protein related to the AIDS virus that was cross-reacting with the antibodies to thymosin a-1, which were used to assay for thymosin a-1.

The first hypothesis seemed to be excluded by studies indicating that AIDS patients who were given injections of thymosin a-1 actually experienced temporary improvement in immune function. Further chemical studies on the peptide found in the blood of persons at high risk for AIDS indicated that authentic thymosin a-1 was often significantly decreased in these patients.

To investigate the last hypothesis, it was decided to examine the chemical structure of the thymus hormones and the various structures that make up the AIDS virus, to see if there were any similarities between the two. If a common site were identified, it would indicate that the antithymosin antibodies were really reacting to the AIDS virus itself!

A computer search was conducted of more than 3,500 proteins, whose amino acid sequences were on file at the sequence bank of the National Biomedical Research Foundation in Washington, D.C., and the sequences of AIDS and other retroviruses from Dr. Robert Gallo's laboratory at the National Cancer Institute. This search disclosed that there was 44 to 50 percent homology between an 18 amino acid sequence in thymosin a-1 and an 18 amino acid sequence in the p17 gag gene product of HTLV-III/LAV (Figure 3). No other homologies were found between any thymus hormone, or other immune response modifier, and any virus protein.

Armed with this finding, the researchers decided to test the antithymosin antibodies to see if they would inhibit the replication of the AIDS virus in cell culture. Sure enough, the antithymosin antibodies indeed inhibited both the uptake of virus into the culture cells, and the replication of virus within the cells. This meant that the antibodies not only were reacting with the AIDS virus, but that they were, in fact, *neutralizing* antibodies. In other words, the antibodies were capable of inactivating the AIDS virus and ultimately destroying it.

These findings may explain why AIDS patients do not produce effective neutralizing antibodies. The homology between the thymus hormone and the virus capsid protein may be sufficient that the immune system does not recognize this particular protein as foreign, and is not stimulated to produce antibodies to it. Conversely, in some AIDS patients, there is marked destruction of the thymus, which may relate to cross-reacting antibodies to the AIDS virus which produce autoimmune destruction of the thymus. Since the antithymosin antibodies are produced against a synthetic hormone, and not naturally occurring human thymosin, they may not attack the thymus. One indication that this may be the case is the fact that the rabbits in which these antithymosin antibodies were produced show no evidence of thymus damage so far.

The Next Steps

Because asymptomatic AIDS carriers could represent between 2 and 5 million persons in the United States alone, and because many recent studies indicate that almost all of these people will ultimately develop lethal disease from the AIDS virus, the importance of rapidly and vigorously pursuing this, and other breakthroughs in this area is obvious. This is the only hope on the immediate horizon to deal with the catastrophic situation in Africa and other areas in the developing sector, and to stop the same catastrophe from hitting the industrial sector full force. It is important to note that to fully and effectively exploit this breakthrough, public health officials must acknowledge the growing body of evidence that environmental factors play a major role in the transmission of AIDS. As long as the U.S. Public Health Service continues to view AIDS as simply a sexually transmitted disease, the necessary overview and commitment to deal with the situation will be lacking.

The most immediate task necessary to exploit the potential of this discovery is funding of the primate studies that are required before human clinical trials can begin. At present, Allan Goldstein believes that human clinical trials might begin in 1½ years, assuming all goes well in the primate studies. Even on the basis of the woefully understated figures published by the U.S. Centers for Disease Control in Atlanta, this 18 months will see another 50,000 U.S. victims of the disease. Moreover, under the present Gramm-Rudman budget constraints on health infrastructure, it is possible that by the time a vaccine for AIDS is achieved, the country will not have a health care system left that is capable of delivering it.

It should also be noted that at present, the Goldstein group is working without any government funding support. The research that led to the development of the potential AIDS vaccine was funded by Viral Technologies, Inc., a private venture formed by two biotechnology companies, Alpha 1 Biomedicals, Inc., founded by Goldstein in 1982, and Interleukin-2 Inc., formed in 1983. The latter company currently holds the patent rights to human interleukin-2, an important biological response modifier, with significant

AIDS: Worldwide Epidemic

The U.S. Department of Health and Human Services (HHS) released a report June 13 summarizing the work of its Special Task Force on AIDS. The official figures are cause for alarm: HHS expects 179,000 American deaths from AIDS by 1991, out of an estimated 270,000 cases that are projected to occur primarily among homosexuals and drug users.

An HHS conference in West Virginia issued an update on the U.S. government's 1985 plan to stop AIDS by the year 2000, calling for a national commission to oversee public, private, and voluntary groups. HHS estimated that $8 to $16 billion would be expended in medical costs on AIDS in 1991, just for the estimated 74,000 cases in that year alone! Because HHS is still committed to not recognizing the growing number of environmentally associated AIDS cases—those transmitted by insect bites, for example—these figures represent a substantial underestimation of the true magnitude of the problem in the United States.

The picture in the rest of the world is just as alarming:

- British government expert Dr. Philip Mortimer reported that AIDS will be killing 5,000 people a year in Britain by the year 1990, and that this death toll will be as high as casualties from traffic accidents. Should present trends continue unabated, or worsen, Mortimer warned, Britain itself could be depopulated by the next century. There are now 335 AIDS cases in Great Britain, 60 so far this year, and more than 20,000 people are infected.
- Official estimates are that 100,000 to 400,000 in West Germany are already infected with AIDS virus.
- AIDS is spreading through Scandinavia at a rate comparable to the United States and other countries where AIDS is considered a serious public health threat. Dr. Stig Froeland of the Riks Hospital in Oslo, Norway, estimated that 2,000 Norwegians, out of a population of 4 million, have been infected by the AIDS virus.
- "AIDS is spreading like wildfire in the British Commonwealth countries of Central Africa" a leading British researcher reported. "Throughout Central Africa the situation is devastating, whether it be the ex-British, ex-Belgian, or ex-French areas. In urban centers, 5 to 10 percent of all sexually active people below the age of 40 are showing positive. In some urban centers 10 percent of blood donors are showing positive."
- "It is as if an entire segment of the population here had been irradiated; what we've got here is a sort of Chernobyl," said a British expert working in Africa, Dr. J. Wilson Carswell. When asked if Uganda were experiencing an AIDS epidemic, Carswell responded: "It was an epidemic last year. It is now a disaster. It's going to wipe out many, many people here."

potential as a treatment for cancer and AIDS as well as diseases of aging. Viral Technologies holds a patent on the synthetic thymosin used to produce the AIDS antibodies.

The problem with such small venture operations is that although they may develop an important product, for which federal funding was not available, they generally lack the resources for large-sacle testing and production. Without the initial private funding, however, the research that led to the discovery could not have been conducted; Goldstein, one of the world's foremost authorities on the thymus gland, did not receive one penny from the National Institutes of Health for his AIDS research, in spite of the fact that AIDS is supposedly the nation's number one public health priority. As Goldstein observed, it will require a major public funding commitment to realize the promise of this research.

A Biological SDI

AIDS is simply the most visible symptom of a general collapse of human health and hygiene worldwide. Outbreaks of measles, drug-resistant tuberculosis, meningitis, and other infectious diseases—once considered things of the past—are occurring today right here in the collapsing inner cities and depressed rural areas. Combined with the widespread dissemination of the AIDS virus in the United States—officially estimated to have infected 1.75 to 2 million people, and probably 10 times as many in reality—this creates the potential for African-style epidemics in this country.

A single vaccine, no matter how effective, will not avail in a situation like Africa or Belle Glade, Fla., where waves of different infectious diseases wash over a progressively more debilitated population. Vaccination requires a host who is at least nourished enough to form an antibody response. No epidemic has ever been stopped by developing a cure while the epidemic was in progress. Epidemics are stopped by public health measures, like quarantine, when necessary—or by running out of victims. The importance of a screening and quarantine program is that it can ensure that any vaccine, or other curative treatment, is not overwhelmed before it can come on line; it can also identify the priority targets for immunization and give some sense of the magnitude of the program required.

For the potential of this most recent breakthrough to be realized, it is essential to situate it in the context of a real commitment to deal with the larger health issues that now threaten the existence of the entire human race. These issues, primarily political and economic, are mediated by the collapse of basic health care, sanitation, and nutrition, under conditions of economic austerity, civil war, and refugee migrations. It is this disastrous situation, combined with "lifestyles" conducive to the spread of tropical-type diseases among their practitioners, that must be altered by a crash mobilization, a biomedical Strategic Defense Initiative, to change the present entropic course of the biosphere. Absent such a commitment, any individual scientific breakthrough will be but one more seed sown on the rocks of a former civilization.

John Grauerholz is a practicing physician on the staff of the Fusion Energy Foundation.

Teller Confirms X-ray Laser Breakthrough

by Charles B. Stevens

U.S. experiments have shown that the nuclear-explosive-powered X-ray laser can be designed to send a beam 1,000 miles with a spread of no more than 5 feet, Dr. Edward Teller told the Senate Defense Appropriations Subcommittee May 9. Teller's formal testimony, as well as his remarks in the question and answer period, shot down the various myths circulated by the Soviets and the anti-beam-defense lobby that the X-ray laser won't work.

This degree of focusing, which is thousands of times better than what SDI critics have claimed to be physically possible, means that a single X-ray laser device could destroy upwards of tens of thousands of nuclear warheads and missiles at any stage of their trajectory. This stunning level of firepower would completely undermine the military credibility of any massive, salvo-type, surprise first strike. In fact, whichever nation struck the first blow in a nuclear war could find itself in the embarrassing position of being "disarmed" by the X-ray laser, while the victim nation maintains its full range of offensive firepower; in other words, the opposite result of what the first-strike nation intended.

Specifically, if one X-ray laser device—popped-up into space above the Arctic ice by a submarine at any time during the 20 minutes it takes ICBM warheads to travel from the Soviet Union to North America—could destroy 10 times the existing Soviet warhead inventory, then hundreds or thousands of such defensive systems could readily defend against any conceivable surprise first strike.

The Soviets are not only working on this X-ray laser concept, but they are ahead of the United States. Teller confirmed the March 25 report to Congress of Strategic Defense Initiative director Lt. General James Abrahamson that the Soviets are two to five years ahead in X-ray laser development.

Doing the 'Physically Impossible'

Almost a year ago, in a front-page *New York Times* article, William Broad reported that scientists at Lawrence Livermore National Laboratory had demonstrated focusing of X-ray laser beams in an underground nuclear test on March 23, 1985. The test disproved the public contention by Soviet scientists and U.S. SDI critics that it was physically impossible to develop X-ray laser optics for beam focusing, as was baldly asserted in the 1984 Congressional Office of Technology Assessment report on SDI. This OTA report was chiefly authored by Ashton Carter of the Massachusetts Institute of Technology, and later endorsed by such leading scientists as Dr. Charles Townes of Stanford University. However, the report was sharply criticized as inaccurate by the national laboratories.

Stuart K. Lewis

Edward Teller: The principle for the X-ray laser "is established," he told the Senate Defense Appropriations Subcommittee, May 9.

In fall 1985 and then later in the winter, various publications, led by coverage in the *Los Angeles Times* and *Science* magazine, claimed that Lawrence Livermore scientists had misrepresented their X-ray laser tests. Based on leaks of classified reports, these publications maintained a campaign of calumny and slander against the Livermore tests and against SDI advocates like Drs. Edward Teller and Lowell Wood.

More recently, Nobel Laureate Hans Bethe of Cornell University reportedly has been passing on disparaging reports on the top secret Livermore results. In particular, Bethe has been quoted as stating that the Livermore experimental diagnostic measurements are not capable of distinguishing between a laser beam output and simple "superfluorescence." Sources report, however, that Bethe did not raise his questions about "superfluorescence" during any of the classified reviews of the program.

Teller Sets Record Straight

Since this original controversy, a further X-ray laser test was reported to have been carried out at the beginning of 1986. Teller's May 9 testimony, stating that the principle "is established" and giving a detailed projection of "beam divergence," was the first official statement since that test. It is a direct refutation of the reported statements of Bethe as well as the articles in the *Los Angeles Times* and *Science* magazine.

In June, the U.S. General Accounting Office issued a review of the X-ray laser experiments that criticized the press campaign against the program. The report was requested by anti-SDI congressmen Edward Markey (D-Mass.) and Bill Green (D-N.Y.). "In our opinion, there was no 'design flaw' in the diagnostic instrumentation as mentioned in the *Los Angeles Times* article," the transmittal letter of the GAO report states. The GAO report also noted that the program "was not being arbitrarily accelerated."

Teller testified to Congress not only that has the U.S. program been quite successful, but that the Soviets are probably two to five years ahead in development of an X-ray laser system. Teller said it is natural that the Soviets have shown no interest in President Reagan's proposal to share SDI technology with them in the future, because they are ahead of us in strategic

U.S. DOE

The Soviets are two to five years ahead of the United States in the development of an X-ray laser system. According to Teller, the Soviets have carried out expensive tests in large, underground tunnels, while the United States has used tunnels that have simple vertical bore holes. Shown here is the Nevada Test Site, where preparations are underway for an underground nuclear test. The cable will be lowered down the hole to relay scientific data to diagnostic trailers at the surface. The Soviets reportedly use 40 such trailers, compared to the five or six diagnostic trailers used in U.S. tests.

defense and probably know what we will discover in the next two years, or perhaps five years. He further emphasized that the Soviet Union has conducted expensive tests in large, underground tunnels, while the United States has carried out only much cheaper, underground tests utilizing simple vertical bore-holes. Teller called for adding $200 million to the SDI program to pay for U.S. tests that are similar to the Soviets'.

The use of expensive, evacuated tunnels in underground nuclear X-ray laser tests indicates that the Soviets are carrying out actual weapon-simulation tests. It is not necessary to test X-ray lasers in space to demonstrate and develop full-scale antimissile and antisatellite applications. In fact, this author does not know—and has found no expert who could otherwise detail—a means whereby the deployment of pop-up X-ray laser weapons could be detected. Even X-ray laser predeployment in satellites would be difficult, if not impossible, to detect. (Nuclear weapons have been designed with extremely thin layers of fissile fuel, which means that the device has an extremely low radioactive signature.)

The Soviets Are Ahead

SDI Director Lt. Gen. James Abrahamson testified that the United States had obtained intelligence data showing that the Soviets were as much as five years ahead in developing X-ray lasers. In particular, Abrahamson noted that the Soviets had conducted an X-ray laser underground test in 1982—probably one of the tunnel tests referred to by Teller—a test that the United States will not be able to carry out until 1987.

The Abrahamson assessment had further backup from a report in a new newsletter, *TechTrends International*, whose first issue May 12 reports that the Soviet Union is carrying out "an energetic developmental program for nuclear-pumped X-ray laser devices at its secret Degalin Valley underground test site." Apparently, this is part of the Chelyabinsk complex near the Ural mountains. The report goes on to state that "X-ray lasers . . . have been high priority development programs in the USSR for at least a decade, with increased activity and funding in the past several years."

TechTrends states further: "The effort . . . involves tens of thousands of scientists, engineers, and technicians, according to the Defense Department and intelligence community officials. . . . Space-based sensors have observed numerous tests at the Degalin X-ray laser test site with as many as 40 trailers containing diagnostic equipment with line of sight from the surface to the X-ray test area underground." *TechTrends* contrasts this with the U.S. practice of seldom using more than "five or six" such diagnostic trailers during tests at its Nevada range.

The Military Implications

The nuclear-bomb-powered X-ray laser has a truly awesome firepower—*a single device is capable of destroying the entire world inventory of missiles and nuclear warheads*. As such, it can therefore find both offensive and defensive applications. Utilized in conjunction with a surprise first strike, the X-ray laser could surgically remove all of the opponents' space-based assets and help suppress any deployment of offensive and defensive missiles.

Because of its high firepower, the system necessitates a minimum of additional requirements such as target tracking, discrimination, and command and control. Therefore, its deployment would be virtually impossible to detect—especially in a fire-on-warning pop-up mode.

However, if both the United States and Soviets have the X-ray laser, it would be far more beneficial to the

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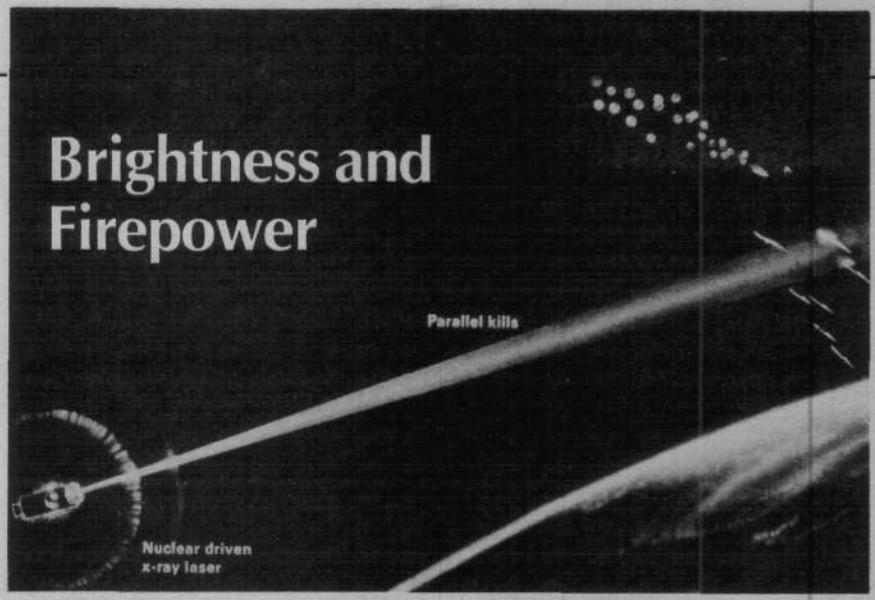
Brightness and Firepower



X-RAY LASER FIREPOWER

In this Department of Defense illustration, a single nuclear-driven X-ray laser (lower left) popped up into space, is shooting down the entire Soviet ballistic missile force in its boost phase. This one module could also shoot down these 10,000 Soviet warheads during their 20-minute flight time. The latest X-ray laser tests indicate that its plasma focusing system makes it possible both to divide the laser output into tens of thousands of individual beams and to point to separate targets.

For directed energy weapons, beam brightness is a measure of the system's firepower: the brighter the beam, the greater the number of missiles or warheads that can be destroyed. There is also an inverse square relationship between brightness and the weapon's maximum effective range. That is, if the number of targets that the beam weapon is to engage is reduced by half, it will have a fourfold increase in effective range, and vice versa.

The specific numbers Dr. Edward Teller gave in his congressional testimony—a beam diameter of 5 feet over a distance of 1,000 miles—confirm reports that the X-ray laser plasma focusing lenses demonstrated in underground tests have obtained a brightness 1 trillion times that of the hydrogen bomb.

Brightness is usually measured in terms of energy or power per unit solid angle—*steradians*. The solid angle is roughly given by the square of the beam divergence angle measured in radians. Therefore, the brightness is inversely proportional to the square of the beam divergence. The figures given by Teller roughly indicate a beam divergence of one-millionth of a radian, a microradian. This is a factor of about 1,000 times smaller than that the Soviet and U.S. critics of SDI say is the minimum that the laws of physics would permit!

Given the inverse square relationship, it also means that the X-ray laser is 1,000,000 times brighter than these critics predict is possible. This would mean that the device could either have a 1,000-fold increase in effective range, or, alternatively destroy 1,000,000 times more targets.

Plasma Lens-Focusing

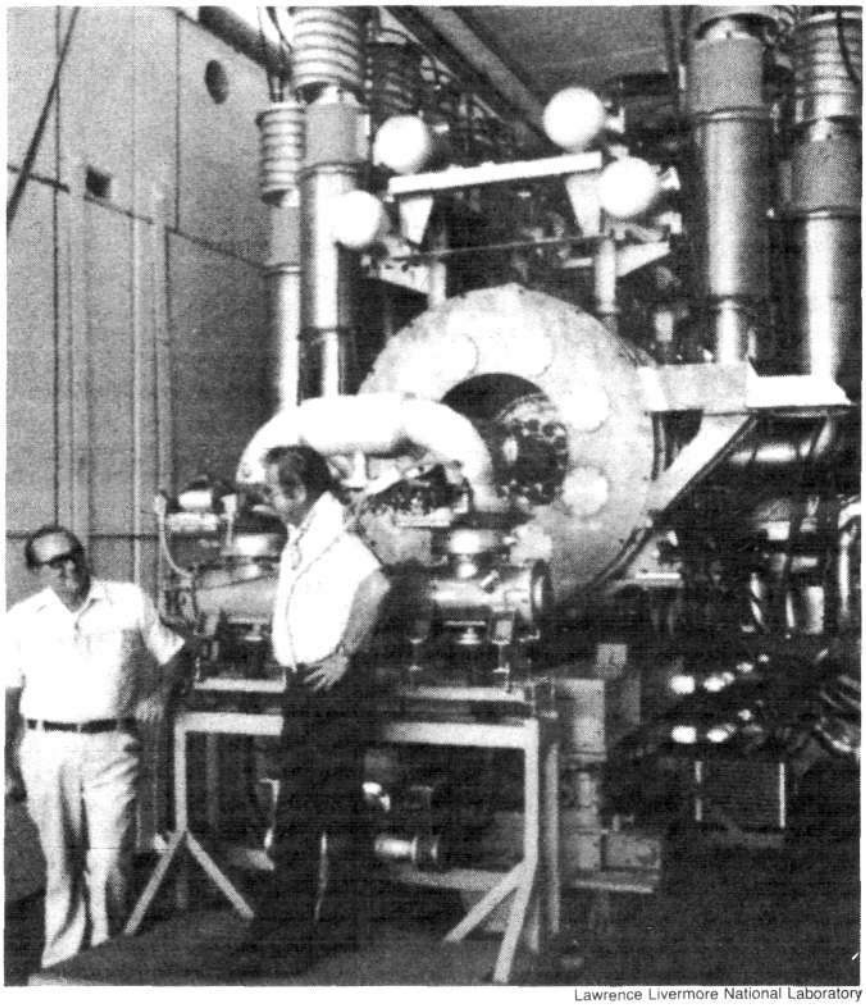
The plasma lens-focusing system provides the means for both readily dividing the X-ray laser output into tens of thousands of individual beams and electromagnetically pointing toward separate targets. This large number of beams opens up entirely new types of firing strategies for X-ray lasers, particularly against massive missile salvos.

In general, massive missile salvos lead to large numbers of warheads passing through relatively small "windows" in space. If these windows can be saturated with a sufficient density of lethal beams, all warheads and decoys could be destroyed without having to discriminate between them or target them individually. The result would be similar to that of the application of grapeshot or machine guns against massed infantry.

The idea here of utilizing a large number of tightly focused beams instead of spreading the laser output evenly over a large area is that a sufficient density of beams achieves the same aerial coverage at a greater range. For example, warheads have an aerial cross section of 1 square meter or more, so having one beam per square meter would be enough to ensure destruction of all targets in a given area. The point is that the empty spaces between the beams represent an increase of least action for this particular firepower application. Given the variety of missile deployments and defensive fields of fire deployment, a wide range of options would be open to the defense beyond this simple model, such as some selective targeting and partial discrimination combined with multiple barrages from different directions against the same window.

An ordinary hydrogen bomb has an energy output on the order of 10^{15} joules (1,000 trillion joules). Without any focusing, this would be evenly distributed over a sphere which has a total of 4 π steradians. Therefore, the brightness would be roughly 10^{14} joules per steradian. At a trillion times this brightness, the X-ray laser would have 10^{26} joules per steradian. To destroy existing types of missile boosters, an energy density of about 1 million joules per square meter would be required. For the tougher, warhead-carrying reentry vehicles, 1 trillion joules per square meter would be needed.

This gives a maximum range for the full output directed onto an individual target of 10 billion meters (about 6 million miles) against a rocket booster and 300 million meters (almost 200,000 miles) against a reentry vehicle. Alternatively, if the output is broken up into 100,000 separately directed beams, the respective ranges would be 30 million meters (almost 20,000 miles) and 1 million meters (about 600 miles). In practice, the output would be divided to obtain lethal kills at a variety of ranges from the same device against multiple kinds of targets. For example, low power bursts at long ranges could be used to destroy decoys, leaving the real reentry vehicles more readily targetable.



Lawrence Livermore National Laboratory

The recent advances in the free electron laser used Lawrence Livermore National Laboratory's 5 million electron volt Experimental Test Accelerator as its source of fast-moving electrons. Shown here is the electron injector and pulse-forming network of the ETA. The large central cylinder houses the cathode structure and ferrite cores of the induction accelerators.

LLNL Announces Breakthrough In Free Electron Laser Work

by Charles B. Stevens

Details of a series of breakthroughs on the free electron laser were reported by scientists from Lawrence Livermore National Laboratory at the spring meeting of the American Physical Society in Washington, D.C., April 28-May 2.

In early 1985, the free electron laser, or FEL, was characterized by then presidential science advisor Dr. George Keyworth as making "revolutionary progress" in developing a laser for missile defense, leaping ahead 20 years. Keyworth told the Lasers '85 conference in December that the national laboratories had demonstrated accelerator technology for powering high-energy FELs, had demonstrated high-power FELs, and had demonstrated laser light propagation through the atmosphere.

A single, ground-based FEL, operating with fighting mirrors popped up into space after detection of a missile attack, could have the firepower to destroy the entire Soviet ballistic missile inventory within a couple of minutes, Keyworth said. He suggested building a dozen such systems to leave no doubt in the mind of a potential aggressor that a surprise first strike could not work.

Dr. Donald Prosnitz of Livermore presented the highlights of these breakthroughs at the APS meeting in a paper titled "Results of Free-Electron Laser Experiments—ED-3."

The FEL is based on converting the energy of a high-energy electron beam into electromagnetic radiation. This is achieved by "wiggling" the electron beam with a magnetic field. The wiggler extracts energy from the electron beam and transforms it into electromagnetic radiation. The FEL can be tuned by changing the dimension and intensity of the magnetic wiggler. It also leads to lasing efficiencies orders of magnitude greater than those based on more conventional atomic lasers.

The FEL Advances

"We have improved the efficiency of free electron laser amplification of high power microwaves from 5 percent to 40 percent by replacing the straight wiggler with a tapered one," Prosnitz reported. "In experiments over the last year, we have amplified 15 nanosecond (1 nanosecond is one billionth of a second), 50,000 watt peak power microwave pulses produced by a magnetron 20,000 times (43 decibels) to 1 billion watts peak power. This is clearly the most powerful source of coherent electromagnetic radiation at this wavelength with efficiencies nearly as good as the most efficient low-power sources (klystrons). The microwave signal we amplified had a wavelength of 8.67 millimeters (34.6 billion cycles per second or gigahertz)."

The recent experiments were conducted at the Electron Laser Facility (ELF) at Lawrence Livermore National Laboratory. The ELF uses the 5 million electron volt (5 MeV) Experimental Test Accelerator as its source of fast-mov-

ing electrons.

A free-electron laser amplifier is a device that can transfer energy from a beam of electrons traveling at nearly the speed of light to a beam of electromagnetic radiation, such as microwaves or visible light. The energy transfer increases the intensity of the electromagnetic radiation.

The advantage of the free-electron laser amplifier is its efficiency in converting electrical energy into radiation and its ability to be tuned over a wide range of wavelengths. The Livermore approach has the additional benefit of being able to produce very high power pulses of radiation.

High power microwaves from a free-electron laser might be able to drastically reduce the length and power requirements of linear charged particle beam accelerators by using a "two-beam" design proposed in 1982 by Dr. Andrew M. Sessler at Lawrence Berkeley Laboratory. The powerful microwave source could also help heat fusion fuel in some magnetic fusion reactor designs. Another application would be microwave power for spaceships and aircraft.

FEL Wiggler

A 10-foot-long array of powerful, 5,000-gauss magnets with alternating north and south poles was used in the ELF wiggler. The high-energy electrons in the accelerator beam oscillate back and forth when they pass through the wiggler. This regular change of direction causes the electrons to give off electromagnetic radiation at wavelengths characteristic of the distance over which the oscillation takes place.

If the electron beam is accompanied by a beam of electromagnetic radiation (which in ELF consisted of microwaves) with a wavelength that exactly matches the electron's oscillation, the electron gives up some of its energy to the radiation beam. The energy transfer both makes the radiation more intense and slows the speeding electrons slightly.

To compensate for the electron's energy loss as it passes through the wiggler, the wiggler is magnetically tapered. This is done by reducing the magnetic field strength along the wiggler's length to exactly match the reduced energy of the electron beam. In this way the electron oscillation is kept in tune with the wavelength of the radiation output throughout the length of the wiggler.

The combination of the properly tapered magnetic field and added length is what significantly increased the power and efficiency of the free-electron laser amplifier over results reported in 1984 using a simple, straight wiggler. In these experiments, 80 megawatts peak power was produced—a 2,500-fold amplification at an efficiency of 5 percent.

Alternative Applications

In addition to providing the basis for missile defense, the existing microwave FEL could be used to drastically reduce the length and power requirements of linear charged particle accelerators, and to heat and confine thermonuclear fusion plasmas.

The accelerator application was proposed in 1982 by Sessler, whose two-beam particle accelerator concept would use two parallel beams of electrons. The first would be an intense, but low-energy beam for free-electron lasing. The second would consist of compact bunches of very high energy electrons. The microwaves from the FEL would be fed into the high energy beam every foot or so.

This is 10 times better than the 10-foot transfer regions achieved with existing klystron-driven accelerators. Thus, the result would be a high-energy linear accelerator that is not only more efficient than present designs, but also is either 10 times shorter or 10 times more energetic than is now possible.

Microwaves have long been used to confine and heat hydrogen fuel at the high temperatures required for thermonuclear fusion. Recently, experiments on the magnetic tokamak have shown that microwaves can be used to maintain electric currents in thermonuclear plasmas. This has led to prospects for "steady-state"—as opposed to pulsed mode of operation—fusion reactor designs.

The current Livermore FEL breakthroughs will revolutionize every aspect of magnetic fusion research. There are even designs, chiefly developed by Soviet scientists, for microwave-driv-

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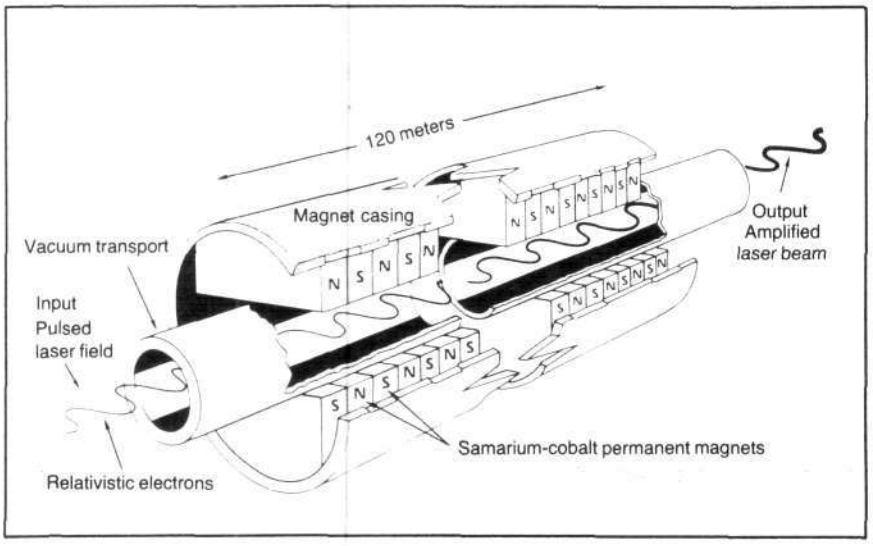
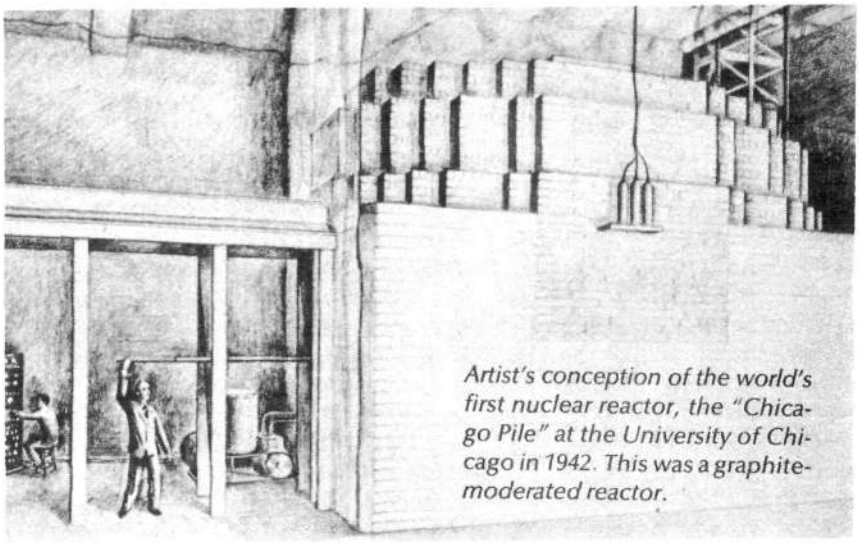


HOW THE FREE ELECTRON LASER WORKS

The free electron laser converts the energy of a high-energy electron beam into electromagnetic radiation. A beam of high-energy electrons enters the free electron laser together with a pulsed laser field. Magnets arrayed in alternating gradients (north and south) on the device cause the electrons to "wiggle," releasing energy to the beam. At a certain distance along the device, the kinetic energy of the electrons is transferred to the input laser beam, thus amplifying it.

The FEL can be tuned by changing the dimension and intensity of the magnetic wiggler. Recent advances have improved the efficiency of FEL amplification of high power microwaves from 5 percent to 40 percent by replacing the straight wiggler with a tapered one.



Artist's conception of the world's first nuclear reactor, the "Chicago Pile" at the University of Chicago in 1942. This was a graphite-moderated reactor.

Argonne National Laboratory

Nuclear Safety: Chernobyl Vs. Western Reactors

by Thoula Frangos and Marjorie Mazel Hecht

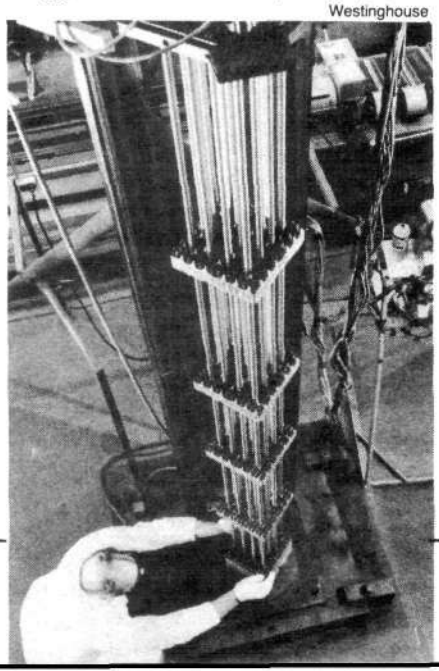
The first thing to know about the Chernobyl nuclear plant accident in the Soviet Union is that no other country has a commercial nuclear reactor of the Chernobyl design. This graphite-moderated reactor has not been used commercially in the West, because it was decided in 1950, by a special committee headed by Dr. Edward Teller, that the design was not a safe one for a civilian power plant.

The Chernobyl reactor is similar in design to the world's first nuclear reactor, built in 1942 during the Manhattan Project and known as the "Chicago Pile."

This first reactor had 385 tons of graphite blocks stacked up in a pyramidal shape with the uranium fuel placed between the blocks. The graphite served as the "moderator" to slow the neutrons to the optimum velocity to promote the chain reaction. Graphite was used because it was the most easily available and cheapest moderator known.

From the beginning, when the "Chicago Pile" was built in the squash court of the University of Chicago's Stagg Field in 1942, safety was a prime consideration. In order to be able to shut down the reaction immediately in case of an emergency, control rods were held on top of the pile by ropes, and a scientist was poised with an axe ready to cut the ropes to drop the control rods into the pile!

Westinghouse



A nuclear fuel assembly for a LWR being inspected. The long tubes are glide sheaths to guide the control rods. Fuel rods (not shown) are inserted through the grids, parallel to the glide sheaths.

After 1942, other graphite-moderated reactors were built as research reactors.

The Role of the Moderator

Uranium alone, without a moderator, can never reach a high enough rate of fission for the reaction to become self-generating (see Figure 1). The reason is that too few of the neutron reactions lead to fission.

It was discovered in the early nuclear research that the very energetic neutrons released at the moment of fission are not as likely to cause a new fission to take place in uranium-235 as are neutrons that have lost some of their initial energy. For this purpose, a "moderator" was introduced in order to slow down the energetic neutrons by making them collide with the light nuclei of the moderator.

To understand how this works, think of this process as billiard balls colliding with other balls. In a collision with a ball of the same mass, a moving billiard ball can lose a large amount of energy—even all of it—if the collision is head on and there is no spin.

But if a billiard ball collides with a much heavier ball, say a bowling ball, very little energy will be transferred to the latter and the billiard ball simply will bounce in another direction.

In a reactor, what is required is a moderator whose nuclei will do what the billiard balls of the same mass do to the moving billiard ball: take up some of the energy of the neutrons, thus slowing them down. Therefore, the materials that work best as neutron moderators would be those with very light nuclei.

Figure 1
THE NUCLEAR FISSION PROCESS

In nuclear fission, atoms of uranium, the heaviest element occurring in nature, are split apart into smaller pieces, releasing a tremendous amount of energy. Of the world's natural uranium only 0.7 percent is the fissionable type, uranium-235; the rest is uranium-238.

Atoms of all the elements are made up of a nucleus, which has smaller particles in it called protons, neutrons, and electrons. The protons and neutrons make up a tiny, very dense center of the atom, and the electrons are scattered around this nucleus at a distance. The number of protons in an atom determines what kind of an element it is. Hydrogen always has 1 proton, for example. But the number of neutrons can change, without changing the identity of the element.

The protons have a weight of 1 mass unit each and have a positive electrical charge. Neutrons also weigh approximately 1 mass unit, but have no charge. Electrons are very small compared to protons and neutrons, weighing about 2,000 times less. However, each electron has a negative electric charge, which will balance a positive charge if both are put together.

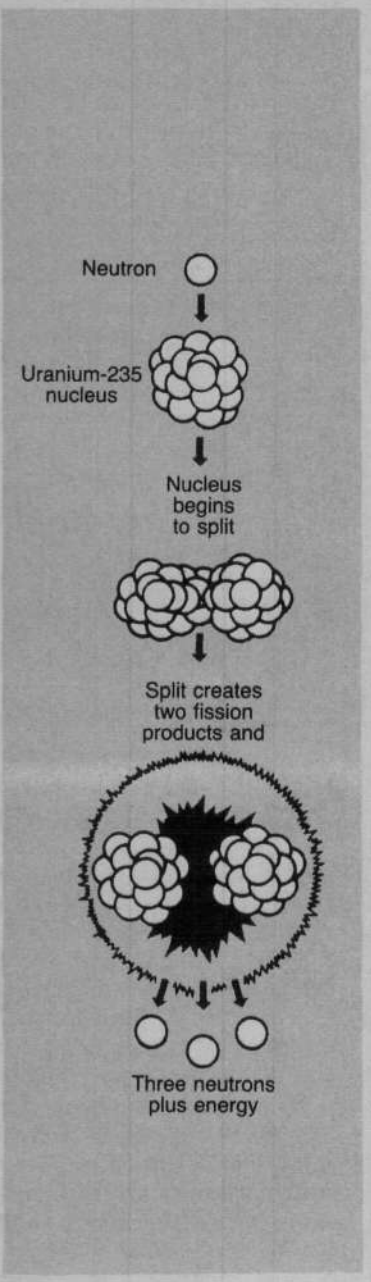
In an atom, the number of electrons and protons are equal, balancing the electrical charges and making the atom neutral. The weight of the atom is the total weight of all the protons and neutrons together. In a uranium-238 atom, for example, there are 92 protons and 146 neutrons, for a total weight of 238 mass units. This is usually called the atomic weight of the atom.

During the 1920s, scientists discovered that new elements could be made by bombarding atoms with the nucleus of a helium atom, called an alpha particle. For example, if an alpha particle is shot into a nucleus of beryllium and stays there, the beryllium atom becomes a carbon atom—another element. The beryllium atom, which has 4 protons and 5 neutrons for an atomic weight of about 9, becomes a carbon atom, which has 6 protons and 7 neutrons and an atomic weight of about 13. The helium nucleus, which has 2 protons and 2 neutrons and an atomic weight of about 4, is absorbed by the beryllium to make carbon.

When scientists bombarded a uranium atom with a neutron, they found that it split into two new elements, although not always into the same combination of new elements. These are called fission products.

As the two new elements split apart, they repel each other because they each have large positive charges. They fly apart at tremendous speeds. This motion causes heat as these fragments are slowed down and stopped in the uranium. In addition to the fragments that break off, neutrons also are released from the fissioning uranium; perhaps two or three neutrons fly off every time a fission or split occurs in the uranium.

This is the most fascinating thing about uranium fission. Not only does a uranium atom fission when a neutron is absorbed in its nucleus, but it gives off more neutrons during the fission. These new neutrons can then go on to produce more fissions in other uranium atoms, thus maintaining a chain of fission reactions—called a chain reaction. Sustaining this chain reaction in a controlled way is the basis for producing energy in a nuclear reactor.



Ordinary water, heavy water, graphite, and the element beryllium have all been used as moderators. In light water reactors, called LWRs, ordinary water is used for both the coolant and the moderator. The LWR is the most common type of nuclear reactor worldwide, and there are two basic types: the pressurized water reactor (PWR) and the boiling water reactor (BWR). (See Figure 2.)

Another Western design is the Canadian deuterium-moderated uranium-fueled reactor, known as CANDU, which uses *heavy* water for the moderator and the coolant.

Graphite As a Moderator

The Chernobyl reactor, unlike these Western designs, uses graphite as a moderator, not water. (See Figure 3.)

Graphite is a form of carbon of the sort used in pencil lead. There are two carbon structures—diamond and graphite. Reactor-grade graphite is made artificially by graphitization of petroleum coke. This simply means pressing, heating, and sintering petroleum coke in order to remove impurities and crystallize the carbon into graphite. Its crystalline form is hexagonal and consists of layers of carbon atoms on top of each other.

One problem inherent in using a graphite moderator is known as the "Wigner effect," named for the Nobel prize-winning scientist Eugene Wigner. Below a temperature of 350° Celsius, radiation damage from the neutrons in the fission reaction causes an accumulation of stored energy in the crystal lattice of the graphite, as the neutron bombardment knocks a carbon atom loose from the graphite's crystal structure. If this less stable structure is then suddenly subjected to a change in

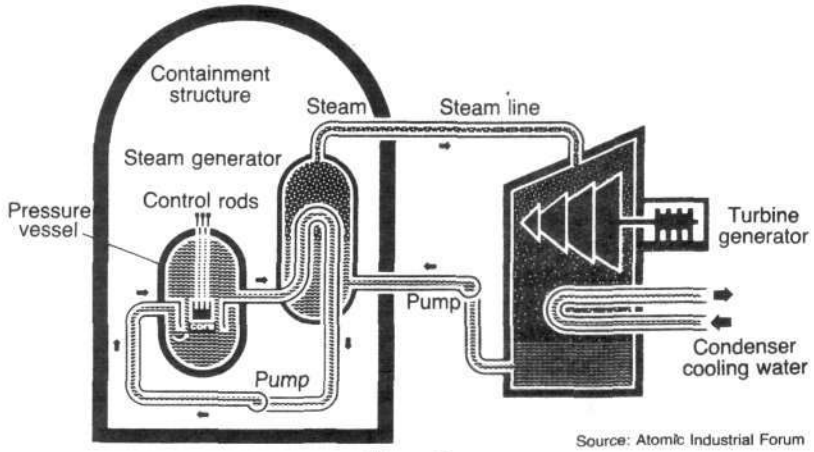
temperature, there will be a sudden release of energy from the graphite, causing a large increase in temperature. Because of this known effect, graphite-moderated reactors operating at fairly low temperatures must follow careful procedures to allow the controlled, gradual heating of the material so that *annealing* can take place, preventing a catastrophic temperature rise. The annealing process restores the graphite crystal structure to its original shape.

Graphite-moderated reactors that operate at high temperatures—such as the high-temperature gas-cooled reactor (HTGR)—do not have this problem.

Another difficulty with graphite stems from its chemical affinity to oxygen, water vapor, carbon dioxide, and metals. This can cause combustion if there is a sudden rise in temperature and the uranium-oxide fuel escapes from the fuel rod that encases it. In fact, this is what happened at Chernobyl, starting a graphite fire.

This problem is avoided in the more advanced HTGR reactor by using chemically inert helium gas as the coolant, instead of water.

Schematic of a Pressurized Water Reactor



Source: Atomic Industrial Forum

Figure 2
HOW A NUCLEAR REACTOR WORKS

The basic layout of a nuclear power plant is not very different from that of a coal-fueled power plant. In a coal-fueled plant coal is burned to produce heat, which boils water contained in steel tubes. This gives off steam, which causes the turbine to rotate.

The turbine, in turn, is connected to the rotor of an electrical generator that produces electric current as the rotor spins in the magnetic field of the generator. Thus the initial burning of coal, a chemical reaction, is turned into electrical energy.

In a nuclear reactor, the nuclear fuel is made up of small, ½-inch diameter pellets of uranium, stacked on top of each other inside hollow tubes of zirconium metal. Thousands of these tubes or fuel rods are arranged in fuel bundles and placed inside the nuclear reactor core.

The fission process occurs in the reactor core, and the heat produced by the nuclear reaction is transferred by a coolant to a steam turbine. The coolant is used both to cool the core and to carry the heat to the turbine. Most reactors use light water as a coolant.

In the pressurized water reactor, or PWR, the pressure is kept high enough so that the water does not boil, but remains a liquid. This water then flows into tubes that are immersed in water that is at low pressure. The low pressure allows the water outside the tubes to boil, producing steam to run the turbine that powers the electric generator.

In the boiling water reactor, or BWR, the reactor core itself is immersed in water. As the water flows past the hot fuel rods, it boils, directly producing the steam that turns the steam turbine.

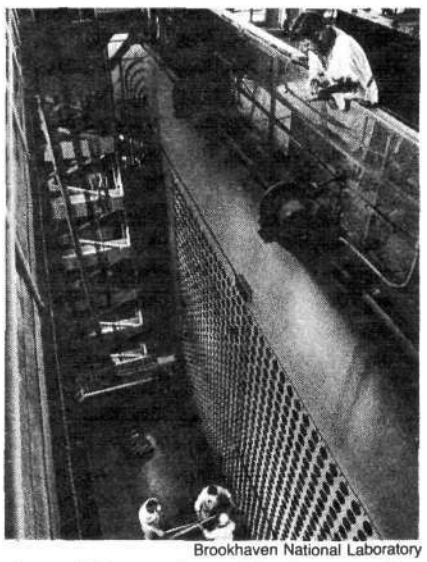
Controlling the Reaction

The nuclear reaction is controlled by the use of control rods. These rods go right into the core alongside the fuel rods. The rods contain the element boron, which absorbs neutrons very easily, capturing them before they cause a uranium atom to fission. The farther the control rods are placed in the reactor core, the less power is produced. This allows the engineer who operates the plant to control how much power is produced or to shut down the process completely by pushing the control rods all the way through the core.

Defense in Depth

"Defense in depth" is the term used for redundant emergency systems built into U.S. nuclear plants. For example, look at the multilevel containment barriers to prevent the release of fission products to the environment. These barriers, shown schematically in Figure 4, are:

- the nuclear fuel itself, fabricated into ceramic pellets that contain the fission products



Brookhaven National Laboratory

A graphite-moderated test reactor, the Graphite Research Reactor at the Brookhaven National Laboratory in New York, which began operating in August 1950. The rows of cylindrical holes are for fuel rods.

• the fuel rods of zirconium alloy, about 12 feet long and ½ inch in diameter, into which the pellets are stacked and sealed

• the steel pressure vessel—up to 75 feet high and 20 feet in diameter, with 9-inch-thick walls—containing the several thousand rods that make up the reactor's fuel core

• the primary containment, an essentially leak-tight shell of steel plate, which encloses the nuclear steam supply system

• the massive containment building, a steel-reinforced concrete structure with walls 3 or more feet thick.

The Chernobyl reactor does not have a steel pressure vessel or overall containment building. Its containment structure covers only the steam system, not the reactor core.

One additional major problem is that the Chernobyl reactor, unlike other reactor designs, has a *positive reactivity coefficient*. In simple terms, this means that when for some reason the coolant temperature goes up, the reactivity goes up. U.S. reactor designs are the opposite: There is a *negative reactivity coefficient*, which means that if the coolant temperature goes up, the reactor shuts itself down.

The Military Question

The United States has one *military* reactor that is graphite-moderated and is used for making plutonium fuel for weapons. This 23-year-old reactor, known as the N Reactor, is located in Hanford, Wash.

It is likely that the Soviets chose the Chernobyl reactor design, despite its known safety problems, specifically because they wanted a dual-purpose reactor—one that could easily make plutonium fuel for weapons *and* electricity at the same time.

The Soviets have 20 reactors of the Chernobyl type, with plans to build more. They also have built some Western-style PWRs that have incorporated more conventional Western safety features.

After the Chernobyl accident, the U.S. Department of Energy accelerated its regular review of the N Reactor design and safety, and appointed an independent committee to review the reactor as well. In a report issued May 21, 1986, Energy Secretary John S. Herrington announced that the Special Safety Review Team had concluded that the N Reactor's graphite was "well protected from the damaging effects of postulated fires or explosions and that the confinement system meets federal requirements for protecting the public."

He also noted several other differences between the N Reactor and the Chernobyl reactor. The Chernobyl reactor, for example, refuels while the reactor is operating. This may maximize output, but requires special systems to maintain safety and control. Also, he said, the Chernobyl reactor kept fuel in the reactor for longer periods and used considerably less monitoring equipment than the N Reactor.

In addition, Herrington said, the N Reactor has multiply redundant safety systems, which are not present in the Soviet design.

The exact cause of the Chernobyl accident is still not known, because the Soviets have not made public the necessary information for nuclear scientists to fully analyze what happened. From what is known, however, we can see that U.S. nuclear plants are very different from Chernobyl in design and safety measures.

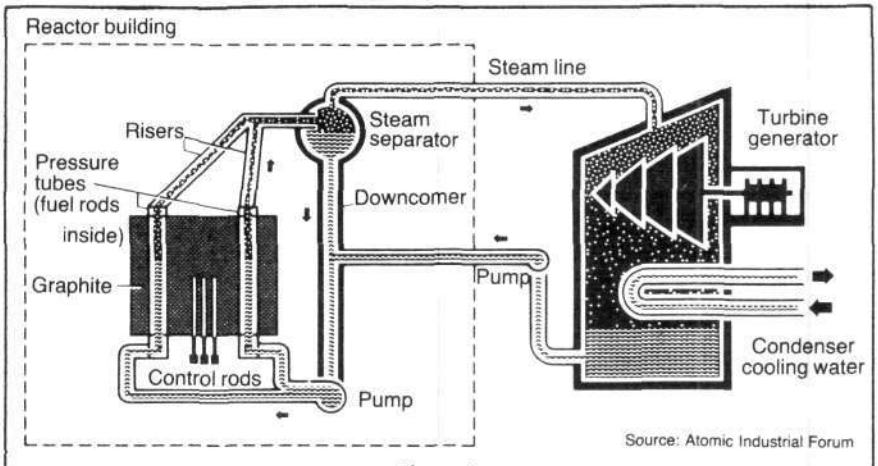


Figure 3
SCHEMATIC OF THE CHERNOBYL REACTOR

The Chernobyl reactor, a graphite-moderated water-cooled reactor, is known as RBMK-1000. Pellets of uranium oxide are sealed into fuel rods made of zirconium alloy and then inserted into 1,700 channels in the 2,000-ton graphite block. The fuel rods are inside pressure tubes. The coolant water in the pressure tubes picks up the heat from the fission process and becomes steam, which is then used to drive a turbine generator. The steam is condensed back into water, which then is recycled through the reactor.

As you can see, the reactor building does not have the protective containment dome that U.S. commercial reactors have.

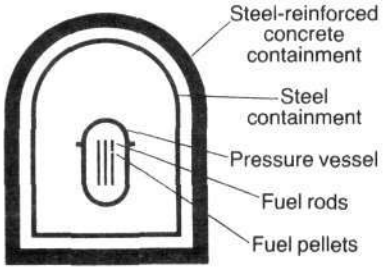
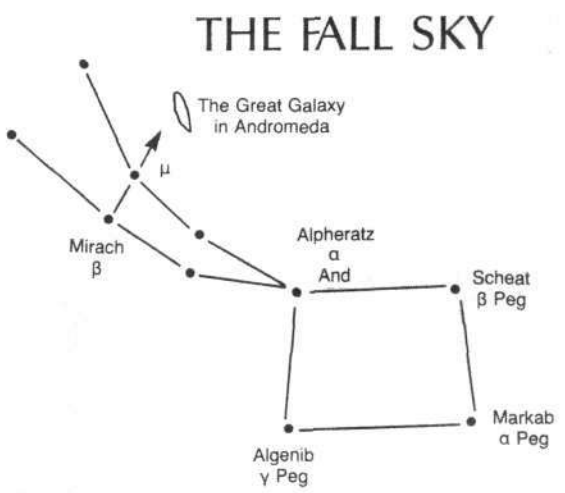


Figure 4
DEFENSE IN DEPTH

The multiple barrier system in Western nuclear plants emphasizes redundancy of safety systems. The effectiveness ot this approach was demonstrated in 1979, during the accident at Three Mile Island, when all but a very tiny amount of radioactivity was contained within the reactor building. After Three Mile Island, U.S. safety systems were further upgraded.

Source: Atomic Industrial Forum



THE GREAT GALAXY IN ANDROMEDA
This outline map shows a section of the constellations Pegasus and Andromeda that forms what I have called a Giant Dipper in the southeast part of the sky. The Andromeda Galaxy is near the handle of this dipper. The "Great Square" part of this dipper should not be too hard to find. Remember that it covers a large area of the sky. Does it suggest to you the winged horse of Pegasus? How many stars can you count inside the Great Square?

Viewing Andromeda and Pegasus

by Jim Everett

Do you know how to tell time by the stars, or find your direction at night? Imagine yourself with no modern instruments, just your eyes for observing at night. How would you construct a calendar, just from your star observations?

Astronomy is the oldest science, and it is especially fascinating to us because we can think through the same scientific problems that early civilizations had to solve. These ancient civilizations developed a very sophisticated body of knowledge about the universe over the centuries. In fact, in these ancient cultures, the population was far more familiar with the sky around them than most people are today. For the early river-going and ocean-going civilizations, navigation using astronomy was essential for survival.

We know this because ancient astronomical science has been preserved in the great epic poems. Vedic poetry, for example, the ancient oral poems of India that, in their present form, are at least 3,000 years old, tell us about the astronomical advances of Vedic culture. In fact, the Vedic epics, as well as later Greek epics, such as Homer's *Iliad* and *Odyssey*, were designed to help people remember and understand the heavens by personifying the constellations and creating stories about them.

These myths are still useful to us today in helping us to learn the sky. In this first of a series of articles on getting to know the sky, I concentrate on the constellations of Andromeda and Pegasus and on the art of "seeing" at night.

The Art of 'Seeing'

In September and October, the neighboring constellations of Andromeda and Pegasus provide an excellent test of your naked eye observation powers and the quality of "seeing" in your geographical area. Your ability to find faint objects in the night sky depends on both of these factors.

Observing powers depend only to a certain extent on how good your natural vision is. Most people who are nearsighted or have some other problem with their vision can see normally with the help of glasses. But you can also teach yourself to "see better." Later, I will give you a few tricks for finding the most distant celestial object visible to the naked eye, the Andromeda Galaxy, whose light has taken more than 2,000,000 years to reach Earth.

Before that, however, you will need to know what other factors affect your ability to see faint objects. Nowadays, the biggest single factor is the presence of city lights, which decrease your night vision in two ways. First, your eyes respond to darkness by dilating or enlarging the pupils. This allows more light to enter, so you can see fainter objects. If there are bright lights around you, such as house lights or street lights, your eyes will not dilate to their maximum extent.

City lights also hurt your vision by reducing the contrast between faint stars and the background sky. If you have ever looked toward a town or city when out in the country, you know that the sky glows in that direc-


The great spiral galaxy in Andromeda.

tion. This glow makes it harder to pick out really dim objects.

Even out in the country, away from all man-made lights, some nights are better than others for looking at faint celestial objects. The biggest culprit is humidity. Water in the air does not have to be in cloud form in order to block out light. On clear but hazy nights, light from the faintest stars will be extinguished by water vapor. Fortunately, in the fall we start to have cool, clear, and dry nights—perfect conditions for a look at the sky.

A Giant Dipper

Taken together, the stars in the constellations Andromeda and Pegasus can be imagined to form a Giant Dipper, much larger than the famous Big Dipper near the Pole Star. First, you must find the body of the dipper. These stars are sometimes called the Great Square in Pegasus. Look toward the southeast and then raise your head about 60 degrees.

If you are not accustomed to measuring angles in degrees, here's a tip: The width of your outstretched hand held at arm's length is about 20 degrees. To find the Great Square, move your eyes three hand lengths up from the southeastern horizon. Each of the sides of the Great Square is between 15 and 20 degrees, so you can use your hand measurements again to make sure you have found the right stars.

Before finding your way over to Andromeda, let's look at Pegasus for a moment. The name comes from the winged horse of Greek mythology. For some reason, the horse is always depicted as being upside down!

The most noticeable thing about Pegasus is the *lack* of stars, compared to nearby regions of the sky. This is so because Pegasus lies above the central plane of our galaxy, which is the most heavily populated region. One of the classic tests of determining how good your vision and the "seeing" are, is to count the stars that lie within the Great Square. Most star charts show 30 or 40 stars, but you will have to have very good conditions to see all of these.

Like most relatively bright stars, the stars that define the corners of the square have two names. The oldest name is its Arabic name. Arabic scholars kept the Greek astronomical tradition alive during the Dark Ages. Scientists of the European Renaissance borrowed the Arabic star names when they began to renew their interest in astronomy. The other star name is usually a letter of the Greek alphabet combined with the constellation name. The brightest star in a constellation gets the first letter, "alpha," and the others are assigned letters in descending order of brightness.

Starting from the northwest corner of the square, the stars are called Scheat (Beta Peg), Markab (Alpha Peg), Algenib (Gamma Peg), and Alpheratz (Alpha And). This last star is actually a little inside the Andromeda constellation, and since it is called Alpha, you know that it is the brightest star in Andromeda.

Alpheratz is where Andromeda's handle joins Pegasus's bowl to form the Giant Dipper. Unlike the Big Dipper, the Giant Dipper has two handles running side by side, two stars at a time. You will use one pair of these stars as a pointer to the Great Galaxy in Andromeda.

The second pair of stars in the handle are called Beta and Mu Andromedae. They are about 4 degrees apart (which is a little less than half your clenched fist held at arm's length). Follow an imaginary straight line north through these two stars another 4 degrees. You will be looking at the Andromeda Galaxy.

The Andromeda Galaxy

The Andromeda Galaxy is a twin to our Milky Way Galaxy. Both contain as many as a trillion stars and both are spiral galaxies.

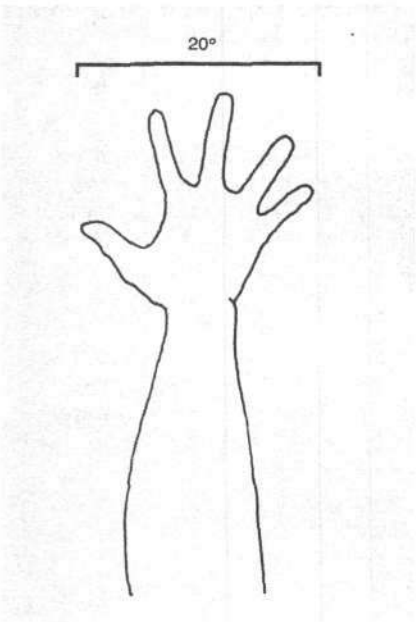
Andromeda is inclined 15 degrees to our line of sight, so we are seeing it almost edge on. Even though it is millions of light years away, it is still surprisingly large in the sky. If our eyes could see light from the faintest edges of Andromeda, it would appear to stretch across 5 degrees, the length of 10 full moons lined up side by side! But even under the best conditions, our eyes can discern only the brightest 2 degrees of its center. To the naked eye, Andromeda is a very faint, fuzzy oval of light.

You will be seeing light that left Andromeda 2,200,000 years ago. Since light travels at 186,000 miles a second, that adds up to too many miles to work with conveniently, so astronomers prefer to measure such large distances by simply referring to how long the light traveled to reach us—a light year. The light year is not a measure of time, but of distance; one light year equals 5.8786 trillion miles.

Whether or not you actually see Andromeda will depend on the seeing conditions and how carefully you look. To increase your chances of success, do the following. Allow your eyes to adjust to the dark for at least 30 minutes. If you try to look when you first come outdoors, you won't find it.

If after a half hour of allowing your eyes to get dark adapted, you still do not see it, try using "averted vision." Your side or peripheral vision is more sensitive to faint light than your direct vision. If you direct your gaze a little to the side of where you want to look, you might be able to see that faint, hazy patch of light.

In the next article, we'll return to the question of how to tell time by the stars.



GAUGING DEGREES IN THE SKY
When your arm is outstretched in front of you, your handspan should measure about 20 degrees.

NMR: Making a Medical Revolution

A Machine Called Indomitable
by Sonny Kleinfeld
New York: Times Books, 1986
250 pages, $16.95

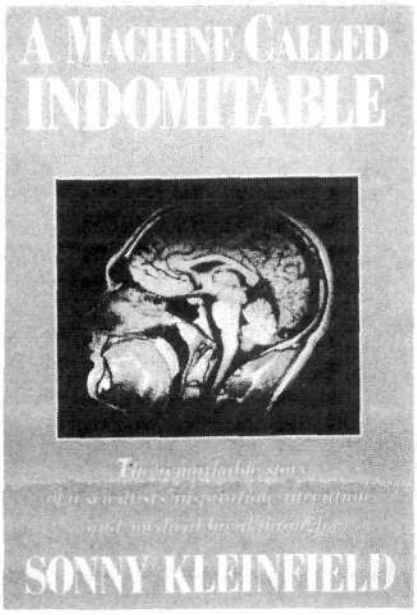
A Machine Called Indomitable documents the remarkable, lonely, and long struggle of Dr. Raymond Damadian to transform Nuclear Magnetic Resonance (NMR) from a test-tube technology used by chemists to a machine that would revolutionize medicine, scanning patients to detect early signs of disease.

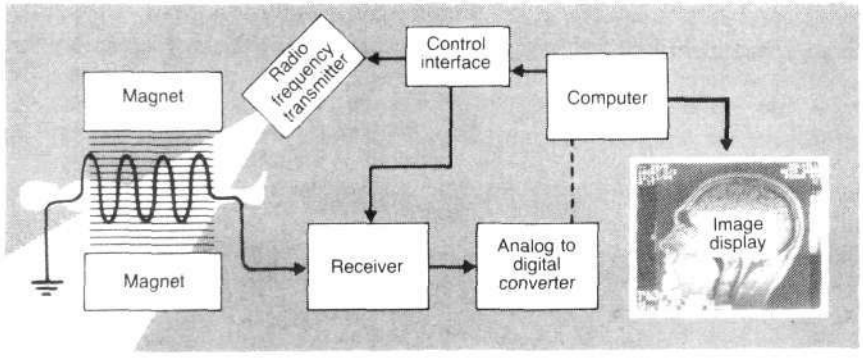
This story tells of his small group's tenacious struggle, long hours of toil, ridicule from the NMR community, funding cutoffs from the National Cancer Institute, and eventually even the enmity of their own university; and illustrates something Machiavelli was quick to point out in *The Prince* : "It must be remembered that there's nothing more difficult to plan, more doubtful of success, nor more dangerous to manage than the creation of a new system. For the initiator has the enmity of all who would profit by the preservation of the old institution and merely lukewarm defenders in those who would gain by the new ones."

Physicians now discuss the NMR technology as a revolution for medicine, that can shorten presurgical hospital diagnostic evaluations and eliminate many costly and sometimes painful diagnostic tests, while providing the physician with superior diagnostic information. NMR can distinguish between different types of soft tissue, show blood coursing through veins and arteries, reveal hemorrhages, pituitary tumors, pituitary lesions, brain stem lesions, and other problems a CAT scan cannot pick up, and provide superior diagnostic information for multiple sclerosis, cardiac, abdominal, spinal, and pelvic studies. Yet, Damadian, in 12 long years of struggle to make this technology a reality, was called "harebrained, mad, wild, wacky, a lunatic," and so on.

Each problem his small team faced seemed insurmountable, although through it all Damadian maintained an attitude of "don't tell me it can't be done, just do it." The first problem Damadian faced was how to focus the NMR signal coming from different parts of a scanned human being. He decided to use a magnet that produced a saddle-shaped field, with a very low field strength at the nadir. The radio frequency used to excite the nuclei in the patient would correspond to this low field strength, and hence NMR signals would be detectable only from this point.

This problem was relatively trivial, compared to the apparently insurmountable technical problems involved in building the superconducting magnets with a crew whose knowledge of electronics was skimpy, at best. Tremendous problems existed wrapping superconducting wire—which often has undetectable defects—around large hoops to create a solenoid. But far worse problems were encountered welding huge dewars together. These giant nested donut-shaped thermos bottles were necessary to hold liquid helium, surrounded





HOW NUCLEAR MAGNETIC RESONANCE WORKS

In an NMR scan, the patient lies on a table surrounded by a receiver coil (shown hooked up to the receiver) and by large magnets. The magnetic field is turned on, tuned to the same frequency as an alternating electromagnetic field generated by a radio frequency transmitter—a frequency that matches the natural frequency of hydrogen nuclei. This boosts the energy level of the patient's hydrogen nuclei into a higher energy nuclear spin state, in the area of the patient's body that is being scanned. Once the radio frequency is turned off, the excited nuclei will reemit the extra energy at varying rates, as they flip back to their lower energy nuclear spin state. This extra reemitted energy is picked up by the radio frequency receiver coils around the patient, and fed to the receiver. Then it is converted from an oscillating wavelength form to a digital form by the digital converter. Once available in digital form, the information is analyzed and color coded by the computer, to form a convenient display image for the physician.

by liquid nitrogen to keep the liquid helium cool.

The dewars perpetually sprung pinhole leaks, and when a leak was welded shut in one place, it usually showed up again somewhere nearby. To pick up the NMR signal, a probe, or coil, large enough to fit around an adult patient would have to be created. Probes had been built, many times before, but for smaller, test-tube use.

It turned out that the set of mathematical equations that determined the proper capacitors necessary to make coils was totally inaccurate and hence worthless when scaled up. The best the team could design, from the trial and error that followed, was a coil 14 inches in diameter. But in May 1977, when the whole assembly was tried with Damadian inside it, it didn't work.

The coil fit very tightly on Damadian, and his body was consequently conducting electricity directly to the coil, overloading the antenna of the new superconducting magnet NMR scanner (dubbed by the team "The Indomitable"). This excessive electrical current conducted directly through his body was detuning the extremely sensitive antenna. His far thinner assistant, Larry Minkoff, M.D., became the first human successfully scanned.

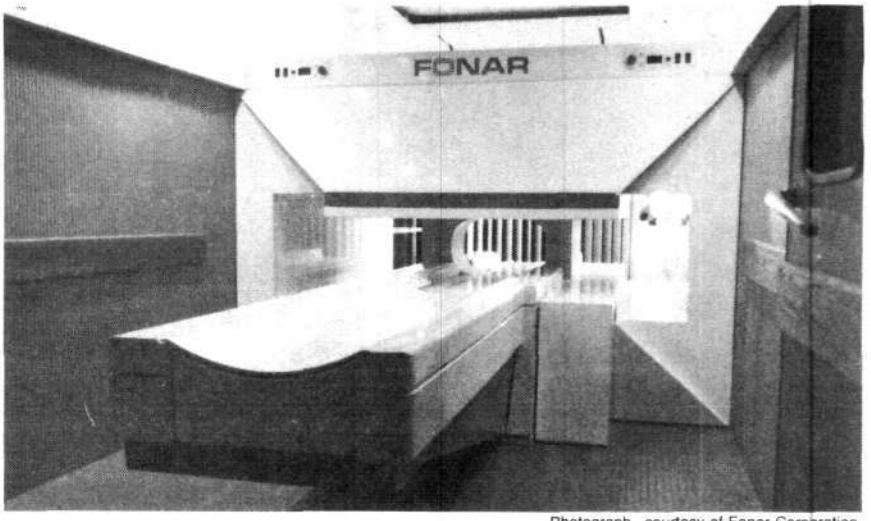
With the first human scans completed, the group decided to incorporate as the Fonar Corporation to raise money for research without battling with the scientific establishment over grant applications. Rather than market the "Indomitable," the first human NMR scanner, Fonar decided to develop a permanent-magnet NMR human scanner.

To improve the signal to noise ratio, Damadian's group ended up starting from scratch again, this time using a two-dimensional Fourier technique with a 3,000-gauss permanent-magnet NMR scanner. The previously discussed superconducting magnet, they concluded, was too difficult and too expensive for a hospital to manage. It required unending quantities of liquid helium and liquid nitrogen, and special personnel to continually refuel the coolants for the superconducting magnet.

In addition, the fringe-field generated by the superconducting magnet destroyed credit cards, physician's beepers, and pacemakers, and turned common metal objects into exceedingly dangerous flying projectiles, necessitating airport-type security to prevent metal objects from inadvertently entering into the vicinity of the superconducting magnet! Fonar Corporation's new permanent-magnet NMR was designed to minimize these fringe-field effects, and had no need for the expensive supercooling.

A Machine Called Indomitable is a fascinating, very personal story of the long struggle to realize a technological dream whose full impact on medicine has not yet been felt. It is definitely worth reading.

—Carol Shaffer Cleary

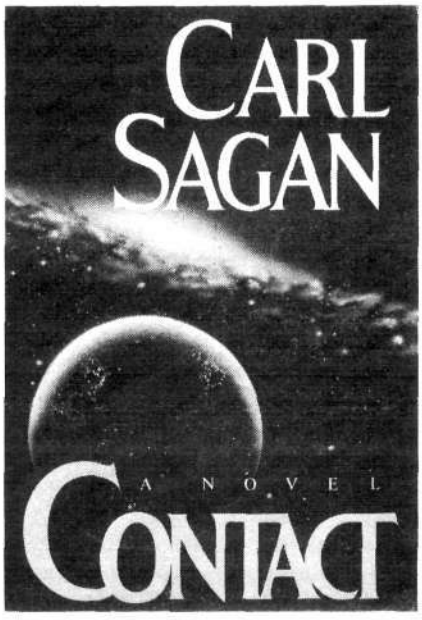


Photograph courtesy of Fonar Corporation

The patient lies in a futuristic-type bed that moves into the machine as the NMR scan begins.

Sagan's Alien World

Contact
by Carl Sagan
New York: Simon & Schuster, 1985
432 pages, $18.95



Anyone who has had the misfortune to watch one of Carl Sagan's television performances, can imagine the ambience of this dull, dull book: gnostic mysticism and pseudoscience. A radio telescope picks up a message from space, which leads to a brief contact with an advanced space civilization.

They have made contact in order to give a message to Earth: God is gone from the universe but He was its creator. God embedded hidden messages in the creation, which can only be revealed through the methods of information theory and the use of advanced large computers. One such message is found after a several-kilometers-long expansion of the number π. When this expansion is arrayed in a grid, the numbers are found to form a circle.

Not only is the philosophy "creepy" and the story banal, but there is a paucity of detail about radio telescopy. What little there is about how an observatory functions is, of course, interesting.

Sagan is a well-publicized proponent of the Soviet position on the nuclear freeze. His book, which parodies religion as fundamentalism, is only a slightly more subtle attack upon Western values. This being the case, we can almost welcome his off-the-wall slander on the Fusion Energy Foundation, since it clearly establishes the distance between Sagan and the FEF.

Nevertheless, we must take exception to his vicious characterization of the FEF as terrorists. The context of the slander is as follows: The pressure of the alien contact has led to a global detente, and all of the nations of the world have collaborated to build a spaceship to the specifications radioed to Earth by the space aliens. The fundamentalists oppose this and blow up the first spaceship.

Sagan writes: "It was never determined who did it. Organizations publicly claiming responsibility included the Earth-Firsters, the Red Army Faction, the Islamic Jihad, and the now underground Fusion Energy Foundation, the Sikh Separatists. . . ."

Ironically, the leftist organizations he cites, such as the Red Army Faction and the Sikh Separatists, are political allies of both Carl Sagan and the Soviet KGB.

—*Carol White*

On Volcanoes, Sunspots, and the Jupiter Effect

The Jupiter Effect Reconsidered
by John R. Gribben and
Stephen H. Plagemann
New York: Vintage Books, 1982
182 pages, $3.95 (paperback)

In the field of natural science today there are two schools of thought: there are those who believe that it is ultimately small, random events that determine the details of the evolution of our planet. And there are those who hold that there must be a higher ordering principle involved in the evolution of the universe that, when better understood, will show us the lawfulness of events like volcanoes and earthquakes.

The Jupiter Effect Reconsidered contains a number of well-presented thoughts in the tradition of the latter school. Although on the surface the authors of the book, two editors from *Nature* magazine, appear to be panic-mongering the population of California into thinking that an earthquake can be expected every time the planets of our solar system align in certain configurations, some of the data they present is very interesting.

In fact, judging from the insistent way in which they present their case, one would think they are using earthquake prediction in the same fashion that an ancient Islamic astronomer, whom they reference, was using the determination of the direction of the great circle from Ghizani to Mecca to make some of the best measurements of the length of day at that time. In the authors' words, "scientists involved in fundamental research . . . must find some mundane justification for their work before it receives the approval of the committees which disburse the money." While this may be an unfortunate axiom in today's world of National Science Foundation grants and the Gramm-Rudman act, it can lead to overstretching a good idea.

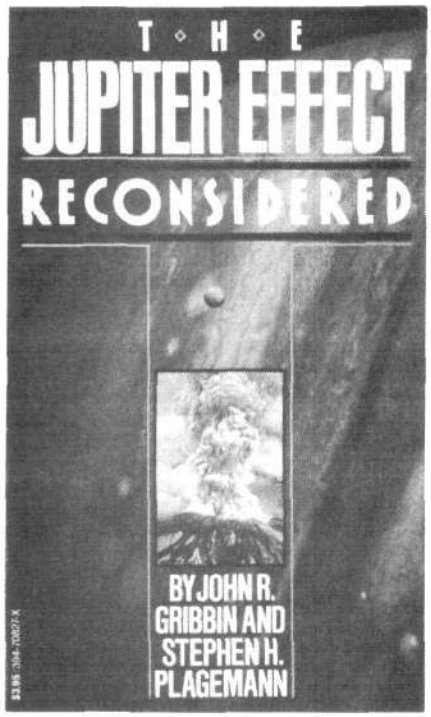
Starting from a basic discussion of the geophysics involved in earthquakes, particularly in the San Andreas fault region, the authors point out that the crucial piece of information missing in order to predict an earthquake is how the tension, which builds up gradually along a fault between two tectonic plates, is triggered for release. By a number of steps involving presentation of a good deal of interesting statistical evidence, they trace this trigger back to the alignment of the planets in our solar system. Sound a bit like astrology? Not by a long shot.

The Jupiter Hypothesis

The authors hypothesize that: The changing configuration of the planets, particularly the inner planets and Jupiter, creates both direct tidal forces on the surface of the Sun and internal solar turbulence caused by the change in the position of the center of mass of the entire solar system. This center of mass moving in and out of the Sun, leads to sizable perturbations in the Sun as it tries to revolve around this point. These disturbances trigger sunspots and other electromagnetic disturbances on the Sun's surface. The change in solar wind resulting from these disturbances interacts with the Earth's magnetic field, which in turn influences our atmospheric circulation.

The authors reference statistical evidence showing in particular a relation between the strength of the aurora borealis and the depth of the Aleutian low pressure system. It is well known in meteorological circles that the position and depth of this particular low pressure system is important in determining the weather in the rest of the Northern Hemisphere. The authors conclude that this change in atmospheric circulation will influence the rate of rotation or, inversely, the length of day of the Earth. This acceleration of the Earth (positive or negative) will be enough of a jolt to trigger the release of tension along a fault and cause earthquakes.

In their first book on this subject, published in 1975, the authors noted that between 1979 and 1982 all nine planets would be located on the same side of the Sun for the first time in 179 years. They predicted that this would produce a major earthquake along the San Andreas fault sometime around



1982. In this second book, they attempt to prove that Mt. St. Helens eruption (1980) was actually the event they were expecting.

Although the evidence presented for the interaction between the planets, the Sun, and the Earth is very convincing, I am not sure we understand these effects well enough to say that there will be a major seismic event once every 179 years because of planetary alignment.

There are two aspects of this hypothesis, however, that I find very interesting. The first is that the authors have tried to explain the patterns observed in weather and seismic activity by the natural cycles observed in the gravitational and magnetic fields in our solar system. The second point is the connection they have found between the Earth's magnetic field and atmospheric circulation.

Back to Humboldt

The influence of the terrestrial electric and magnetic fields on weather has to be one of the most neglected facets in the fields of meteorology and climatology today.

Continued on page 61

Books Received

Nuclear Power Technology Vol. 1: Reactor technology. W. Marshall, ed. Oxford University Press, 1983. Hardcover, 503 pp., $65.

Management of Radioactive Materials and Wastes: Issues and Progress. Shyamal K. Majumdar and E. Willard Miller, eds. Pennsylvania Academy of Science, 1985. Hardcover, 405 pp., $35.

The Industrial Laser Annual Handbook, David Belforte and Morris Levitt, eds. Tulsa: PennWell, 1986. Hardcover, 250 pp.

Symposium on Lasers and Particle Beams for Fusion and Strategic Defense held April 18-19, 1985 at the University of Rochester. Gaithersburg, MD: Fusion Power Associates, 1986. Paperback, 167 pp.

Molecules and Radiation—An Introduction to Modern Molecular Spectroscopy, by Jeffrey I. Steinfeld. 2nd edition. MIT Press, 1985. Hardcover, 493 pp., $37.50.

AIDS—Papers from *Science*, 1982-1985, Ruth Kulstad, ed. AAAS, 1986. Paperback, 653 pp.

The Molecular Basis of Cancer, Peter B. Farmer and John M. Walker, eds. Wiley-Interscience, 1985. Paperback, 349 pp.

Photosynthetic Systems—Structure, Function and Assembly, by Susan M. Danks, et al. John Wiley, 1983. Paperback, 162 pp.

Biosynthesis of the Photosynthetic Apparatus—Molecular Biology, Development and Regulation, J. Philip Thornber et al., eds. Alan R. Liss, 1984. Hardcover, 405 pp.

Pattern Formation—A Primer in Developmental Biology, George M. Malacinski and Susan V. Bryant, eds. Macmillan, 1984. Hardcover.

A Practical Guide to Molecular Cloning, by Bernard Perbal. Wiley-Interscience, 1984. Hardcover, 554 pp.

Immunology of the Bacterial Cell Envelope, D.E.S. Steward-Tull and M. Davies, eds. Wiley-Interscience, 1985. Hardcover, 391 pp.

Coenzyme Q—Biochemistry, Bioenergetics and Clinical Applications of Ubiquinone, G. Lenaz, ed. Wiley-Interscience, 1985. Hardcover, 517 pp.

Physics Through the 1990s, by the National Research Council. Eight paperback volumes: Overview; Atomic, Molecular, and Optical Physics; Condensed-Matter Physics; Elementary-Particle Physics; Gravitation, Cosmology, and Cosmic-Ray Physics; Nuclear Physics; Plasmas and Fluids; Scientific Interfaces and Technological Applications. National Academy Press, 1986. $160. Also sold separately.

Chernobyl and the 'Big Lie'

Continued from page 9

for Ralph Nader's "Public Citizen" group in the May 19 *New York Times*. The ad, signed by Robert Pollard and Daniel Ford of the Union of Concerned Scientists, is a fund-raising piece with the message that the Russians and Americans are the same when it comes to "covering up nuclear dangers."

Using Diamond's line, the ad warns: "the Chernobyl nuclear plant, contrary to earlier reports, did have a containment building. Indeed, the design used by the Russians bears a striking resemblance to the long-suspect design used by General Electric." The ad includes a map of locations of the 39 GE plants in question. "Check the map to see how close you live to a GE nuclear plant," the ad warns ominously.

To all but the most credulous, the ad is a joke. In the first place, Pollard and Ford have been thoroughly discredited in the scientific community because of their history of lying about nuclear power. Interestingly, Bernaro noted that although he invited the Union of Concerned Scientists to attend task force meetings discussing core melt accidents, "their participation was shallow indeed"—they rarely showed up. They have a "vested interest" in shutting down U.S. plants, not in safety studies.

The Public Citizen ad raises allegedly "secret" safety issues about 39 General Electric plants that were publicly aired in Congress and put to rest in 1978. Nevertheless, the Public Citizen group uses this to demand that the Nuclear Regulatory Commission halt construction and licensing of 29 commercial power plants now being built, saying that they had the potential for catastrophes like the one at Chernobyl.

Public Citizen's "Big Lie" number one is of course to state directly what their friend Stuart Diamond only implied—that the Chernobyl plant has a containment building. Second, it broadcasts a totally fabricated scare story about a "confidential 1971 memo" by nuclear safety adviser Dr. Stephen Hanauer. The ad says that Hanauer's secret memo advises the government not to let GE build this type of plant because the "pressure suppression containment system" was unsafe. Public Citizen sounds the alarm that the government, nuclear regulatory officials, and GE are thus conspiratorily involved in a "30-year cover-up of nuclear safety dangers."

Public Citizen neglects to mention that the so-called secret safety issues involved were exhaustively and publicly discussed and resolved by Congress and the Nuclear Regulatory Commission when the very same memos were surfaced by the anti-nukes in 1978. Public Citizen also neglects to let readers know that the same Dr. Hanauer stated in a letter to the Nuclear Regulatory Commission on June 20, 1978: "My current opinion is that designs including pressure suppression containments can be licensed, because we have adequate assurance of their safety. This was also my opinion in 1972."

A spokesman for the Nuclear Regulatory Commission commented: "The technical issued were specifically discussed in a report called 'A Technical Update on Pressure Suppression Type Containment in U.S. Boiling Water Reactor Plants,' which was put out in July 1978 to address that subject to members of Congress and the public. That report concluded that the designs of pressure suppression type containment had adequate safety margins to protect the health and safety of the public."

The issues raised in the Public Citizen advertisement are addressed in detail in the response of General Electric. GE documents how the safety issue raised by Hanauer—how a pressure suspension containment system compared to other "dry" containment systems—was subjected to testing, review, and modification in the 1970s. The record of this successful testing, of course, is not secret and is information accessible to Public Citizen and to reporters.

GE also refutes in detail the Big Lie that Chernobyl's safety system bears any resemblance to GE's nuclear reactors. As one GE spokesman put it, "to say that our reactor and Chernobyl are the same is like comparing a Rolls Royce to a Yugo—they are both automobiles with four wheels. . . ."

Dr. Joseph M. Hendrie

Continued from page 9

their standard in the water reactor line for many years, and the 1,000-megawatt designs for which the heavy components were to be produced at the Atommash plant (which has so many problems now)—both those designs were early 1980s.

In 1979, after Three Mile Island, I talked to a high-level Russian delegation from the Ministry of Electricity. They were making their annual visit to the Department of Energy to discuss matters of mutual interest in electrical generating, and they had me over to explain what had happened at Three Mile Island. We talked about it at some length through interpreters. They then showed me and gave me a set of drawings of their 1,000-megawatt PWR which they said was going to become their standard power machine. That's the one that had the Western type containment on it and the emergency core cooling systems. But that's 1979. We had been making big pressure vessels since the late 1960s. So, I think that's the reason that they went to graphite.

Question: So you think that they didn't have the technological sophistication, and that's why they built the graphite reactors?

I don't know. These graphite machines, even the one at Chernobyl, were finished quite recently. They nevertheless are a design and a concept that is really late '50s sort of thinking. I'm sure there are some upgrades in the recent ones that reflect more recent technology, but they really in many ways are a technology that we ought to have gone beyond. They have positive void coefficients—

Question: Can you explain that please.

It means that if the power goes up, the reactivity goes up, because the water is a poison in that system. When you raise the power and boil a little more water and reduce the water density in the fuel channels, that's a positive reactivity. That would really panic us. We don't permit machines with positive coefficients.

Question: You mean we don't license those designs.

We don't license them.

Dr. Richard Wilson

Continued from page 10

available for release; not all of it—you never get all of anything anywhere—but you will be down by enough of a factor to make it safe. You wouldn't even bother to evacuate anybody. . . .

I am hoping, and expecting to be invited to visit the Soviet Union. . . . They have that American bone man in there, who will probably be able to save a fair fraction of the ill people. We call the lethal dose of radiation 500 roentgens. You can give a whole body dose of 1,000 roentgens and save three-quarters of the people. That's been done, because people have been cured of leukemia that way. You kill the leukemia with that high dose, replace their marrow, replace their blood, and three-quarters of them survive, and that's quite remarkable.

The Jupiter Effect

Continued from page 59

For a glimpse at how much we have forgotten in this respect, look through the most well-known treatise on the state of natural science 150 years ago: Alexander von Humboldt's *Cosmos*. It is very obvious that the scientific community of his day was looking for the relation between changes in the magnetic and electric fields of the Earth, and other physical phenomenon such as weather and earthquakes. Humboldt's reference to the observation of one of his contemporaries that earthquakes are more common during the equinoxes is a similar idea to that discussed by Gribben and Plagemann.

If the field of natural science is to break out of the containment of statistics-gathering that has almost no causal understanding behind it, we will have to go back to Humboldt's way of thinking. It is necessary that the scientific community work for a level of understanding that will enable us not only to passively predict earthquakes, but also to actively intervene, for instance, on the droughts that now occur on a global scale. One facet of this problem that should be straightforward to clarify is the effect of the planets' and the Sun's magnetic field on terrestrial weather. *The Jupiter Effect Reconsidered* is a refreshing first step in this direction.

—Beth Cohen

X-ray Laser

Continued from page 46

United States. This is because X-ray lasers are more effectively deployed against *offensive* missiles strikes, for the same reason that prevents the X-ray laser from being utilized as a weapon of mass destruction against targets on the surface of the Earth: Even highly focused X-ray laser beams can penetrate only part way through the Earth's atmosphere. And this ability to penetrate the atmosphere is much greater when it is fired in an upward direction, as would be the case against incoming warheads passing through space.

Given this fact, and other advantages that naturally accrue to the defense side, *defensive* X-ray lasers would have vast superiority over X-ray lasers deployed to protect and convoy an *offensive* missile strike. The military implications of the X-ray laser are asymmetrical because only the Soviet Union is engaged in building and deploying an increasingly effective surprise first strike capability. Even if both sides have the X-ray laser, it is most effective against the aggressor.

This can be seen from the simple fact that if a surprise, massive first strike is launched and completely fails, it would leave the victim in a vastly superior strategic position. The aggressor's offensive forces would have been depleted, while the victim's remain in reserve.

As Teller noted in the body of his testimony, while the present situation of Soviet superiority in this area is ominous, the basis for much hope exists. The X-ray laser augers a new scientific and technological age, affecting every aspect of science and technology. With it we will be able to probe the interior of atoms of living and nonliving matter, in situ, for the first time, making atomic-scale pictures of living cells. Biology, medicine, and materials science will be revolutionized overnight. Major advances in the fusion process itself will be obtained.

What is necessary, as Teller indicated in his testimony, is for the nation to overcome the screams and obstructions of the treasonous liberals who want to stop the U.S beam defense program—and who support the Soviet propaganda.

Pasteur Conference

Continued from page 18

(1) There is no doubt that ultraweak photon emission from biological systems is a sensitive indicator of biological states.

(2) This photon emission originates probably from a delocalized coherent electromagnetic field within the cell population, working as a powerful information basis within and between the cells.

(3) There are ample indications that the DNA forms the informational center of this field, both from the standpoint of potential information and from that of actual information. This field may work as the sensitive antenna to the external world as well.

On AIDS

The keynote speech of the third session was given by Dr. Mark Whiteside of the Tropical Institute of Medicine in Miami, Fla. Whiteside presented overwhelming evidence, utilizing the case of Belle Glade, Fla., for the fact that brutal economic collapse conditions, or environmental factors, are crucial to the uncontrolled propagation of AIDS in the tropical regions.

After Whiteside, one of France's leading virologists, Dr. Hervé Fleury, presented evidence that at least three new deadly diseases in addition to AIDS had broken out of animal reservoirs into man in Africa—the viral hemmoraghic fevers called Marburg Fever, Ebola Fever, and Lassa Fever.

To conclude the panel, Garance Upham-Phau presented the contributions of Pasteur's student Charles Nicole, founder of the Pasteur Institute in Tunisia, who developed a theory of epidemics.

Toward a Biological SDI

The final session of the conference outlined the program of the Fusion Energy Foundation and a special Biological Task Force of the weekly magazine *Executive Intelligence Review* for a Biological Strategic Defense Initiative. It was noted that recently SDI proponent Dr. Edward Teller had also begun to discuss the need for a crash research effort to combat AIDS in the context of the SDI program and national security.

Dr. Charles Gregg from Los Alamos, N.M., explained the significance of the circular intensity differential scattering (CIDS) machine and the potential for developing this work in optical biophysics—research in which Pasteur himself was the pioneer.

Gregg presented a description of CIDS and its more sophisticated successor, multiparameter light scattering (MLS), from the historical, theoretical, and instrumental viewpoints. CIDS is a special case of the more general MLS technology. CIDS and MLS spectra for a variety of organisms and biological materials were selected from data taken in the Life Sciences Division of the Los Alamos National Laboratory, and in the laboratory of Mesa Diagnostics, Inc. These methods for identifying microorganisms were compared with other rapid identification methods. It is clear that more than supercoiling of DNA is involved in production of MLS spectra, Gregg said.

Another very efficient method of identifying closely related diseases was shown by James Frazer, M.D. from the University of Texas Health Science System, M.D. Anderson Hospital and Tumor Institute, Houston, Tex., a pioneer in nuclear magnetic resonance (NMR). Frazer presented a history of basic biophysics research since the end of World War II.

The final presentation was given by Jacques Cheminade, a leader of the European Labor Party in France, on the political relevance of Pasteur's work for today. Cheminade also presented a resolution to the body that was unanimously endorsed: A declaration to Prime Minister Chirac calling upon France to defend science against the brutal irrationalist attacks epitomized by the antinuclear energy terrorists in West Germany, the propaganda against the U.S. space program, and the attacks on basic biological research at the Pasteur Institute in France. What the antiscience mob did to Lavoisier must not be repeated, the resolution said.

Another resolution, proposed by Cheminade was also unanimously adopted. It called for the creation of a laboratory of optical biophysics at the Pasteur Institute, and with the commitment to make groundbreaking discoveries within the 10 years leading up to the 1995 centenary of Louis Pasteur's death.

—Warren Hamerman

Free Electron Laser

Continued from page 49

en inertial confinement fusion.

Dr. Grant Logan of Livermore has recently developed an innovative approach to fusion reactor design involving the use of microwaves. The basic idea is to tailor the fusion plasma physical parameters in such a way that most of the fusion energy is emitted directly in the form of microwaves. This can more than double the efficiency of electricity generation in power plants based on such designs. Logan has pointed out that by utilizing more advanced fusion fuels, such as helium-3, it is possible to achieve virtually radioactive-free, clean fusion reactors with extremely efficient microwave outputs. Such systems would have broad applications in industry and space propulsion.

Also on the horizon is a general purpose fusion-powered FEL. The fusion reactor would efficiently generate microwaves that in turn efficiently drive an electron beam accelerator, whose energy is then efficiently converted into any desired wavelength of electromagnetic radiation in the FEL.

Fusion Breakout

Continued from page 13

tion of 50 billion fusion reaction neutrons.

"Our thermonuclear fuel burning conditions were excellent," reported Storm, "In fact, these equal the best results ever achieved by any fusion scientists in the world."

"Our results were so good," Storm said, "that we only need to improve the fuel density by about a factor of 10 and the temperature by about a factor of three in order to achieve the fuel burning conditions necessary for an inertial confinement fusion reactor."

The parameters "do indeed scale favorably with increasing laser energy," Storm said, referring to the powerful Nova laser used to drive the fusion reactions.

The powerful light ion beam accelerator PBFA-II, at Sandia National Laboratory in New Mexico, has already demonstrated that it has the energy to ignite inertial fusion pellets. In the coming years, PBFA-II could provide the means to fully demonstrate high gain targets whose scientific design principles Nova will be exploring.

Scandinavia supports the SDI

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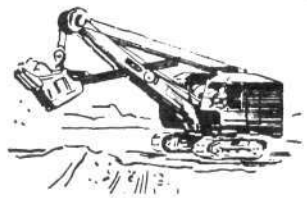

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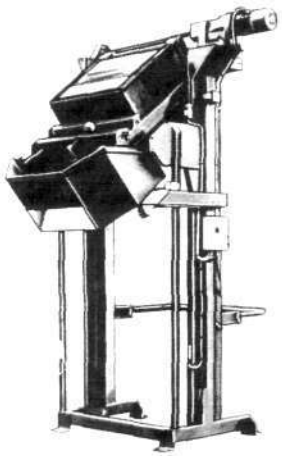

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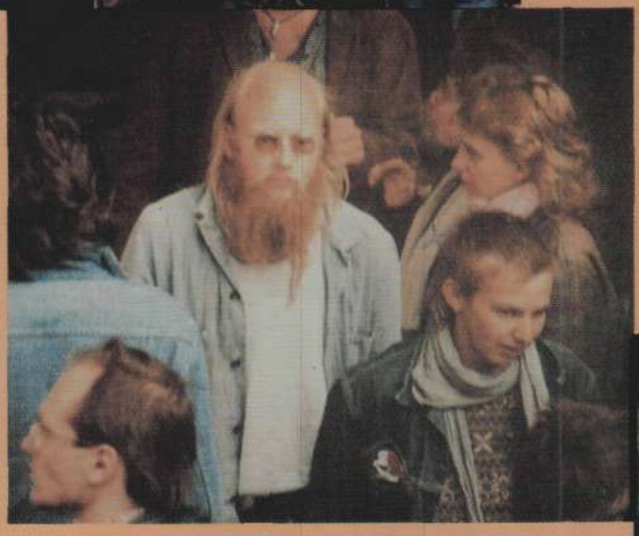
Green Terrorists at War

Continued

Braunschweig, June 12

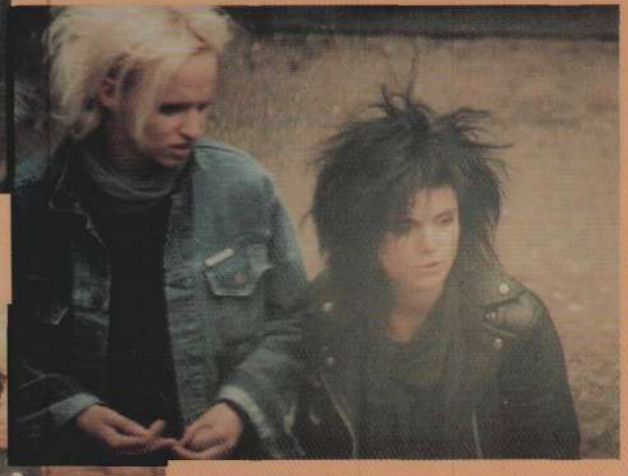


Green-terrorists were unable to stage a full-scale attack at an election rally in the town square, because of support from townspeople for the rally. However, 200 terrorists massed in front of a local restaurant that evening where a campaign event was scheduled. Most were armed. They surrounded the restaurant, jeering and punching those who approached the entrance.

The police, numbering about 200, escorted the 50 people already inside the restaurant to their cars. The terrorists pursued the cars, and at one stoplight, a terrorist jumped out and pointed a pistol at a passenger; the car ran the light to get away.

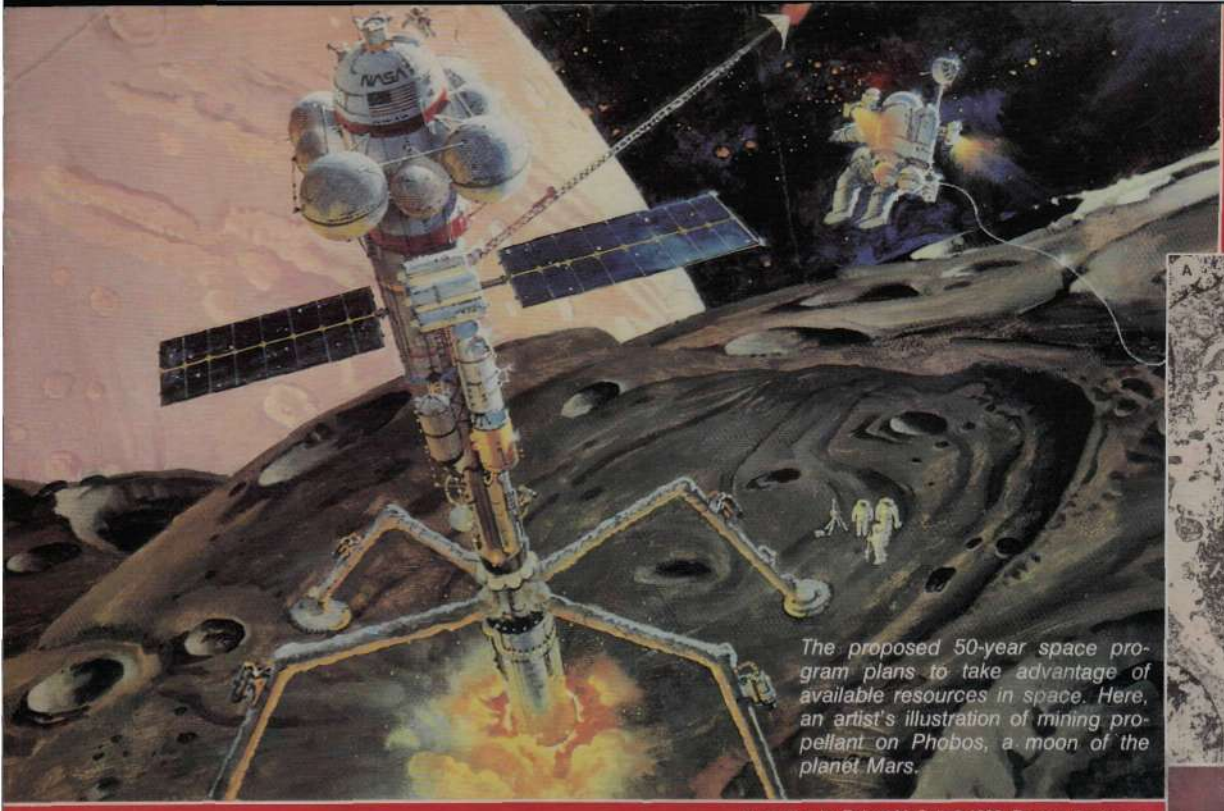
The Greens in the photos are "professionals," many of them veterans of the bloody three days of riots May 16-18 at the Wackersdorf nuclear reprocessing site.

Green-terrorists massing around the restaurant where the campaign meeting was scheduled. These photos were taken from inside the restaurant.



Above and right: Two of the professional photographers traveling with the terrorists. Many times their photos of nuclear supporters then appear in terrorist magazines as targets.

Right: The terrorist support network includes many journalists like these, who said they were "doing a scientific study on the election campaign." They talked and joked with the Green-terrorists, looking for "police brutality" against the armed terrorists and taking pictures.



The proposed 50-year space program plans to take advantage of available resources in space. Here, an artist's illustration of mining propellant on Phobos, a moon of the planet Mars.

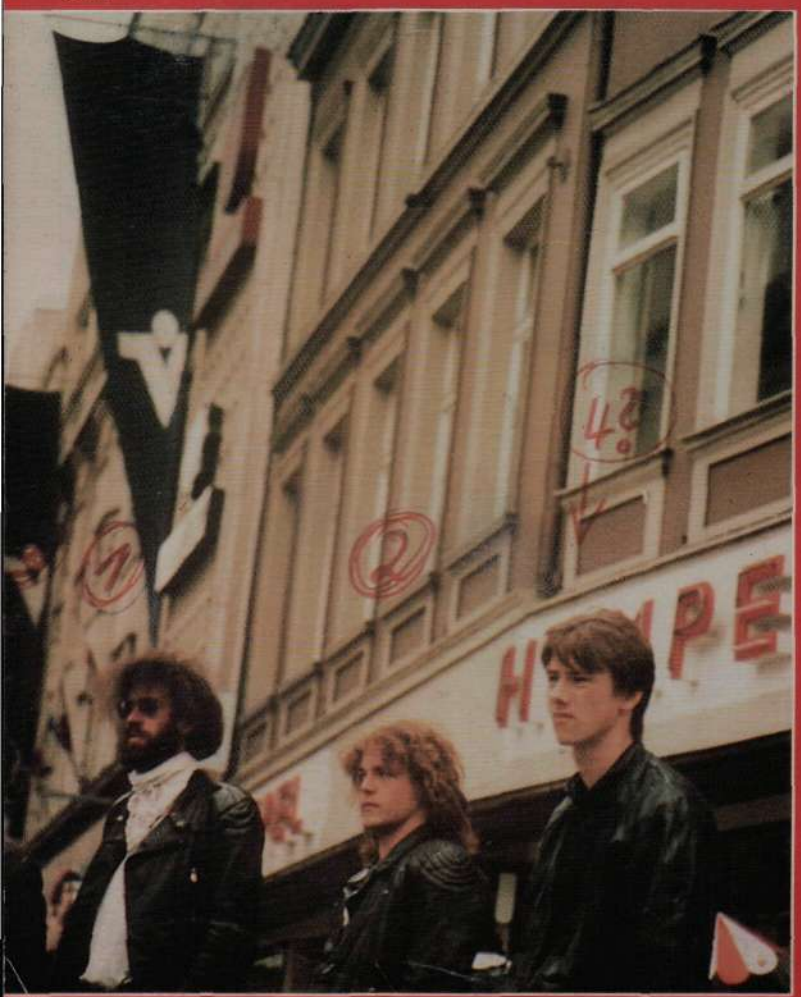
Illustration by Robert McCall, © 1986, Bantam Books, Inc.

A multinucleated leukocyte producing particles of AIDS virus (A). Large numbers of virus particles can be seen along the margin of the cell. A mature virus particle with the characteristic cylindrical core is shown in (B). Below are blood samples from an AIDS patient.

Zaki Salahuddein/NCI

National Institute of Allergy and Infectious Disease

Three terrorist coordinators surveying a campaign rally in the small town of Braunschweig June 12. They are wearing the terrorist uniform—black leather jackets, reinforced to protect them in battle. They counted the number of local police, rally marshals, and participants to assess the possibility of attack. The individuals are numbered in the photos to track their movement from town to town.



In This Issue

OUR NEXT 50 YEARS IN SPACE

Returning to the Moon by the year 2005 and moving on to colonize Mars by 2015 are the highlights of the exciting national space program proposed by the National Commission on Space. Recalling President Kennedy's challenge to the nation 25 years ago to put man on the Moon, the Commission calls for "vigorous leadership" to begin to colonize our solar system. Aside from the obvious economic benefits, the mission would return cultural optimism to the nation and its education system. Marsha Freeman reviews the report, *Pioneering the Space Frontier*, and interviews Commission chairman Tom Paine.

AIDS: A VACCINE IS WITHIN REACH

A major breakthrough in medical research promises not only to detect carriers of the AIDS virus, but also to prevent these carriers from developing the lethal disease. John Grauerholz, M.D., tells how researchers at the National Cancer Institute and the George Washington University School of Medicine have discovered that the antibodies they prepared against a thymus hormone were able to neutralize the AIDS virus. Combined with a mass screening program, the new discovery potentially could be used to save the millions of carriers of the AIDS virus from certain death.

GREEN TERRORISTS WAGE WAR

No amount of abuse from the U.S. environmentalist movement has prepared Americans for the shock of seeing the Green Party and its offshoots in action in West Germany after Chernobyl. As the exclusive photos on the inside covers show, among the several thousand antinuclear Greens is a hard core of trained terrorists, ready to kill. The photos show some of these terrorists and their zombie "punk" entourage attacking the June election campaign of the pronuclear Patriots for Germany party, a group formed to support NATO and oppose the formation of a Red-Green coalition government.