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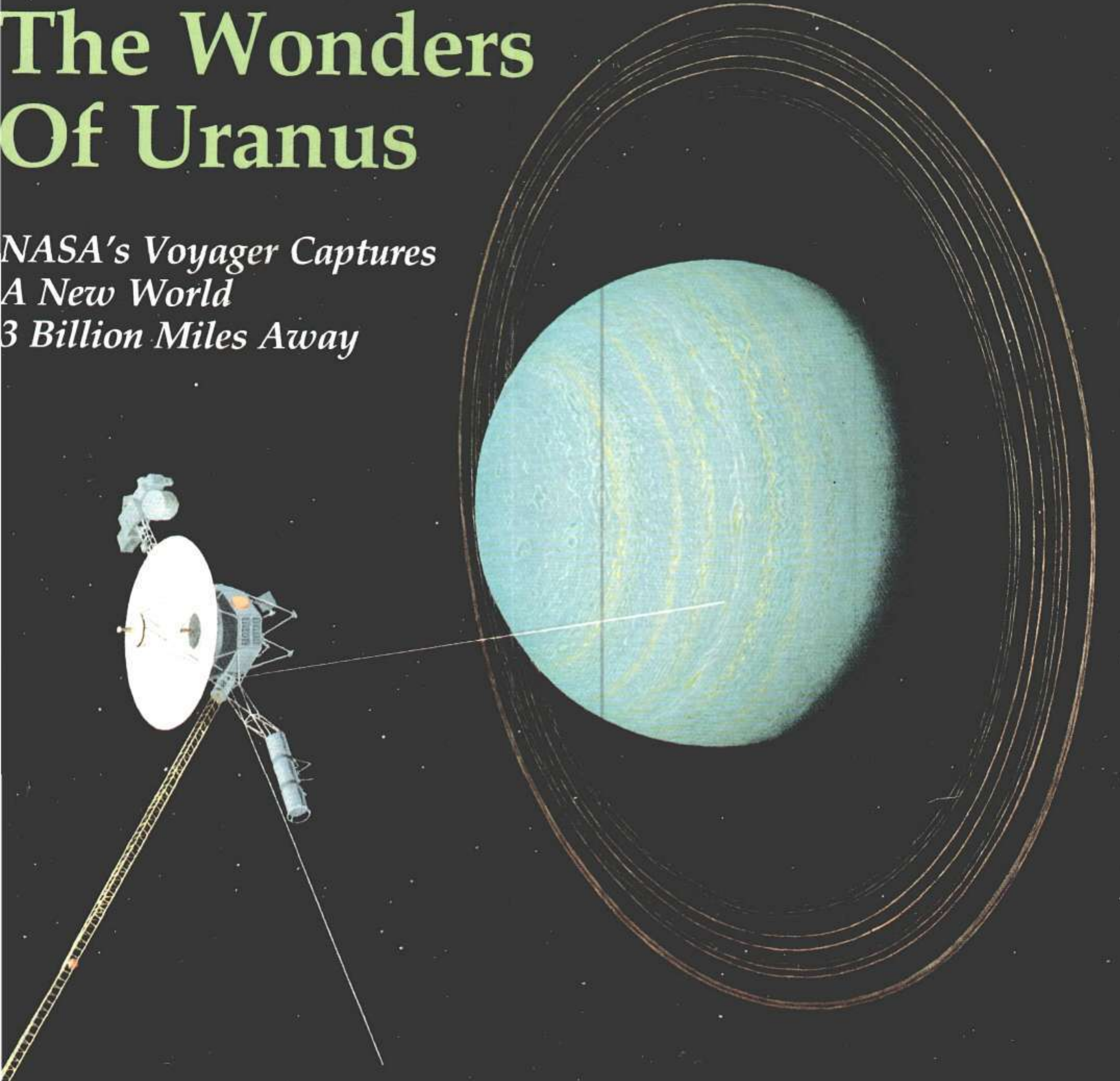

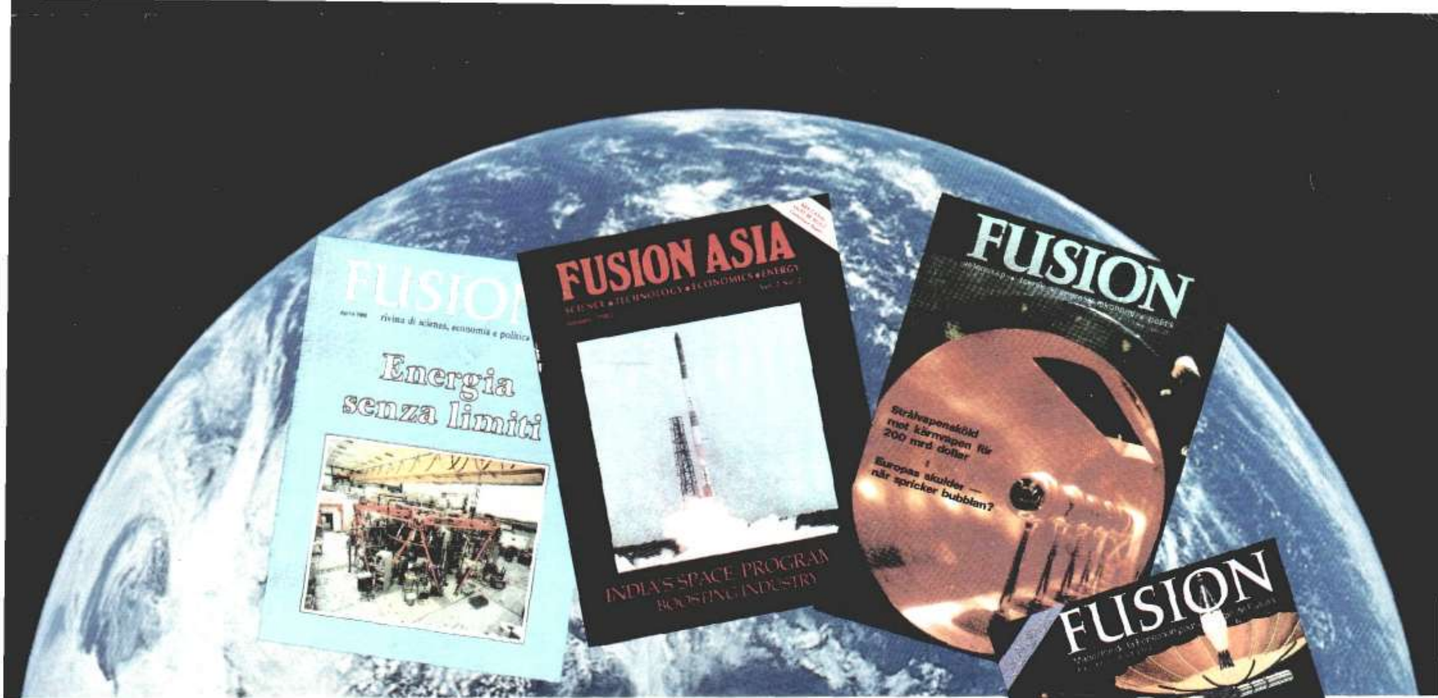

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Features

News

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On the cover: Illustration by Don Davis of a computer-generated view of Voyager 2 about 45 minutes after it passed through the plane of Uranus's rings. Illustration is courtesy of NASA; cover design by Virginia Baier

The Frontiers of Physics?

In this issue we report on a number of new discoveries, or more precisely, a recasting of old discoveries, that are nibbling away at what are normally considered to be the unchallengeable assumptions of physics. We welcome these developments as a healthy sign.

Are the results we are reporting at the frontiers of physics? We think not. What is missing is a commitment on the part of the scientific community to challenge the most fundamental assumptions of physics: to do away with the abominable notion that the universe is an epiphenomenon of the interaction of particles and forces.

The exciting aspect of the discoveries we report, coupled with a brief communication from nuclear physicist Erich Bagge, is the convergence upon an alernative treatment of certain problematic notions otherwise accepted in physics: for example, the existence of the neutrino and the nonexistence (or at least polarization) of the vacuum.

It is clear that much of the work we are reporting depends upon the fine structure constant. It appears in the empirical formula that describes the variation of what was heretofore known as the gravitational constant; it appears in physicist B. Soldano's work as the bridge between his "correction factor" and Planck's constant; and it appears as an apparent constraint that is violated in the Darmstadt results. Lawfully, this should be the case, because the fine structure constant is closely tied to the rotational action of "orbiting" electrons in an atom.

The simplest way of thinking about the fine structure constant is in terms of a planetary model of the atom. It may be likened to the aberration of the Earth's orbit caused by the shift of its axis, which occurs much in the way as a spinning top widens its spin orbit as its axis tilts toward the ground.

The fine structure constant itself tantalizes because it is approximately the inverse of the "golden mean angle." This is the angle found by dividing 360° by the square of the golden mean, ($360 \div 2.618 = 2.618$, approximately 137°). This angle crops up repeatedly in the placement of leaves as they form around a stem. And the golden mean ratio itself is found throughout the morphological structure of animals (in particular the human body) and in shell formation.

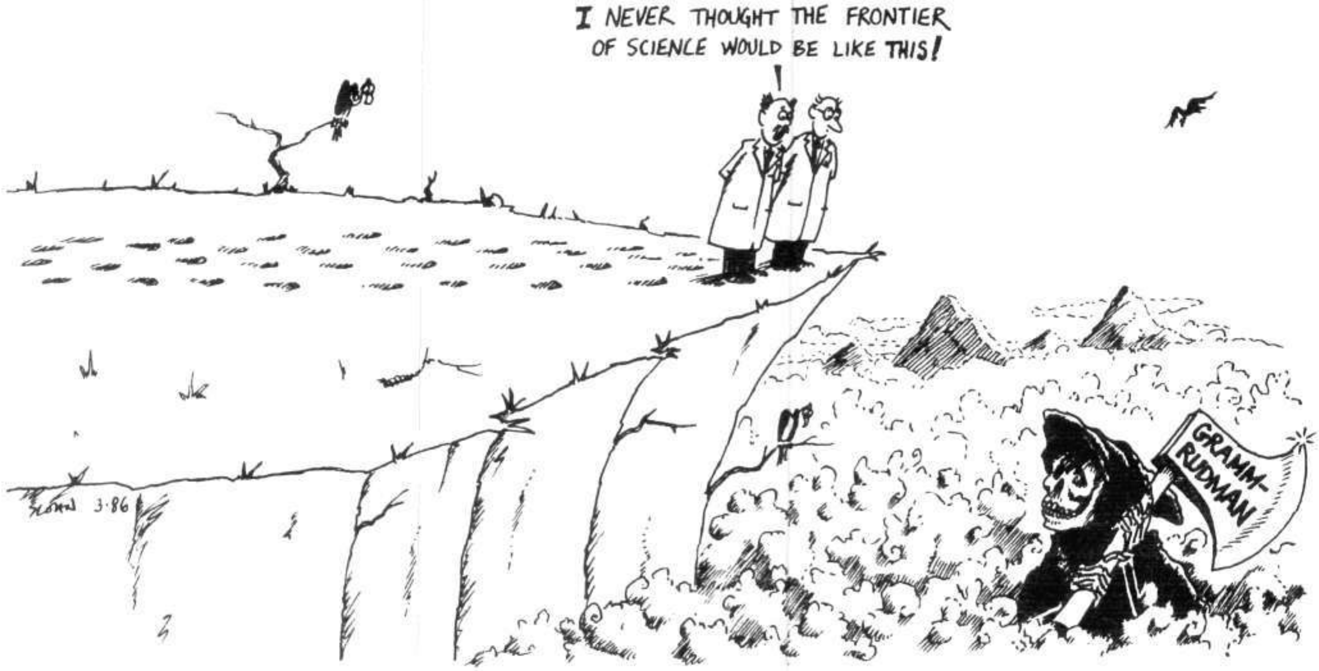
What is the significance of the new results reported upon in this issue?

We are not prepared to say yet, but it is clear that their *implications will be revealed only as physics rejects the* present, fundamentally algebraic approach for a return to the geometric approach that guided the work of Gauss, Riemann, and their scientific predecessors. The prominent *appearance of the fine structure constant is merely* one indicator that such a shift in approach is long overdue.

The Classical Method and Natural Law

Every major development in modern physics has always carried forward the method of Leonardo da Vinci and Johannes Kepler. Both approached science with the sure knowledge that the universe was organized according to an overriding natural law. They believed that God's universe was both good and beautiful, and therefore that physical laws must be essentially harmonic in character. Both saw the golden mean as an essential harmonic characteristic of the creation.

For Leonardo or Kepler, it would have been ludicrous to pose any physical process as a purposeless epiphenomenon of the interaction of brute particles imbued with dumb force. Kepler came to his great achievements in astronomy because he was fully convinced that God gave man the task of uplifting his mind by understanding the lawful ordering of the Sun and planets.



Leonardo da Vinci anticipated all of the greatest achievements of modern hydrodynamics, including emphatically the existence of shock waves, because he knew that man's reasoning mind could understand this universe, which is governed by natural law, and that man's task was to use his God-given reason to continually perfect the Creation.

The predominance of natural law assures the coherence of the universe—and our own ability to act upon it. This coherence is not at all uniformity; it cannot be found by a search for a fundamental particle. The law of the universe is not a set of rules governing the behavior of objects; it is a process of perfectability.

The universe acts upon itself not as a continually repeating cycle, but as a spiral rotation, which continually grows in potentiality as it expands; and this growth in potentiality, in turn, is continually expanded. This is true for the universe as a whole, in the macrocosm, and it is equally true for the microcosm. In this sense, the universe is fundamentally hydrodynamic in nature—electrohydrodynamic.

For both Leonardo and Kepler, the golden-mean ratio best expressed this ordering principle, because it is the projection in visual space of this kind of hydrodynamic processes as self-similar, logarithmic spiral action. (Not accidentally, populations also grow by this same, "fibonacci series" golden-mean ordering principle. A couple of rabbits who reproduce themselves after maturing one month, grow in a series 1, 2, 3, 5, 8, 13, and so on; and each term in this continuing series approaches more and more closely in a golden mean ratio to the preceding term.)

It was obvious to Leonardo that the human body and plants must follow the same spiral, rotational geometry he identified in the flow of water and the pattern of cloud formation, the same we see in the formation of galaxies, and the same that governs all fluid motion. It was Leonardo, with his collaborator Luca Pacioli, who first identified the significance of the "divine ratio," the golden mean, in all life processes, including the living universe.

Johannes Kepler took this further, and identified five laws of planetary action: the three commonly associated with him; the lawful distancing of the planets from the Sun according to the golden mean principle which is embedded in the constructibility of the five regular Platonic solids; and the harmonic ordering of eccentricities of the planetary orbits according to scale steps governing the distance between perihelion and aphelion of neighboring planets.

The Universe Is Negentropic

Unlike Isaac Newton, Kepler rightly insisted that the planetary orbits are primary, and that the mass of the planets was derived from the harmonically preformed orbits. This is precisely the conceptual framework from which the work of B. Soldano must be viewed. Is it not obviously the case that if Soldano is correct, what appears to us as matter is merely a singularity within a highly complex field structure: That is the proper implication of the divergence of the inertial and gravitational binding energy of matter.

The only law of the universe is the lawfulness of its own self-development and transformation. This is the means by which the Creator continues to perfect his creation. A collection of particles that operates randomly to provide apparent or episodic organization locally could never develop according to such an inborn principle of perfection. The Second Law of Thermodynamics is a useful calculating device in certain problems relating to the efficiency of mechanical and thermodynamic processes, and so on. It is in no way a guiding universal principle. To the contrary: the universe is negentropic not entropic.

We see this in the fact of our own existence as mankind—and more surely in the potential of future mankind to know and inhabit the universe.

'Mr. Gas Turbine': An Appreciation of R. Tom Sawyer

Courtesy of American Society of Mechanical Engineers

R. Tom Sawyer
June 20, 1901–Jan. 22, 1986

R. Tom Sawyer, inventor of the first successful gas-turbine-charged diesel locomotive and a founding member of the Fusion Energy Foundation, died Jan. 22, 1986 at age 84.

In 1918, at age 17, Tom Sawyer showed a drawing of a gas turbine engine he had designed to his high school teacher Julius Stone. "That is our future power plant for centuries to come, but you and I will not live to see the day," Stone told him. But he was wrong; he did live to see the day in 1947, at the age of 93.

Tom Sawyer devoted much of his life to the development of the gas turbine engine, and the name "Mr. Gas Turbine" stuck with him ever since George Huebner, director of Research at Chrysler, introduced it.

Born June 20, 1901 in Schenectady, N.Y., Tom grew up with a love for things mechanical. His father, president of the Electrical Street Railroad Association, explained to him at age 5 how electricity was made of positive and negative ions and how it was used to do work. It was he who influenced Tom to go into the public power business.

While attending school, Tom held a number of summer jobs, ranging from mechanic at Seagrave Co., to engine tester at Cushman Motor Co., and draftsman at Tennessee Power Co.

He graduated from Ohio State University in 1923 with a B.S. degree in electrical engineering, later earning a B.S. in mechanical engineering after submitting a thesis on diesel electric locomotives.

Tom's first job was at the General Electric Co. in Schenectady in the steam turbine test department in 1923. The next year he helped assemble a diesel locomotive at the Erie Works, and the year after that he delivered the first diesel locomotive sold in the USA to the Bronx switching yard of the Central Railroad of New Jersey. This was a 600 horsepower, 60-ton locomotive, and Tom patented a relay design for a complete automatic transfer to accelerate the locomotive.

In 1927, Tom asked his boss for a motor and generator, which he installed into a new auto, and then he took this electric-driven car with him on a freighter to Australia. There he used it to help sell 10 electromotive rail cars to the Victorian Railways, each with a gasoline engine-generator and two motors on one truck. From Australia he traveled to Switzerland, where he met Dr. Büchi, the inventor of the turbocharger, and to Berlin, where he saw his first gas turbine.

Tom joined the American Locomotive Company in 1930 because they needed someone who knew diesel locomotives. Four years later, he married Ruth Ennis, whose father had designed the world's largest steam loco-

The Closed-Cycle Gas Turbine

Tom Sawyer ceaselessly promoted the closed-cycle gas turbine as the "most efficient turbine burning any fuel." The steam turbine, he said in 1985, is of the open-cycle type, "the same as the jet and practically all other gas turbines being built today. The reason the closed-cycle gas turbine is more efficient is that the air or helium coming out of the tubine has to be cooled down before it goes back into the compressor. Cooling it with water produces steam, which requires no additional fuel.

"When a new product is invented it often takes 50 years before it is really accepted, and in this case the closed-cycle gas turbine was invented in 1935, just 50 years ago. Several companies are now building a few, so in another 10 years, the closed-cycle gas turbine should be popular, especially since powdered coal is a good fuel for it. Also there is an organization pushing the helium-cooled reactor and the most efficient way to produce power is to use the helium to drive a closed-cycle gas turbine."

motive, "Big Boy." At American Locomotive, he continued his work with diesels. And in 1951, he designed for the U.S. Army the world's first gas turbine locomotive with mechanical drive, which is now on display at the National Museum of Transportation in St. Louis.

Although he retired in 1956, Tom never stopped promoting the gas turbine. In 1959, he became editor of *Gas Turbine* magazine with its first issue in January 1960. Three years later he produced the first Gas Turbine Catalog. He was also active as exhibit director for the Gas Turbine Division (which he had formed) of the American Society of Mechanical Engineers. This included organizing a conference in Sydney, Australia in 1969, and one in Tokyo in 1971.

Throughout his life, Tom was involved in national and international associations promoting advances in technologies. He was a member of Sigma Xi; a fellow and life member of IEEE; a life member Society of Automotive Engineers; a fellow, life, and honorary member of The American Society of Mechanical Engineers; a member of the American Nuclear Society; and a life member of AIAA.

On the Frontiers of Technology

He was also on the board of directors of the American Rocket Society with Dr. Pendary and Dr. Goddard who organized it before the Soviets launched Sputnik. (According to Tom, the U.S. government and others did not believe in large rockets until 1957, when Sputnik showed they would work.) Tom also helped form the American Nuclear Society in 1954, and assisted in founding the Atomic Industrial Forum.

Of his many books that helped push the technology forward, *The Modern Gas Turbine* (1945), published by Prentice-Hall, was most popular and was republished in England, Japan, and the Soviet Union. It described many gas turbine applications—the jet engine, vehicle and automotive engines, and all sizes of power generators.

Another book, *Applied Atomic Power* (1966), described the nuclear gas turbine power plant that was built by the West German government 20 years later.

—*Thoula Frangos*

Letters

Food Irradiation and AIDS

To the Editor:

You people want to destroy us before time. With all the radiation we have enough of cancer without this [food irradiation], which is as bad as AIDS.

Leopololina Boehm
New Orleans, La.

The Editor Replies

This letter was sent to us with a xerox of an article titled "Zapping Your Daily Diet: The Risks of Food Irradiation" by Mark Mayell in the February 1986 issue of *East West Journal*.

The article's theme is what the antinukes have termed "food fascism," and the author catalogs the antinuclear, antitechnology, antipopulation litany of the likes of Drs. Sidney Wolfe and John Gofman. The author dismisses the scientific evidence showing food irradiation to be safe with the following: "Many people feel that there is an energy' or 'life force' inherent in foods. Radiation's potential effect on a food's life force may be important, though not amenable to scientific inquiry."

The scare stories relayed by author Mayell are the same tired lies about food irradiation repeated by all the antinuclear activists. As with the question of civilian nuclear power, it does not seem to matter that these stories have been refuted in great detail by scientists. The antinukes keep repeating their scare stories regardless of the facts, perhaps hoping that if they repeat their lies often enough, the lies will turn into truths.

Interestingly, the same people who are on the warpath against food irradiation are the champions of the AIDS virus, protecting it from quarantine measures and thus ensuring that the deadly virus is given every opportunity to spread. It seems as though these antinukes see AIDS and other epidemic diseases as a way, as Prince Philip of the World Wildlife Fund put it, to "cull" an overpopulated earth.

A Campaign for Cultural Optimism: *Fusion* in Every Library!

After the Shuttle accident Jan. 28, Fusion Energy Foundation supporters initiated a campaign in the memory of the Shuttle crew to put Fusion *magazine in high schools, colleges, and libraries across the country, beginning with those schools from which the astronauts had graduated.*

Nearly 6,000 bulk subscriptions have been donated so far, and before the end of 1986, the foundation would like to increase this to 100,000. If you would like to participate in this campaign, call or write the FEF in Washington, D.C. Donations to the foundation are tax deductible.

We print here some of the letters the foundation has received from recipient schools.

To the Editor:

Thank you very much for the donation of 80 subscriptions of *Fusion* magazine to Firestone High School. The students and staff are very appreciative of this donation in memory of Judith A. Resnik.

Please communicate our thanks to the Fusion Energy Foundation supporters who made this gift possible.

Diane Greene
Superintendent's Office
Board of Education
Akron, Ohio

To the Editor:

The staff and gifted students of VanDevender Junior High wish to thank you for sharing *Fusion* magazine with us.

We share together the memory of the astronauts of the Challenger and will make good use of your gift in their memory.

Steve Farner
Vice-Principal
VanDevender Junior High School
Parkersburg, West Virginia

To the Editor:

On behalf of the faculty and students of Satellite High School, I would like to thank you and the supporters of the Fusion Energy Foundation for the

Continued on page 35

News Briefs

Stuart K. Lewis
NASA launches model of Goddard's rocket.

NASA CELEBRATES FIRST LIQUID FUEL ROCKET FLIGHT

NASA launched a model of the first liquid rocket to celebrate the 60th anniversary March 16 of Robert H. Goddard's historic launch. Appropriately, the event took place at the Goddard Space Flight Center in Greenbelt, Md., which bears the inventor's name. Col. Howard Kuhn depicted Goddard and Jon Rains his assistant, while a crowd of 300 cheered the launch.

NEW ETHICS FOR MEDICAL PROFESSION: MURDER OF TERMINALLY ILL

The American Medical Association revised its code of ethics in March to allow physicians to withhold food and water from the terminally ill and the irreversibly comatose, announced Dr. Nancy Dickey, head of the AMA Council on Ethical and Judicial Affairs, March 15. The revision took 2½ years to formulate.

"At issue was whether removing food and water was tantamount to murder," Dickey said. "Society and technology have changed to the point where there are tremendous numbers of patients who are in a coma and being maintained by artificial technologies. . . . The physician's primary obligation is to sustain life, not to prolong it. . . . There is absolutely nothing that states you must feel compelled to or should even feel guilty if you choose not to. It simply says there are no ethical pronouncements against the physician who decides to [remove life supports]."

HEAD OF WEST GERMAN MEDICAL ASSOCIATION ATTACKS EUTHANASIA

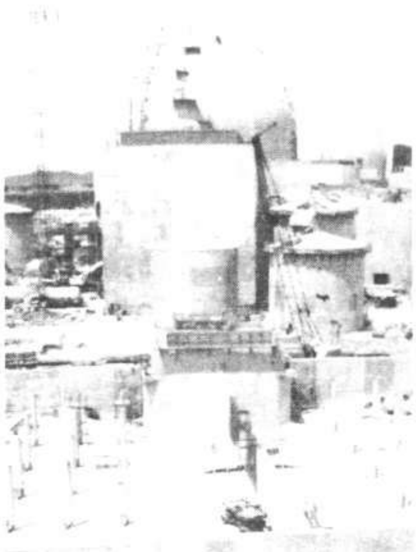
Dr. Karsten Vilmar, president of the German Doctors Chamber, attacked euthanasia as a return to the policies of the Nazis. In an interview with the mass-circulation *Bild am Sonntag* Feb. 23, Vilmar said: "If active death-help were to be legalized among us, what would come next would be death injections for the solution of sick pensioners. . . . We must rather recognize on what path we are entering if we don't make active death-help punishable for a doctor. Euthanasia, in the Third Reich was indeed also introduced and prepared with the so-called right of mercy killing. It is simply not tolerable if we come to the point that human beings can be put to sleep like animals. . . ."

TELLER SAYS MIRROR-FOCUSED LASERS CAN DEFEND EUROPE

It would be "relatively easy" to hit and destroy Soviet intermediate-range missiles using a "pop-up" mirror to focus a ground-based laser, Dr. Edward Teller told a March 3 meeting of the Wehrkunde military organization in Munich. The mirror would be effective even as it was being rocketed out of the atmosphere, he said, and it would not be vulnerable to a preemptive attack, as would an orbiting mirror. Soviet SS-20s and shorter range missiles would be sitting ducks, because there fuel tanks are vulnerable to destruction in the boost phase.

FEF HOLDS CONFERENCE ON SDI TECHNOLOGY IN BELGIUM

A conference on the technological and industrial implications of the Strategic Defense Initiative drew 65 persons in Liege, Belgium Feb. 26. Cosponsored by the Fusion Energy Foundation and Atlantic Association of Belgium, the conference covered the strategic situation, in particular the importance of the military economic mobilization of the Soviet Union. German-language *Fusion* editor Heinz Horeis spoke on the ABCs of beam technologies, and French-language *Fusion* editor Laurent Rosenfeld descibed the spinoffs of the SDI program, comparing the situation to Roosevelt's mobilization of the U.S. economy at the beginning of World War II.



Courtesy of *The Laborer*, Jan-Feb. 1986.
The domed containment building of Unit 1, a structure 244 feet high.

LARGEST U.S. NUCLEAR PLANT NEARS COMPLETION

The Arizona Nuclear Power Project, the largest nuclear plant in the Western world, is now in the final stages of completion. Located 55 miles from downtown Phoenix, the 3,513-megawatt three-unit Palo Verde plant will provide more than 25 percent of Arizona Public Service Company's electric needs. At the peak of construction, more than 6,000 union building tradesmen were employed at the site. Approximately 6 million cubic yards of earth were excavated, more than

77,000 tons of reinforcing steel were installed, and about 694,000 cubic yards of concrete were mixed and poured.

DR. ROBERT J. MOON, IJFE EDITOR, CELEBRATES 75TH BIRTHDAY

With music, jokes, reminiscences, food, and drink, the 75th birthday of Dr. Robert J. Moon, a pioneer in the nation's effort to harness the power of the atom, was celebrated Feb. 14. One hundred and fifty appreciative friends attended the event sponsored by the Fusion Energy Foundation. Moon, professor emeritus at the University of Chicago and editor-in-chief of the *International Journal of Fusion Energy*, has been on the frontiers of nuclear research for decades. In 1929, as a student in the physics department at the University of Chicago, he proposed a doctorate thesis on fusion energy, but was told that "everything is already known about fusion." Undeterred, he moved to the department of physical chemistry, and in the course of his work on electron diffraction, he built what was at the time the world's largest cyclotron. When the Manhattan Project was organized, Moon played a crucial role in the construction of the first nuclear reactor. Later, he was the first to build a scanning X-ray system that led to today's CAT scanner, the first to discover the correct cathode surface for a high-current electron gun, and the first editor of *The Bulletin of Atomic Scientists*, just to note a few of his accomplishments.

Peter Rush

Dr. Moon: Ready for another 75 productive years.

FOOD AND DRUG ADMINISTRATION KILLS SMALL ARTIFICIAL HEART

The Food and Drug Administration ordered the manufacturer of the artificial heart, Symbion, Inc., to remove the newer, smaller version from all medical institutions, even though it is the only one capable of fitting into the smaller chest cavity of a woman. "*I think the FDA should recognize its responsibility for* the denial of life-saving technology," said Robert Jarvik, M.D., developer of the artificial heart. The smaller device was also defended by Dr. Denton Cooley of Houston, who carried out the first implant operation in 1969, as virtually identical to the larger device and very promising. About 20-25 percent of heart patients die because there is no available transplant.

FEF SEMINAR ON AIDS AND ITS CHALLENGE TO SCIENCE

The Fusion Energy Foundation and the weekly *Executive Intelligence Review* cosponsored a seminar Feb. 22 on the scientific problems posed by AIDS. The presentations ranged from a historical view by Warren Hamerman of optical biophysics from the standpoint of Louis Pasteur's breakthroughs in the mid-19th century, to a shocking expose by Dr. Mark Whiteside of the Institute of Tropical Medicine in Miami of the spread of AIDS through the south. AIDS is a tropical disease syndrome spread by insects and is currently out of control in areas of economic squalor, he said. It is rampant in south Florida and south Texas because mosquitoes breed there year-round, and in slums like Belle Glade, Fla., people get an average of 100 mosquito bites per day. Ten percent of the general population in Belle Glade, he said, test positive to the AIDS virus antibody—the same percentage as in tropical Africa.

PRINCE CHARLES'S VALET DIES OF AIDS

According to the Jan. 27 issue of the West German mass circulation daily *Bildzeitung*, Prince Charles's valet died recently of AIDS. The paper notes that this was the same individual whom Princess Diane wanted fired on the grounds that he was too "intimate" with her husband. This is the second reported death from AIDS within the immediate circles of the British royal family. The first was Lord Avon.

LOUSEWORT LAURELS TO CHICAGO CITY COUNCIL

This issue's Lousewort Laurels award goes to the City Council of Chicago for its ordinance declaring the city a "nuclear free zone." Adopted by a voice vote March 12, the ordinance bans the design, production, or storage of nuclear weapons in Chicago and requires a phase-out of the city's nuclear weapons industry within two years. We agree with Illinois Governor James Thompson: the ordinance is "stupid and un-American. . . . Are we supposed to just lay down for the Russians?"

Viewpoint

Radon in Houses: What Are the Dangers?

by Dr. Bernard L. Cohen

Recently there has been widespread publicity about *radon*, a naturally occurring radioactive gas, believed to cause 5,000 to 30,000 deaths from lung cancer in the United States each year. In some areas where radon levels are high, the situation verges on panic. What is this new threat?

Radium occurs in all rock and soil, and by purely natural processes, it converts into radon, a gas that percolates up out of the soil into the air. If this occurs outdoors, the radon mixes high into the atmosphere becoming heavily diluted, but, if it occurs under or adjacent to a house, the radon may be trapped inside for some time. Radon levels in houses are, therefore, typically 10 times higher than outdoor levels.

Each radon atom eventually converts into other short-lived radioactive atoms known collectively as "radon daughters"—actually they are radioactive isotopes of lead, bismuth, and polonium—which then float around in the air. As we breathe, these radon daughters are sucked into our lungs where they frequently deposit on surfaces, exposing nearby cells to their radiation, which can cause lung cancer.

It is estimated that this radiation exposure is giving the occupant of an average house about one chance in 300 of dying of lung cancer. In something like a million American homes, the radon level is over 10 times the average, giving occupants over 10 times the risk, or more than one chance in 30.

According to this estimate, radon exposure in the average home reduces the life expectancy of the occupants by 25 days. We live with far greater risks: Smoking a pack of cigarettes per day reduces life expectancy by 6.5 years, being poor (versus being well-to-do) reduces it by 4 years, being 25 pounds overweight reduces it by 2 years, and motor vehicle accidents reduce it by 200 days. For the average person, radon is less of a threat than any of these. For example, for it to be as dangerous as motor vehicle accidents, one's house would have to have 8 times the average radon level—$8 \times 25 = 200$.

Undisputed King

However, compared to all other *radiation* risks, radon is the undisputed king. It gives the average American 50 times more radiation than even antinuclear activists claim we will eventually get from nuclear power operations. According to government estimates of the latter, radon is thousands of times more harmful. People who live near the Three Mile Island nuclear power plant get more radiation exposure from radon *every day* than they got in total from the highly publicized reactor accident there.

We get a hundred times more radiation exposure from radon than we ever got from nuclear weapons tests, and 10 times more than the average American gets from medical and dental X-rays. If anyone worries about radiation in any way, shape, or form, he should be worrying about radon in his house.

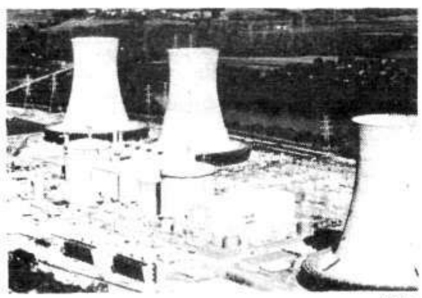
It is interesting that wastes from coal burning include radium, which eventually converts into radon. It turns out that this *radioactive waste* is thousands of times more harmful to human health than all of the nuclear power radioactive wastes!

Nuclear power also has its radon problems, principally from mill tailings near uranium mines. However, it turns out that the lives saved in mining uranium out of the ground to produce fuel for nuclear plants greatly exceeds the harmful effects of the mill tailings. In fact, this aspect of nuclear power saves thousands of lives for every life lost due to effects of nuclear reactor accidents and radioactive waste! And that is all because of radon.

There is some rationale for the public's interest in radon. There are presumably a million American homes with high enough radon levels for the radon risk to exceed our risk from motor vehicle accidents. This radon risk can be substantially reduced by relatively simple remedial actions. For example, for half of the year, in a home with a basement, you could open two windows, then recycle the air through the house with a large fan in one window; homes with a crawl space can open two vents.

Measuring Radon in Your House

In order to identify these homes, the University of Pittsburgh operates a nonprofit measurement service. If you would like a measurement survey for your house, send a check for $12 (payable to the University of Pittsburgh) to: Radon Project, University of Pittsburgh, Pittsburgh, PA 15260. This covers the cost of the postage for us to send you the form and return it after our analysis, and provides information for interpreting the results and suggestions for remedial action if the level is too high.



GPU

There's more exposure from radon every day than from the TMI incident.

Bernard L. Cohen is Professor of Physics at the University of Pittsburgh, and a well-known expert on nuclear power and radiation. His most recent book is Before It's Too Late: A Scientist's Case for Nuclear Energy.

Stuart K. Lewis

There is no "right to die." Members of the Schiller Institute at the New Jersey State capitol in Trenton protesting against proposed euthanasia legislation.

KILLING THE COMATOSE

Judge Takes Stand Against Starvation Treatment

by Linda Everett

EDITOR'S NOTE

When the Nazis began their euthanasia campaign, they justified it by defining the retarded, elderly, and terminally ill as "useless eaters," a burden on the state finances. Today the same euthanasia is phrased more prettily: The elderly and ill have a "right to die," we are told.

But the ugly motivation behind this euthanasia campaign is the same as in the Nazi period. In these days of budget deficits and cutbacks, the apologists for dying with dignity say, there just isn't enough money to waste on expensive medical care to keep such "useless eaters" alive.

Now the euthanasia advocates have expanded their pool of victims, redefining the word brain dead to include anyone in a comatose state, despite the fact that coma recovery programs have demonstrated a 92 percent recovery rate for patients previously defined as "brain dead," and a 35 percent recovery rate among so-called vegetables—men, women, and children who recover to lead normal lives.

The latest technique in eliminating these so-called brain dead is by withdrawing their food so that they can die "naturally" by starvation, a measure that is being proposed for legislative adoption in several states. As the following report documents in uncomfortable detail, such a form of death is torture for the victim. But whether the method of murder is such slow torture or the quicker cyanide form of murder advocated by the Swedish euthanasia movement, the point remains that killing human beings, no matter how ill they may be, is murder.

The prescription for preventing this nation's descent into the moral abyss that permitted the Nazi atrocities is simply a heavy dose of cultural optimism. This means investing the nation's resources into scientific and technological frontier areas in order to come up with cures for disabling diseases and indeed for the process of aging itself.

* * *

The nation's courts are under siege by family members seeking court permission to give their comatose or highly disabled relatives a so-called dignified death by starvation. This includes a wave of "right-to-die" bills prescribing starvation treatment for patients who never indicated that they wanted such treatment. In the midst of this move to make euthanasia a normal policy, there was a significant victory by a Massachusetts judge who sees starvation as neither ethical nor dignified.

The magnitude of the crisis can be seen in these two typical cases:

- A California man, whose wife was termed a "human vegetable," tried to eliminate all her food and water because he considered her brain injured state "an unacceptable assault on her dignity." The woman smiles, turns to face visitors, and gazes at the sunshine when her curtains are drawn.
- A 30-year-old New Jersey woman is judged by relatives to be "permanently comatose" or in a "persistent vegetative state" and therefore suitable for an "ethically accepted" starvation death. The physicians and caretakers of this relatively healthy young lady disagree. She has a high level of awareness, moves her head to follow visitors around the room, and responds to light, pain, and more. Her physicians feel she is, in fact, seriously disabled and not even in a coma. Her case, and her life, are still pending.

The Brophy Victory

In October 1985, Massachusetts Probate Court Judge David H. Kopelman ruled that the state is "morally obligated to sustain the life an ill human being, even if one is in a persistent vegetative

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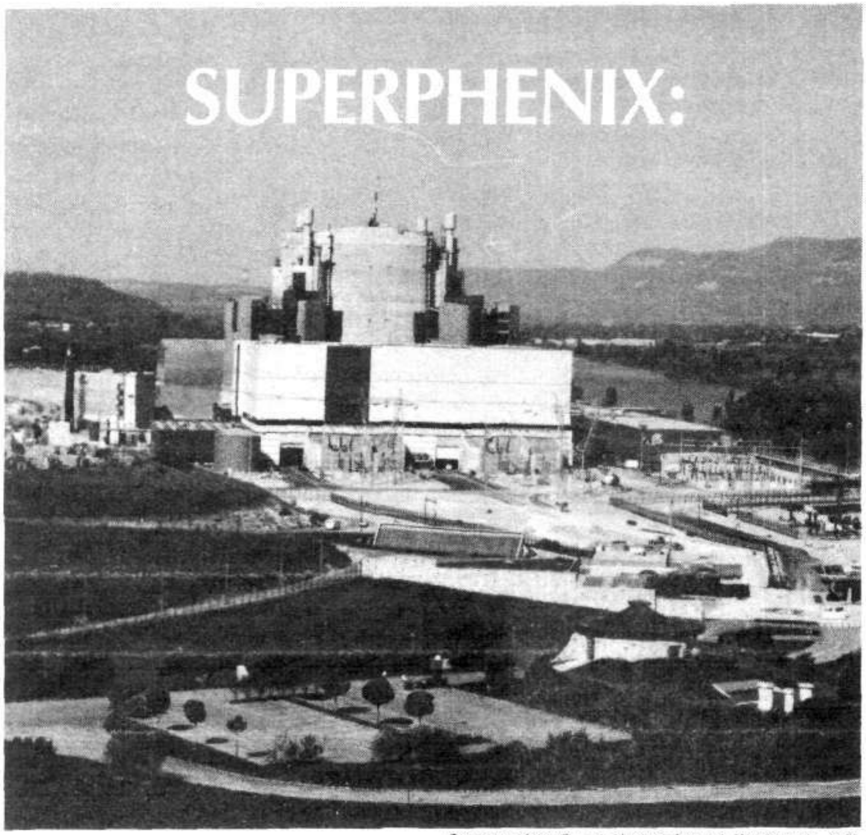

Courtesy of the French Nuclear Attaché, Washington, D.C.

France has the nuclear lead worldwide, producing about 65 percent of its electricity from nuclear plants. Here, the Superphenix fast breeder reactor at Creys-Malville.

World's Largest Breeder Comes on Line

by Laurent Rosenfeld

The world's first industrial-size breeder, the 1,240 megawatt-electric (MWe)Superphenix in Creys-Malville, France, began supplying power to the grid Jan. 14. The reactor went critical Sept. 7, 1985, and after numerous tests the fast breeder progressively increased its power, producing enough steam to drive one of the plant's two turbines.

Although it delivered its first kilowatt hours to the French power grid Jan. 14, tests will continue for several months before Superphenix is scheduled to reach its nominal power of 1,240 MWe in mid-1986.

Without doubt, France has the nuclear lead worldwide. Although the overall French nuclear power capacity, with an installed power of roughly 38 gigawatts-electric (GWe), is second in the world (the United States is at 74 GW; Soviet Union, 24 GW; Japan, 22.6 GW; West Germany, 16.1 GW; and United Kingdom, 12.3 GW), France is number one in terms of the total portion of its electricity coming from nuclear power.

The French utility company, Electricité de France (EDF), is now operating about 50 nuclear power plants. During 1985, about 65 percent of the electricity produced in France was nuclear, with a peak level of 70 percent last August. No industrial country of similar or larger size reaches half this figure.

The Fast Breeder Bonanza

The Superphenix is a liquid-metal-cooled fast breeder: it produces more fuel than it consumes.

To get an idea of what this means, imagine a man stranded in a mountain refuge during a violent snow storm. The refuge has a two-day supply of dry wood, so if he carelessly consumes the wood, he will die of cold on the third day. If he gathers "worthless" wet wood and dries it in front of the fire, drying as much or more wood than he consumes, his wood reserve would last forever if there is an unlimited supply of wet wood around his refuge. The stranded man would have created a "breeder" of burnable wood.

The dry wood represents uranium-235, the only fissile isotope of uranium, which constitutes only about 0.7 percent of naturally occurring uranium. Most natural uranium, 99.3 percent, is uranium-238, and unburnable like the wet wood. The breeder can transform this into a combustible (fissile) material, plutonium-239. This means that if known reserves of uranium represent the equivalent of 40 years of the present world electricity consumption, then breeder reactors, in theory, could make those same reserves last 140 times longer because uranium-238 is 140 times more abundant than uranium-235.

This means that the breeder gives us 5,600 years of power reserves from natural uranium. To put it the way Valéry Giscard d'Estaing did in 1980, when he was still President of France, the relatively small uranium reserves of France represent more energy than "all of the oil deposits in the entire Middle East."

Superphenix is not the first fast breeder ever built, but it is the world's only industrial-scale breeder. In fact, the first nuclear reactor ever to produce power in 1951, the U.S. EBR-1 in Idaho, was a breeder. Since then, however, breeder programs have been slowed down to a crawl in most countries, except France and, to a lesser extent, the Soviet Union.

After having built several small research fast breeder reactors—including Harmonie, Masurca, Cabri, and

Rapsodie—the French Atomic Energy Commission (CEA) built the 250-MWe Phenix reactor in Marcoule. Phenix produced its first kilowatt hour of electricity in December 1973 and reached full power in March 1974. It was then the largest breeder in the world, and remained so until the Soviets built the 600-MW BN600 in Beloyarsk in 1980.

Superphenix was constructed in record time—7 years, less than half the time it now takes the United States to put a conventional nuclear plant on line. The construction company, NERSA, was especially set up for that purpose. Its shares are divided among the French utility EDF (51 percent), the Italian ENEL (33 percent), and a consortium of the German RWE and the Belgian, Dutch, and British utilities SBK (16 percent).

Conventional Versus Beeder

Any nuclear reactor is based on a chain reaction. A neutron is used to hit a uranium nucleus and either bounces off, is captured, or splits the nucleus. When the nucleus splits (fissions), it breaks into two fragments and releases two or three neutrons, which, in turn, can hit other nuclei, producing the chain reaction.

These fission-produced neutrons, so-called fast neutrons, are emitted with an energy of 1 to 2 megavolts, corresponding to a velocity of 15,000 to 20,000 kilometers per second. These fast neutrons are usually rather inefficient in triggering new fissions in uranium-235 because they bounce off the uranium nuclei without splitting them.

In fact, a slow neutron has 460 more chances of fissioning a U-235 nucleus than a fast neutron. Therefore, in a conventional nuclear reactor, a moderator, consisting of light nuclei like water or graphite, is used to slow the neutrons down to velocities of about 2 kilometers per second, a speed roughly equivalent to the thermal agitation of the atoms of the moderator. These slow neutrons are then called thermal neutrons, because they have reached thermal equilibrium with the medium.

The problem with using slow neutrons is that most of the light nuclei used as moderators can also capture neutrons, making criticality—the chain reaction—not so easy to obtain. Only heavy water and graphite, of the var-

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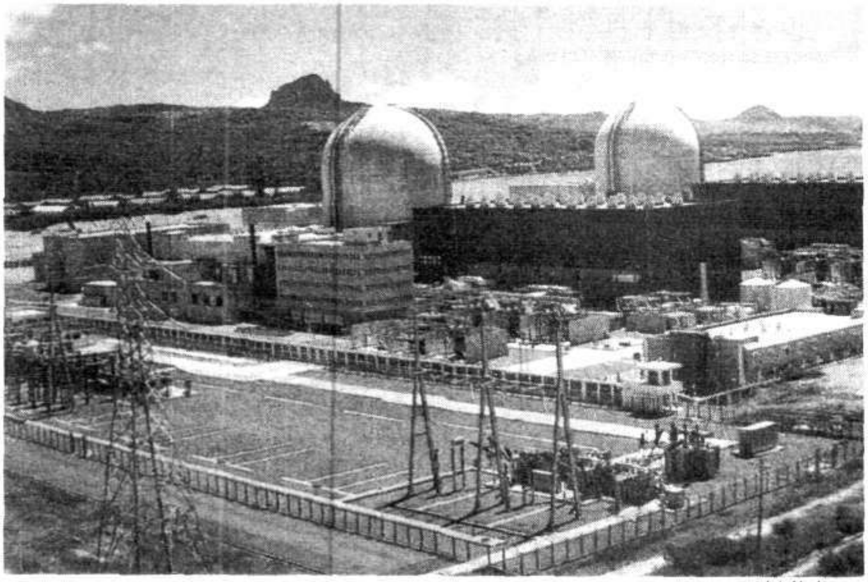


J.J. Nerbonne

Taipower chairman L.K. Chen: "If we don't start soon on the fourth nuclear construction, we'll see a power shortage by 1990." Above, Taipower's third nuclear plant.

Taiwan's Fight to Go Nuclear

by Joseph J. Nerbonne

Joseph Nerbonne, a former correspondent for the Associated Press and a longtime resident of Taiwan, reports here on the current battle against the environmentalists.

"The Taiwan government has definitely decided not to build its fourth nuclear station," according to J.J. McGettigan, senior project engineer for the power generation service division of Westinghouse Electric Corporation, which has sold many components to the Taiwan Power Company's (Taipower) three nuclear plants.

In an interview in December 1985, McGettigan attributed the decision to "public pressure."

"My original 10-day trip has now grown to 40 days. I've been reading the local papers as well as talking to power company officials, and it certainly seems that the government is bowing to public pressure, which for the very first time looks as though it's against any more nuclear power plants on the island."

When this reporter noted that in his many years in Taiwan he could not recall any vocal opposition to the other three nuclear power plants now in full operation, McGettigan replied: "It doesn't take too much imagination to envisage this place going the way of the States—which is backwards. Taiwan at the present time can build a nuclear power station in about 6 years while in the United States, the same plant will take 15 years to construct.

Although the Republic of China's legislature approved construction of a fourth nuclear power plant as early as 1980, it took until the present time to complete all preliminaries, like site location and funding. Then, out of the blue, for the first time, a vocal opposition, or at least a number of questioning scientists plus 61 legislators, asked what was the economic value of yet another nuclear plant, and demanded precise details concerning safety factors, nuclear waste disposal, and environmental pollution.

Premier Yu Kuo-hwa then said there was no hurry to start building the fourth nuclear plant. He ordered a temporary halt to the bidding and construction plans and ordered Taipower to communicate with the public and convince them that their misgivings were misguided. At the same time, Premier Yu went on record as a supporter of the fourth plant, saying there was not the "shadow of a doubt in his mind" regarding the necessity of building another nuclear plant on the island.

In addition to Taiwan, Yu noted, some 30 other countries have built 320 nuclear reactors that are now furnishing power for themselves while another 195 are under construction. The Republic of Korea, Yu pointed out, now has four nuclear stations operating with five more under construction. "Furthermore, long-range computer projection forecasts that Taiwan will begin to feel a power shortage by 1989 if no new power projects are completed before that time."

The Media and the Ecology

As if to assuage mounting public opposition, the Atomic Energy Council here reported that after a 10-year ecological study along the northern coast, the two nuclear power plants in northern Taiwan have had no observable effect on the ecology of that coast.

Taiwan Power's vice-president, I-hsien Chu, said in an interview: "One really couldn't say that there's been an organized campaign against nuclear power plants on Taiwan, but rather over the years there has been a rash of stories in the press citing ecological problems here and all over the world and this has stirred up some opposition. Then we found ourselves with a new group, the environmentalists who worry about and oppose anything and everything from fish in the sea to the disposal of nuclear fuel, and then we got a little flak from our own legislature. . . . I think it was all engineered by the newspapers."

"For almost two years, Taiwan had a negative growth rate but in the 1970s we built many power plants all over the island, and we here at Taipower know that if we don't start soon on the fourth nuclear construction we'll see a power shortage by 1990. Present installed capacity is 14,000 megawatts and our peak demand last summer was 9,000, so we have 5,000 MW in reserve."

Nuclear installed capacity at the present time is about 37 percent of the total, but 50 percent of the kilowatt hours used.

"Our prediction for this shortage is based on a 6 percent power demand growth rate, so our reserve power will all be consumed before long. The government's attitude is that it has to be built—the problem is the timing, that is, getting the maximum benefit out of it," Chu added.

L.K. Chen, chairman of the surprised Taipower—which has built scores of coal and oil-powered units, not to mention hydro and nuclear plants, without a question being raised—stepped into the heated discussion with the statement: "The Republic of China is not the United States and the decision of American power companies not to build any more nuclear power plants does not apply here."

Chen was commenting on a remark made by W.S. White, Jr., chairman of the American Electric Power Company, that "In time, one will see nuclear plants again being built but not for a long time, possibly not before the year 2000."

Chen noted that: "The United States is endowed with rich natural resources. It enjoys the luxury of choosing coal, water, or nuclear energy, while Taiwan has neither enough coal or water to employ. What is left for Taiwan but nuclear energy?"

U.S. Nuclear: Moving Backwards

How has the United States slipped so sharply backwards in nuclear power? Westinghouse senior project engineer McGettigan put it this way: "Power companies in the United States have to put their money up front to purchase the turbine generators and other components and they have to pay interest on the loans, and then when legal costs of groups like Jane Fonda's are added on, the cost of a new nuclear plant quadruples.

"Plants costing from $1 billion to $2 billion will effectively double in cost because of legalities and that's why no plants are being built today." In addition, he said, "The amount of money tied up and being paid in interest to banks is really astronomical—an out-and-out aberration."

"Things have gotten so discouraging that a very aggressive and active Virginia Electric Power Company (VEPCO) just chose not to fight and ordered us [Westinghouse Electric Corporation] to scrap two units we had recently completed building.

"Both are now being destroyed and we're talking of a loss of anywhere from $40 to $100 million.

"We'll have to sell them as scrap and it hurts to see it, I can tell you that. VEPCO just decided 'to hell with it.'

"We tried to sell those two units . . . to mainland China but found they have no intention of investing in nuclear plants. . . . It's a question of employment there and they have a lot of people digging out fossil fuel. Since pollution controls are lax, they don't have to worry about conservationist groups protesting air pollution from sulfur dioxide."

McGettigan stressed the economics of going nuclear: "If we assume that the cost of power for a nuclear plant is one; the cost for the same amount of power from a coal plant would be 15, and for an oil-fired plant it would be somewhere between 25 and 30. It's something like the razor blade company which is only too happy to give you the razor free because it knows that you have to come back and buy its blades."

Westinghouse is currently concentrating on improving efficiency, he said. For example, in Fawley, Ala., where the nuclear power plant was considered to be the most efficient in world, Westinghouse gave them a new design for the nozzle block and rotation and stationary blade paths. "We upped their efficiency by 2 to 3 percent," McGettigan said. "If the income from the plant is say $1 million a day, the 2 to 3 percent increase would be considerable, you can easily see."

AMPUTATING AMERICA'S FUTURE TECHNOLOGY:

The Reagan Administration Fusion Budget

by Charles B. Stevens

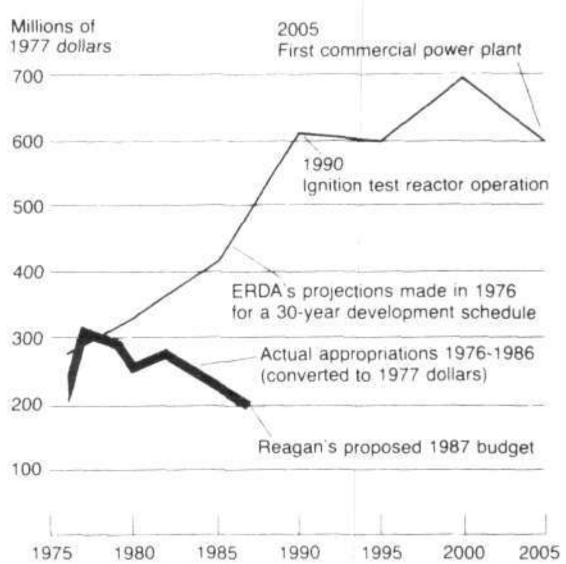
The manifestly inadequate fiscal year 1987 fusion research budget request of the Reagan administration, if passed by Congress, will undermine any prospect for a successful reindustrialization of U.S. economy over the coming decades. More immediately, it will sabotage Reagan's own Strategic Defense Initiative (SDI) project for developing effective missile defenses.

Although the proposed budget appears to be a linear extrapolation of previous real cuts implemented since the Carter administration in 1976, the cumulative impact has reached a point where the scientific base of this essential program is endangered. The further cuts mandated under Gramm-Rudman will intensify this process.

The actual appropriations from 1976 to 1986, together with the fiscal year 1987 Reagan request for magnetic fusion research, are shown in Figure 1 (solid line), converted to constant 1977 dollars. The dotted line plots the projections made by the government in 1976 for the budget necessary to realize commercial fusion electric power plants by the year 2005.

As can be seen, the actual budget is now at about one third the level needed for fusion energy development, by the government's 1976 projections. In

Figure 1
FUSION BUDGET VERSUS REQUIREMENTS FOR FUSION DEVELOPMENT
The actual fusion appropriations from 1976 to 1986 (heavy line) are shown, in addition to President Reagan's proposed budget for fiscal year 1987. The Reagan budget, as can be seen, sinks significantly lower than the Carter administration's budget. More startling is the comparison of the actual funding with that projected in 1976 (thin line) by the U.S. Energy Research and Development Agency, the predecessor to the Department of Energy, for the achievement of commercial fusion by the year 2005.



Lawrence Livermore National Laboratory
The huge magnet of the MFTF as it was being moved from its fabrication site to the experimental building.

Deferring the Future?

After eight years of planning and construction and $350 million, the magnetic mirror fusion program at Lawrence Livermore National Laboratory will close down. According to the program's assistant associate director, Keith Thomassen, the proposed 1987 budget would have cut the allocations for the program by 34 percent, and Gramm-Rudman was expected to cut it further.

When *Fusion* questioned the lab, a spokeman said the administration's reasoning in cutting this area of reseach was that because oil prices are falling, there is no energy crisis, and therefore we can defer investments in fusion power.

fact, the proposed 1987 budget will begin to substantially cut into the scientific base of the fusion program as funding descends to levels below those of 1976.

Whereas previous cuts have primarily undermined the technological prospects of realizing the commercial potentials of fusion energy, the current round of cuts will destroy substantial portions of the program's scientific base. Now the scientific muscle of the fusion program will be reduced to a fraction of what it was in the mid-1970s. This is especially the case, given the fact that the government-calculated inflation rates are generally much too low, particularly for scientific R&D.

This disaster is exacerbated by the actual distribution of the remaining resources of the program. To an accountant it would appear far more rational to maintain a large, capital-intensive experimental facility then to fund a diversity of smaller efforts with higher per scientist operating costs.

But the direct result of this accountant's reasoning is that the proposed budget cuts will wipe out large areas of basic fusion and plasma research.

Ironically, the U.S. fusion program has been able to meet—and in many cases substantially exceed—all of the scientific goals projected in the 1976 government study. As Figure 2 shows, there has been consistent progress as fusion experiments have moved toward meeting the physical parameters needed for fusion energy production. It is now likely that both the European JET tokamak and the U.S. light ion beam PBFA-II at Sandia will demonstrate the conditions needed for substantial net energy production—despite the fact that neither device was originally designed to attain this goal.

As the budget has decreased, the economic stakes have increased. In recent years, studies of fusion's economic potential—such as those carried out under the direction of Dr. John Nuckolls of Lawrence Livermore National Laboratory—have shown that current economic potential for fusion energy is far greater than that originally projected in the mid-1970s. According to one 1983 study, fusion has the potential of producing electrical energy for as little as half the cost of current and future nuclear fission and fossil fuel power systems, and commercial prototypes could still be achieved before the year 2000.

A detailed review of the fiscal year 1987 budget request demonstrates that this potential is being forfeited and that substantial segments of the scientific base are being gutted. Table 1 gives a breakdown for the magnetic fusion R&D program from fiscal year 1985 to fiscal year 1987 in current dollars.

It should be noted that it is impossible to give any comparable analysis for the inertial confinement laser and particle beam pellet fusion R&D effort because this program was not even given a separate budget line in the current request. The detailed figures for this program will not be released until and if the various directors of the U.S. national laboratories—Los Alamos, Sandia, and Lawrence Livermore—decide to make them available. In fiscal year 1986, the Reagan administration had proposed a zero budget for inertial confinement.

The major subsectors of the magnetic fusion energy program shown in Table 1 are: (1) applied plasma physics, which covers both small fusion experiments and the university-based programs; (2) confinement systems, which consists of the large experiments; (3) development and technology, which provides the technology base for commercial reactor construction; and (4) planning and projects, which oversees the design and construction of the next major phases of the magnetic fusion program, such as the construction of engineering and prototype fusion reactors.

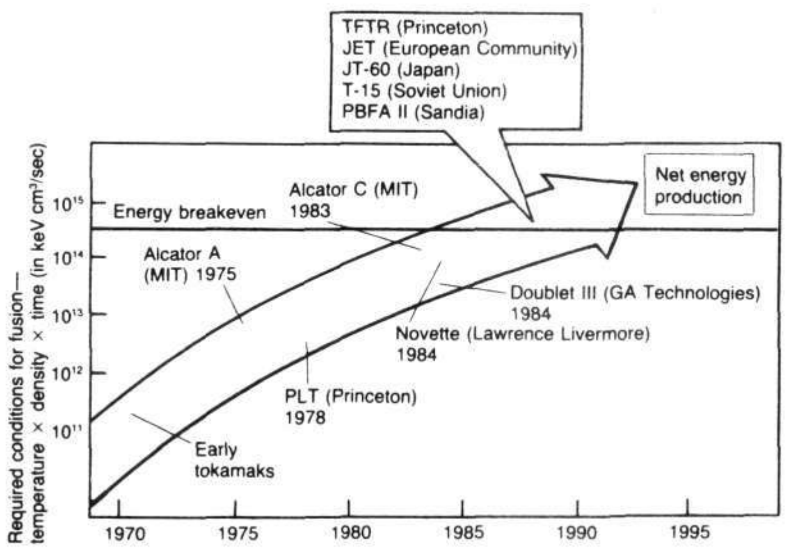


Figure 2
PROGRESS IN ACHIEVING CONDITIONS REQUIRED FOR FUSION POWER
While the fusion budget has been steadily eroded, the major fusion experiments have proceeded to make more than the expected progress toward the goal of net energy production.

Phasing Out the Future

As shown in the table, planning and projects—that is, the future development of the program—is all but phased out. The budget request notes that it is hoped that "international collaboration" will lead to some kind of future development, a myth fostered by former presidential science advisor George Keyworth, a zero-growther.

In the applied plasma physics division, which covers a substantial portion of the scientific base of the fusion effort, it is not immediately apparent that major cuts are being implemented. The further budget detail (Table 2), however, shows that broad areas, such as experimental research operations, are being decimated, with a 50 percent

Table 1
FISCAL YEAR 1987 BUDGET REQUEST
FOR MAGNETIC FUSION ENERGY

	FY 1985 Appropriation	FY 1986 Appropriation	FY 1987 Request	Request vs 1987 Base
Applied plasma physics				
Operating expenses	$ 78,937	$ 69,692	$ 70,700	$+ 1,008
Capital equipment	3,170	5,619	4,500	− 1,119
Subtotal	82,107	75,311	75,200	− 111
Confinement systems				
Operating expenses	206,395	188,650	177,500	−11,150
Capital equipment	15,400	14,529	7,100	− 7,429
Subtotal	221,795	203,179	184,600	−18,579
Development and technology				
Operating expenses	67,900	57,059	50,510	− 6,549
Capital equipment	5,100	4,330	1,890	− 2,440
Subtotal	73,000	61,389	52,400	− 8,989
Planning and projects				
Operating expenses	12,201	5,528	4,780	− 748
Capital equipment	3,800	3,801	3,820	+ 19
Construction	32,500	12,653	8,200	− 4,453
Subtotal	48,501	21,982	16,800	− 5,182
Program direction				
Operating expenses	4,150	3,608	4,000	+ 392
Subtotal	4,150	3,608	4,000	+ 392
Total				
Operating expenses	369,583	324,537	307,490	−17,047
Capital equipment	27,470	28,279	17,310	−10,969
Construction	32,500	12,653	8,200	− 4,453
Magnetic Fusion Energy	$429,553	$365,469	$333,000	$−32,469

cut over two years.

Although it would appear that the confinement systems portion of magnetic fusion R&D—which has consisted of two main lines of approach, the linear tandem mirror and toroidal systems like the tokamak—is at least being maintained near the same levels, the actual budget proposal states that "to accommodate present fiscal constraints, further research on tandem mirrors is being deferred. . . ."

The result is that the world's largest fusion experiment, the nearly completed MFTF-B at Lawrence Livermore National Laboratory, "will be mothballed." In other words, qualitatively half of the magnetic fusion confinement systems will be cut.

Cutting National Security

The U.S. fusion R&D program has demonstrably provided the lion's share of the technology, science, and personnel for the Strategic Defense Initiative (SDI) to make offensive nuclear missiles obsolete. Because of its broad scope, the fusion program has especially been a breeding ground for innovation in science and technology. The proposed fiscal year 1987 fusion budget will significantly curtail any such future contributions.

Some measure of the resulting strategic loss to U.S. national security may be judged by this example:

The most potent missile defense weapon yet developed is that of the nuclear explosive pumped X-ray laser. The first generation X-ray system could destroy upwards of a score or more ICBMs per X-ray nuclear explosive. Recent, basic science advances indicate that this capability could be vastly increased to a point where one X-ray nuclear explosive could take out the entire Soviet ICBM fleet. And the X-ray laser is just the first of an entire family of new types of directed energy systems made possible by the high energy densities of fusion.

Currently, U.S. researchers can access these high energy densities only with expensive nuclear weapons tests, which greatly hinders the development and perfection of new possibilities, like the gamma ray laser, as well as the existing X-ray laser. An economical alternative is to use laboratory inertial confinement fusion, like that produced by laser or particle beams. Inertial confinement fusion in the laboratory, in fact, can attain even higher energy densities than those generated in thermonuclear weapons.

Recent intelligence reports from the Soviet Union indicate that under the direction of Academician E. Velikhov, Soviet scientists have succeeded in combining magnetic fusion with inertial confinement to obtain significant fusion plasmas on a laboratory scale.

It is reported that compact tori magnetic plasmas have been injected into metal cylinders that are then imploded—the approach generically known as the imploding metal liner. This combined magnetic-inertial approach appears to be the technologically most accessible means for laboratory generation of fusion plasmas. Is the United States researching this area of fusion

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Table 2
BUDGET BREAKDOWN IN APPLIED PLASMA PHYSICS

	FY 1985	FY 1986	FY 1987 request
Experimental research operations	$21,501	$14,413	$12,455
Fusion theory program	$22,644	$19,046	$17,500
Basic experimental plasma research	$16,024	$14,866	$13,215

The cuts in these scientist-intensive areas will be devastating.

Who's Out to Destroy NASA?

by Carol White

While the Soviets launched their space station and sent two astronauts into orbit, the U.S. press continued to manufacture a scandal of massive proportions against the U.S. National Space and Aeronautics Administration.

Every NASA decision made over the past several years is being second guessed, and the media is using all its persuasive power to try to turn the American public against the space program. While every conceivable scandal is being dredged up, the real scandal is being covered up. The Presidential commission has *not* asked: Why was a manifestly incompetent person for the job, William Graham, made acting administrator of NASA, and who put him there?

Other questions that must be asked concern the Shuttle disaster itself: where was William Graham when the decisions were being made, and what was his input into the decision-making process?

Whether or not the accident was related to the extreme cold, it was a mistake to fly the Shuttle under abnormal weather conditions. Why was such a mistake made? It is interesting, but not significant, that there was dissension among the engineering personnel working for NASA contractors as to whether to fly. It is obvious, but unimportant, that it would have been a plus for the President if he could have delivered his State of the Union speech with the Shuttle flying.

The Shuttle may or may not have had some close shaves on earlier flights, but the fact remains that it had an excellent safety record—until Jan. 28, 1986, two months after Graham assumed responsibility for the agency. This can be attributed to the extra edge given to the program by the exceptional quality of leadership offered by James Beggs, whose on-the-spot command decisions provided the necessary margin between mission success and tragic failure.

Who Got Rid of Beggs?

Yet James Beggs was forced out of his position in December 1985, when he came under criminal indictment for malfeasance that allegedly occurred with defense contracts when he was a vice president at General Dynamics. The charges against Beggs are so flimsy and unlikely to hold up in court, that one must conclude that someone was trying to use anything in order to force Beggs to leave NASA.

The question here is, who in the Justice Department was responsible for pushing through this indictment and why? Indeed, one special agent of the Justice Department, Gary Black, appears to have been replaced after he recommended against such prosecution of Beggs in early 1985.

The Questions That Must Be Asked

Why was a manifestly incompetent person for the job, William Graham, made acting administrator of NASA, and who put him there? Where was William Graham when the decisions were being made, and what was his input into the decision-making process?

Surely a decision as serious as that involved in forcing the head of NASA out of a position of key importance to national security and the Strategic Defense Initiative would have had to involve Attorney General Meese.

Why the Graham Appointment?

The replacement of Beggs by Graham thus becomes particularly significant. Graham's appointment was forced through by White House circles despite opposition at NASA. The White House patronage machine had lobbied for six months to get Graham appointed as deputy director to fill the vacancy left by Hans Mark, who had left the agency to become chancellor of Texas University.

NASA resisted the White House pressure for several months on the basis that more qualified candidates were available, and that Graham was not qualified to assume the responsibility of second in command. Graham's past experience had been as a defense consultant on questions related to arms control, and he was something of an expert on the question of how electromagnetic pulses affect missile launches. He did not have experience as a top administrator, nor was he an expert on questions regarding the space program. He was, however, an active member of the California Republican Party, whose patronage machine was pushing for his appointment.

Within days after Graham became deputy director of NASA, James Beggs was forced to take a leave of absence as administrator because of the indictment against him. Graham was then made acting director of the agency. From the minute that he stepped into Beggs's shoes, he made it clear to everyone concerned that he was there to clean out the "old boys." He was so abrasive that it was feared that many of the most qualified top management of the agency would be driven to resign.

What Graham Did

If the Shuttle accident had not occurred, it seems certain that the Graham appointment would have still resulted in the erosion of NASA's performance, only more slowly. For example, Graham began to remove qualified staff from their posts: In February, Beggs's assistant Phil Culbertson was "relieved of his responsibilities" as general manager of NASA.

If there was a problem in the decision-making process that led to the accident, if indeed the flow of information to the senior officials of NASA was inhibited, one reason for this could be the lack of confidence in Graham already felt by NASA staff. In an agency known for its "open door" policy, Graham walled himself off from the staff. An organization like NASA is like a military unit: It depends upon the high morale of its "troops" for that edge in performance, which up to Jan. 28 had guaranteed its excellent record.

Where was Graham during the final review before that Shuttle launch? James Beggs or his representative Hans Mark had always been present at that final review. Had Beggs remained in command, it is likely that he would not have allowed the flight to proceed, merely because the subfreezing weather of the previous night might be expected to have unpredictable consequences.

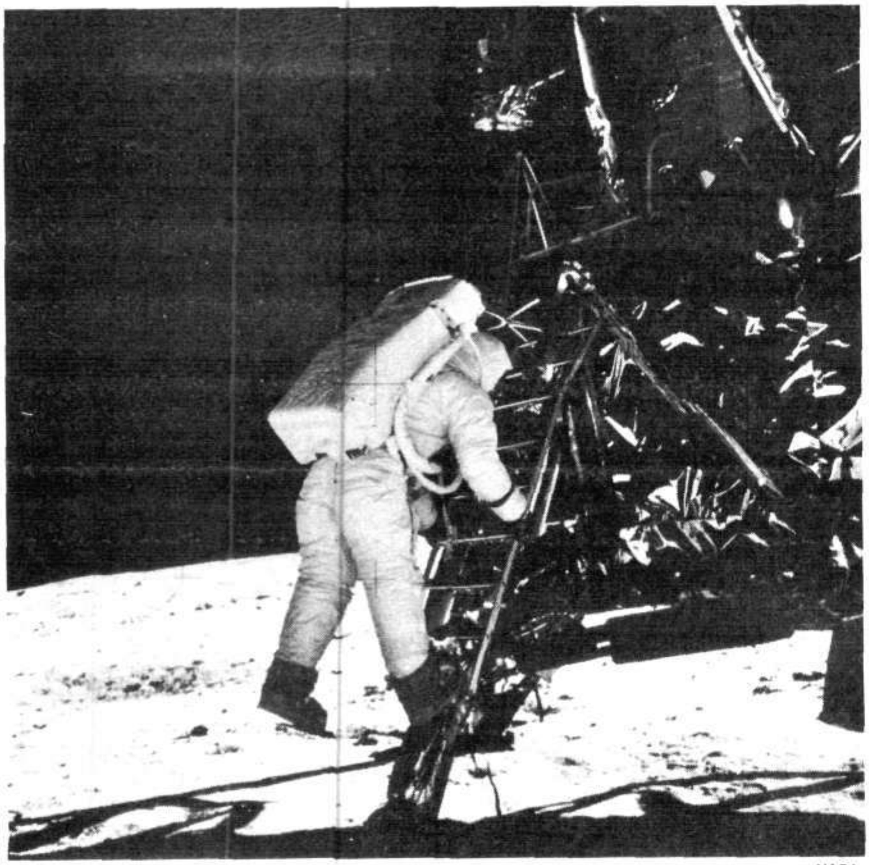
But Graham did not participate in the final review before the launch. He had gone down to the launch site on the Saturday before the originally scheduled Sunday launch, Jan. 26, and he postponed that launch, reportedly over staff objections. His presence was so abrasive and confidence in his judgment was so minimal, that rumor had it then that he was mainly concerned that the Shuttle not interfer with that Sunday's Superbowl.

The Future of NASA

It is clear that many of the Shuttle systems were more marginal than we would like because of budget constraints on NASA. But if we are to have a space program, then some risks are inevitable. Every Shuttle flight contains an apreciable amount of risk. The question is whether such risks are necessary and whether the payoff is sufficient to warrant taking them. On Jan. 28, President Reagan expressed the spirit of the nation when he answered both questions affirmatively.

Now we are told that there will be at least a year's delay in the next Shuttle flight. In fact, Graham told Congress that the solid rocket boosters will need to be completely redesigned and its flight schedule sharply reduced. Hopefully we can assume that when James Fletcher takes control of NASA, the program will regain its momentum. Clearly we must not only replace the destroyed orbiter, but we must build the fifth orbiter originally planned to complete the fleet.

We cannot become a nation that refuses to take risks. Otherwise we will cede the exploration of space to the Soviets and abort our own destiny.



NASA

"To meet the modest goals the President has layed out—continuing the Shuttle program and building a manned space station—requires ending the irrational approach to economics that has dictated that the space program must be 'cost-effective.'" Above, NASA's Moon landing.

Cost-Accounting: Slow, But Sure Death to NASA

by Marsha Freeman

The most dangerous enemy NASA has is the anti-Hamiltonian economics of both the liberal and conservative variety. The former insists on spending no money except on social welfare here on Earth, while the latter insists on "privatizing" space exploration and development. The end result of both philosophies is the same: no aggressive space program and no commitment to developing the advanced technologies that could gear up U.S. production and move the economy out of the depression.

A quick course in the economics of NASA's Apollo program should be enough to convince any reasonable, thinking citizen that a crash program in the frontier technologies of space is a good investment. Even by the conservative estimate of Chase Econometrics, the Apollo program put back $14 into the economy for every dollar spent. At the height of the Moon program in 1965, NASA was introducing 6,000 new technologies per month to private industry and agriculture, spurring the only period of real industrial growth and productivity increase the country has seen since World War II.

Computers and electronics, new materials, remote sensing for agriculture, and medical devices from the intensive care monitoring systems to the artificial heart all got their start from NASA.

Cost-Accounting

Although President Reagan himself took a strong stand for continuing the space program and committed the nation to building an operational space station within a decade, his economic policies—from the Gramm-Rudman across-the-board cuts to the idea that private enterprise can do it—ensure that this commitment cannot be met.

From 1965 to the beginning of the Reagan administration, funding for NASA had been falling in constant dollars. NASA administrator James Beggs, coming to head the agency from industry, was able to secure the President's promise that the NASA budget would increase by at least 1 percent each year in real dollars, despite the strenuous objections of the Office of Management and Budget.

But this year, under the first round of Gramm-Rudman cuts, NASA lost more than $200 million from its budget, and at the same time the agency has had to cope with the loss of a crew and orbiter. The administration's fiscal year 1987 request for space cuts NASA's budget by 3.5 percent in real dollars.

The funding request made by NASA for next year's work on the space station was about $580 million. The agency is now budgeted for this at a level of $410 million, although the OMB had proposed a grand total of only $100 million for the program next year.

Instead of defining the space station program by its projected capabilities, the major concern has been to limit the amount of money spent. When President Nixon announced the Space Shuttle program in 1972, he gave NASA a limit of $5.2 billion for its development, about one-quarter of what the Apollo program cost.

NASA has been given $8 billion as a ballpark estimate of what this project can cost, and it has to make the design and operation decisions within that constraint.

Western Europe, Japan, and Canada have been invited to participate by contributing major modules to be added to the basic structure, not so much out of concern for international cooperation, but to more closely approximate the station that NASA will not get the money to build.

The same kind of penny-pinching has degraded the Shuttle program. Throughout the program's development, NASA was forced to make many kinds of design and technology decisions based on the cost-accounting criterion. Even safety-related improvements that had been planned for the Shuttle system have been cut out of the budget in the past five years.

The past six years of the space program in fact, have amply proven—contrary to tightly held beliefs about the "magic of the marketplace" and the responsibilities of private enterprise to finance research and development efforts—that only the federal government, representing both the resources and interests of the entire nation, can push forward the frontiers of basic science and create the capabilities for their commercial application in industry.

Cost Vs. Launch Frequency

The obsession that Shuttle missions should "pay for themselves" has led to a situation where increases in the price NASA charges commercial customers have made it more difficult for the United States to compete with the government-subsidized European Ariane reusable rocket. This has put pressure on NASA to fill its payload with as many paying customers as possible, to bring more money into the federal Treasury.

The frequency of Shuttle launches largely determines the cost of each launch. According to NASA, the cost of each Shuttle mission, if four are flown per year, is $350 million per flight. Doubling the flight rate to eight per year brings the cost down to $197 million each. At the projected future NASA rate of 24 launches annually, each mission will cost $91 million.

The pressure to bring the cost per launch down has been too much of a factor in determining what the number of missions per year should be. Ironically, the same media and spokesmen who criticize NASA for having a too ambitious launch schedule, which they claim led to the Challenger loss, are equally critical of the cost of the system, which is largely determined by launch frequency.

Leading the free-enterprise faction is the Heritage Foundation, based in Washington, D.C. Heritage spokesman Milton Copulos stated categorically on television after the Jan. 28 disaster that the "private sector" should build a Shuttle orbiter—if it were determined to be a good investment, that is. Copulos's palaver about private investment is simply a cover story for cutting the NASA budget with impunity.

The Heritage Plan to Shut Down NASA

In its recent budget document, "Slashing the Deficit: Fiscal '87: A Proposal by the Staff of the Heritage Foundation for the Budget of the U.S. Government," Copulos calls for paring the Shuttle budget by $500 million and beginning the privatization of NASA.

"There is now a real danger that further subsidy and monopolization activities by NASA will stifle private sector participation" in space, Copulos writes in the document. "The federal government should move immediately to cancel its plans to construct a fifth Shuttle with taxpayer money. Instead, "a thorough strategy for privatization of commercial space activity is necessary. Eventually all commercial space-launching services should be handled by private firms."

According to NASA, private consortia have tried and failed, over the past years, to raise the money needed to build a Shuttle orbiter.

What Do We Need in Space

To meet the modest goals the President has layed out—continuing the Shuttle program and building a manned space station—requires scrapping the budget proposal that the administration has submitted to Congress for next year and ending the irrational approach to economics that for 15 years has dictated that the space program must be "cost-effective."

The point is, that given the nation's future, a crash program in space is not only cost-effective in the broad sense, but also the only way to rejuvenate the crippled U.S. economy.

As Alexander Hamilton prescribed in the early years of the nation, the government must take the lead in building the infrastructure and great projects in scientific advancement to ensure that there will be plenty of room for industry to grow.

Los Alamos 'Trailmaster' Drives for Fusion

by Charles B. Stevens

Los Alamos National Laboratory announced in early 1986 that the first stage of its "Trailmaster" electrical pulsed-power program had been successfully completed. According to the Trailmaster program manager, Dr. Charles Fenstermacher, this new technology could provide an extremely economical, quickly assembled, and highly versatile means of experimentally exploring a wide range of high energy dense processes, such as ignition of thermonuclear fusion reactions, creation of X-ray lasers, and laboratory-scale simulation of nuclear weapons effects.

Currently, high energy, pulsed-power systems, like the 100-trillion-watt Particle Beam Fusion Accelerator II (PBFA-II) light ion facility at Sandia National Laboratories and the 100-trillion-watt Nova laser fusion facility at Lawrence Livermore National Laboratory, cost from $50 to $170 million dollars and take many years to design and construct. Trailmasters, specifically tailored to explore a particular high energy density regime, could be designed and built in a few months at a cost of a few tens of thousands of dollars per experiment.

The Trailmaster converts the cheap energy of chemical explosives into compressed, high-power pulses of electrical energy. The key to the system is an electric circuit "opening switch," which makes it possible to compress the current as much as 500-fold in time and space. In this way a billion-watt electric pulse can be amplified to a 100-trillion-watt power level. The electric pulse can then be tailored to drive a myriad high power devices, such as X-ray lasers and nuclear fusion reactors.

The switching science and technology being developed at Los Alamos, however, is applicable to a wide range of other pulsed-power systems. For example, the Trailmaster switching technology could be utilized in more conventional capacitor bank systems to vastly improve the range of high energy accessible to university laboratory facilities working on fusion plasmas, particle accelerators, and lasers. In other words, the Trailmaster program could lead to a general revolution in pulsed power and high energy research and development.

The Technology of High Energy Density

Throughout history, high energy density has determined the frontiers of science and economic progress. The higher energy density of steam engines provided the means for reaping the bounty of deep-lying coal and mineral deposits and harnessing metal-forming machines. In this century, high energy density has unlocked the limitless energy potentials of the atomic nucleus.

In recent decades the quest to realize thermonuclear fusion reactions has led to the exploration of plasmas. Plasmas represent a fourth state of matter—solid, liquid, and gas being the first three. When matter is raised to a sufficiently high temperature, its atoms break up into negatively charged electrons and positively charged ions. Because these constituents, electrons and ions, are electrically charged—unlike the relatively neutral atoms of an ordinary gas—plasmas are dominated by electric forces and the magnetic fields generated by the relative

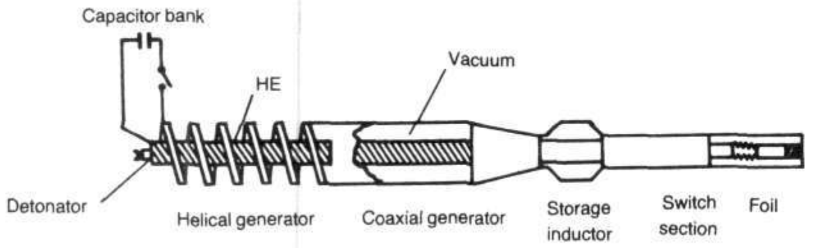


Figure 1
SCHEMATIC OF TRAILMASTER LAYOUT

Trailmaster was conceived as a method to convert the cheap chemical energy of high explosives (HE) into compressed, high-power pulses using storage and switching (which compresses the pulse width to tens of nanoseconds) to amplify the pulse 100-fold. This generates an intense burst of X-rays that could be used to ignite inertial fusion or to pump X-ray lasers.

A small electric current derived from a capacitor bank is switched into the magnetic coils of the helical generator. The detonator then sets off high explosives surrounding the generator. The resulting compression of the magnetic field converts the chemical energy released to an increased electrical current in the generator's imploding coils. The result is a greatly amplified electrical pulse that passes through the coaxial generator and into the storage inductor. From here it is switched out and compressed, amplifying it. Finally, the pulse is directed onto a cylindrical foil, which causes the foil to implode and produce a high-temperature plasma that generates an intense burst of X-rays.

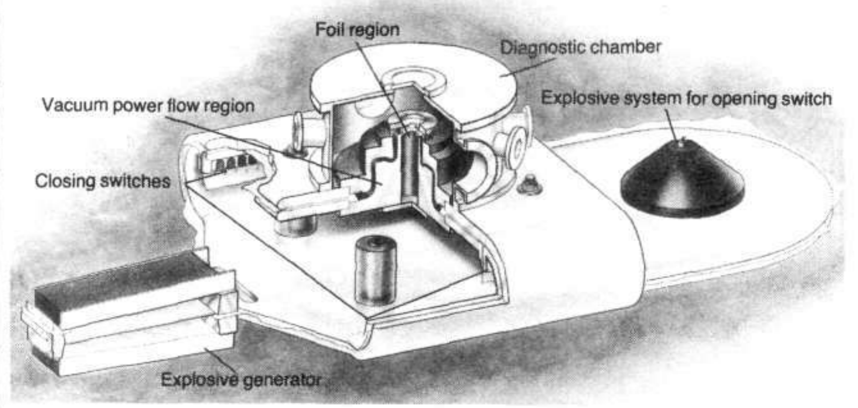


Figure 2
LAYOUT OF PIONEER I EXPERIMENT
The Pioneer I foil implosion system, which succeeded in meeting the program's objectives in a series of five experiments.

Los Alamos National Laboratory

motion of charged particles.

Actually, the conventional states of matter found within the Earth's biosphere are quite rare in the cosmos at large. Most matter in the universe, like the Sun and other stars, is in the plasma state.

Plasmas and Switches

In the quest for higher energy densities, the plasma state offers virtually unlimited possibilities, because plasmas are held together by macroscopic electric and magnetic fields, while ordinary matter is characterized by limited chemical bonds. Intense electric and magnetic fields that would destroy the chemical bonds—and therefore integrity—of ordinary materials can improve the integrity of plasma configurations.

Besides withstanding much larger concentrations of energy, such as intense electric currents, plasmas also can be rapidly transformed into entirely new configurations. For example, a plasma can proceed from a state in which it offers virtually no resistance to the flow of electricity to one in which it suddenly becomes highly resistive.

An example of this is the plasma focus research of Dr. Winston Bostick of the Stevens Institute of Technology in New Jersey. In the plasma focus device, large electric currents are transported between two metal electrodes via a series of spiral plasmas. The spiral plasmas, or plasma vortices, look like strings and are nested together to form a conducting surface between the metal electrodes. The microstructure of these strings is force free. That is, while extremely large electric currents are flowing through the plasma, and therefore large magnetic fields are present together with substantial fluid motion of the plasma itself, all of these different forces or "energy flows" line up in parallel spirals so that they do not interact.

This so-called Beltrami-type, force-free plasma configuration is quite similar in geometry to that seen in some superconductors, with the distinction that the plasma must be sustained at millions of degrees Celsius and the superconductor at near absolute zero temperatures. In both cases the force-free, Beltrami configuration conducts electric currents with virtually no resistance.

Under the right boundary conditions, however—such as too high a level of electric current or a change in the macroscopic geometry of the plasma vortex sheet, the individual vortices will unravel over extremely short time spans—lasting as little as a billionth of a second. The process is like that of a laser. The unraveling of one vortex can set off the destruction of another and a chain reaction conflagration results.

With the sudden disappearance of the plasma channels, the electric current flow between the two metal electrodes is rudely interrupted. The result is like attempting to stop an ocean wave with a simple vertical wall. When the wave hits the wall, it compresses and grows greatly in amplitude, concentrating its energy in the process. Similarly, with the disruption of the plasma vortex channels, the electric current pulse is compressed and grows rapidly in amplitude.

One essential component of the Trailmaster program is using such plasma switches to compress electric currents many hundred times.

The Trailmaster Configuration

Figure 1 shows a circuit diagram of the Trailmaster and Figure 2 shows the experimental setup. The process begins by storing an ordinary power level current pulse in the magnetic coil. Chemical explosives surrounding this coil, and carefully configured into implosion lenses, are then detonated. The implosion lenses compress the coil and its magnetic field. The degree of energy densification is simply given by the volume of compression achieved.

This implosion process compresses the electric current that is generating the magnetic field in the coil, and in the process converts the explosive energy into electric energy. The result is a surge of current—a current pulse in the shape of a wave. By opening a switch at the appropriate time, this current surge can be transferred to a new electric circuit. And by properly tuning the elements of the two circuits and having a sufficiently fast opening switch, the current surge can be compressed in the same manner as the ocean wave hitting a wall.

The dynamics of the chemical explosion and the geometry of the coil configuration limit the speed of compression that can be achieved in this manner. The time scale characteristic of an efficient conversion of explosive chemical energy to electric current is on the order of 250 microseconds, about one quarter of a thousandth of a second. The switching out of this current surge into a second circuit further compresses the current to a pulse lasting about 500 nanoseconds (1 nanosecond is one-billionth of a second)—about a 500-fold compression or power amplification.

The Front End

The final current surge and its wave form—literally, the geometry of the wave—are essential parameters in the end use of the Trailmaster output. Because these characteristics can be readily adjusted by changes in the circuit tuning matchup, the Trailmaster makes an extremely versatile energy driver for a wide variety of devices.

In its simplest form, the Trailmaster could be utilized to produce intense bursts of X-rays, accomplished by a second implosion process. The current is passed through a small cylinder made from a thin metal foil. The huge current rapidly transforms the foil into a cylinder of plasma. The intense magnetic fields generated by the current simultaneously exert an inward force on the foil plasma, which leads to its rapid implosion. Because the final compressed metal plasma reaches high densities when the foil implosion arrives at the axis of the cylinder, most of the kinetic energy of the foil implosion and magnetic energy is converted into heating the foil plasma to extremely high temperatures.

The result is a powerful, concentrated burst of X-rays produced by the hot, dense metal plasma. This intense X-ray source can be utilized to create powerful X-ray lasers or for ignition of thermonuclear fusion reactions. The X-rays can also be used directly to simulate the effects of nuclear weapons. (When nuclear weapons detonate, the sudden burst of nuclear energy that they release generates a plasma "fireball" whose chief energy output is in the form of intense X-rays.)

When these X-rays irradiate satellites, missiles, or other systems, they generate electric currents along metal surfaces. These currents, in turn, generate electromagnetic waves on the interior of the satellite or rocket. This process is called system-generated electromagnetic pulse and can easily destroy or at least disrupt the internal electronic controls of these satellites and missiles.

The threat from system-generated electromagnetic pulse is extremely difficult to predict and protect against. The Defense Department's Defense Nuclear Agency currently must test satellites and rockets against system-generated electromagnetic pulse with expensive underground nuclear tests that cost from $10 to $100 million. Trailmaster would provide a laboratory-scale facility for such tests at costs in the range of tens of thousands of dollars.

The main approach currently being pursued in inertial confinement laser fusion research is that of X-ray driven implosion. Laser pulses are converted into X-rays, which then irradiate a small pellet of fusion fuel. The X-rays are ideal for symmetrically and efficiently burning off the outer layer of a fusion fuel pellet. This smooth "ablation" of the target surface leads to precisely the type of even compression, or implosion, of the interior of the fuel pellet to extreme densities needed for high-gain inertial fusion. The Trailmaster X-ray burst produces the same type of smooth pellet implosions, without the need for an expensive laser.

Nonlinear Waveforms

These immediate applications of Trailmaster are only the beginning. The Trailmaster converts an acoustic shock wave, generated by the chemical explosive lens, into an electric pulse in a coil. The shape and parameters of the electric pulse can be tuned by both the circuit and the explosive lens design. The geometry and characteristics of the resulting current waveforms are not just those of a simple sinusoidal wave; a properly tailored waveform should be seen as something like a highly nonlinear soliton, or potential soliton.

And just as the change in current in a plasma focus can lead to a dramatic change in the geometry and electrical properties of plasma vortices, the final Trailmaster current waveform can be tuned to produce significantly different physical regimes in the front end of the machine. For example, the waveform can be tailored to drive specially designed plasma pinches for fusion, or to generate charged particle acceleration, or to tune the X-ray output of specially designed cylindrical foils.

Energy, as such, is not just simply scalar. Its intensity and geometry determine entirely different physical re-

Continued on page 62

ON THE FRONTIERS OF PHYSICS

Galileo Proven Wrong!

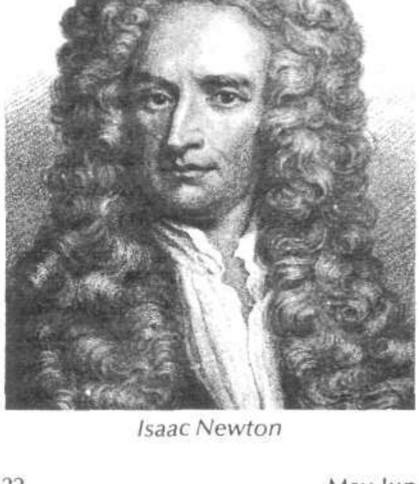
by Dr. Robert Moon and Carol White

For 300 years it has been an unchallenged law of physics that gravitational and inertial mass are the same. Experiments in the last 15 years, however, indicate that it is time to call this law into question.

Johannes Kepler's ground-breaking theory of the orbital motion of planets within the solar system treated the mass of the planets as derived from their position. For him, the orbits themselves were primary and depended upon principles of physical geometry.

This was not in contradiction with Galileo Galilei's contention that all bodies, dropped from a given height, would fall to Earth in precisely the same time regardless of differences in their masses.

To account for the apparent empirical validity of Galileo's discovery, Isaac Newton, when he derived his theory of gravitational force from the product of the masses of two attracting objects (divided by the square of the distance between them), had, perforce, to equate their inertial and gravitational masses. In his view, the gravitational mass of the falling object was exactly balanced by its gravitational resistance. Einstein's subsequent revision of Newton's theory maintained the equivalence of inertial and gravitational mass.


Isaac Newton

Recent Experiments

Over the past 15 years, experimental results have shown that the gravitational constant assumed by Galileo is not precisely constant; it varies according to the mass of the attracting objects. Experimenters in Queensland, Australia, among others, have reported upon the variation of gravity with depth in mines and boreholes. They were able to correctly predict the densities of intervening rock formations from these calculations.

All of the estimates of the gravitational constant were higher than the conventional, laboratory determined one. An empirical formula that accounts for the discrepancy was determined to be $V(r) = -G_\infty \frac{m_1 m_2}{r}(1 + \alpha e^{-r/\lambda}) = V_N(r) + \Delta V(r)$.

The Fifth Force

Recently, a group of physicists, led by Ephraim Fischbach of the Department of Physics of the University of Washington, challenged the foundations of accepted doctrine in physics by offering an explanation of this discrepancy. They claim to have discovered a fifth force, which acts as a repulsion between gravitating bodies and varies according to the mass number of the bodies and their distance, reaching a maximum at approximately 200 yards.

If they are right, Galileo's "discovery" that all bodies fall to Earth at the same time, regardless of their mass, will have been proven false. Fischbach published this revolutionary assertion in the Jan. 6 issue of *Physical Review Letters*.

Of course, the amount of the discrepancy involved is orders of magnitude below what might have been ob-


Do all bodies dropped from a given height fall to Earth in precisely the same time, regardless of differences in their masses? Galileo's contention has been considered law for 300 years, but now this law has been challenged. Here, a portrait of Galileo in 1640.

served by Galileo (assuming that he actually conducted an experiment—and there is a convincing body of thought indicating that he did not). According to accepted theory in the physics community, there are four forces: the *electromagnetic force*, related to the charge of objects; the *gravitational force*, which depends upon the distance between objects and their mass; the *strong force* within the nucleus, which is presumed to account for the fact that the nucleus is held together, despite the repulsive electromagnetic force; and the *weak force*, which is the discrepancy that occurs in the formation and dissolution of electron-positron combinations from gamma rays, correlated to the supposed existence of the heretofore undetectable neutrino.

Although Fischbach's findings are extremely interesting empirically, it is our view that his approach is wrong theoretically. Force theory, as such, is incorrect. Even the traditional classical physicist must admit to being in a quandary when he tries to express exactly the forces operating among three bodies simultaneously. As we have argued in the pages of the *International Journal of Fusion Energy* and *Fusion* magazine, the correct approach to physics must look upon the universe as a self-developing whole.

Force vs. Work

Forces are typically described as primary relationships between objects. We argue, instead, that they should be looked at as symptoms of a disturbance within the physical geometry of the universe—with the appearance of a force indicating work done against the universe. Thus, we agree with Kepler when he asserted that the orbits came first, and the planets were created within them, according to laws of physical geometry.

In the modern period, this point of view has received confirmation in the work of the Mexican astronomer Luis Carrasco, who has demonstrated the correlation of the mass of astronomical objects—ranging in size from the planetary to the galactic—with their rotational spin.

The ratio between the gravitational force and electromagnetic force is 40 orders of magnitude (1/10,000-trillion-trillion-trillionth). The strong force of the nucleus is, of course, orders of magnitude greater than the electromagnetic force, as is evidenced by the power of a nuclear explosion. The "fifth force," according to Fischbach, would have an order of magnitude 12 times smaller than the gravitational force, which itself is 40 orders of magnitude smaller than the electromagnetic force.

Fischbach asserts that not only do we have four forces operating, but that there is in addition a fifth, which acts as a repulsion between objects and is at its maximum at a distance of 200 meters. This is a surprising distance, since it is neither an astronomical distance nor an atomic distance.

The results Fischbach obtained do not depend upon independent experimental work, but represent a relooking at the work of Roland von Eötvös, a Hungarian scientist who made a number of precise measurements of the acceleration of different bodies under gravitational acceleration. For more than a decade, Eötvös compared the gravitational acceleration of substances like copper and platinum alloy, a silver and iron sulphate mixture, a copper and asbestos mixture, water and copper, and tallow and copper.

Eötvös concluded that these bodies were accelerated at the same rate within what was then assumed to be an acceptable level of error. Fischbach has taken the Eötvös data and after reviewing them (as described below) has concluded that Eötvös's conclusions were erroneous.

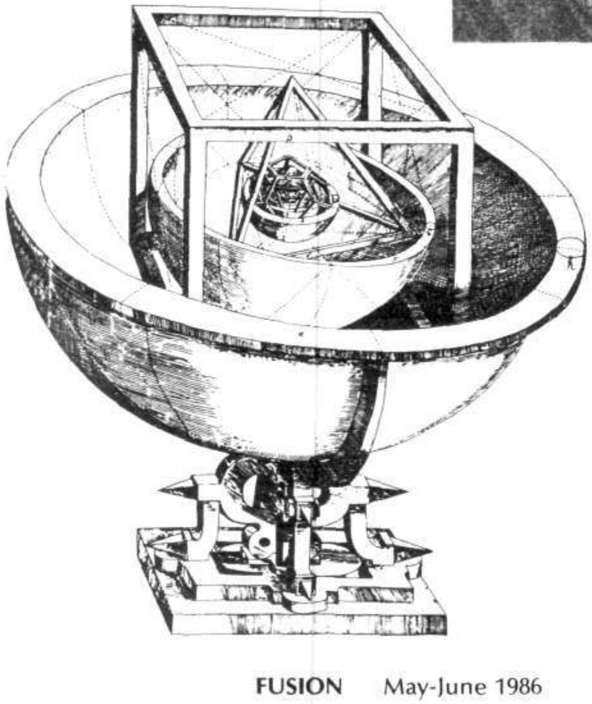
Fischbach looked at the data from the point of view of modern physics, discounting the effects of the strong and weak forces (unknown to Eötvös). He then subjected the remaining error to statistical analysis and determined, according to the standards of high-energy physics, that there is a significant error and that it is incorrect to state that the acceleration of these bodies was equal.

The formula Fischbach used to determine the so-called fifth force, was actually derived by D.R. Long, who published it in the magazine *Nuovo Cimento* in 1980. It has also been referred to in the work of several scientists who used it to account for discrepancies in the measurement of the gravitational constant.

The Soldano Theory

Dr. B.A. Soldano, professor of physics at Furman University in Greenville, S.C., offers a more fundamental explanation of this discrepancy, which entails a far more revolutionary challenge to accepted physics. Writing in the *International Journal of Fusion Energy* (Vol. 3, No. 3), he postulates that there is a difference between gravitational and inertial mass that not only accounts for Fischbach's results, but also accounts for many other so-called paradoxical findings that have been plaguing modern physicists.

According to Soldano's theory, that portion of the gravitational energy that can be accounted for by the coming together of nucleons (neutrons and protons within the nucleus of an atom) is not identical to the inertial energy associated with it. Soldano has found this discrepancy to be numerically equal to a correction factor of -5.05×10^{-12}—a factor that can account for a wide variety of otherwise unaccounted for results. In his recently published journal article, "Gravitational



Kepler took the opposite approach from Newton and Galileo. He did not view "forces" as primary; instead he derived his laws of planetary motion from the physical geometry of the planets and the Sun. Here is an engraving from the first edition of Kepler's Mysterium cosmographicum in 1596, which shows how the orbits of the planets can be circumscribed by the five Platonic solids.

Binding Mass, Nonequivalence, and the Foundations of Physics With the Lageos Satellite As a Laboratory," Soldano writes:

"For decades, a conflict has raged in physics over the question of the primacy of classical physics inherent in general relativity or of quantum mechanics. At present, physics maintains two parallel paths and occasionally attempts to interrelate these two conflicting disciplines.

"We take the position that an answer to the question of primacy already exists. Specifically, we propose to show that classical physics, slightly modified to accommodate a restricted nonequality between inertial and gravitational binding mass, leads to a purely classical explanation of the quantum *h*. Further, we propose to show that the seeds of a resolution of the above conflict already exist in the framework of both quantum mechanics and general relativity. . . .

"In order to obtain accurate enough parameters for resolving a wide array of problems in both general relativity and quantum mechanics, we shall begin by demonstrating that the Lageos

Is Time Absolute? A Look at the Fine Structure Constant

The fine structure constant, α, is approximately 1/137.036. It's reciprocal, $1/\alpha$, is calculated by dividing Planck's constant *h* by the square root of the electronic charge, e^2, and multiplying this by the reciprocal of the permeability of free space, μ_0, times the velocity of light, *c*, that is, $1/\mu_0 c$, and then multiplying this product by 2. Meter, kilogram, second, ampere (MKSA) units are used throughout in order to be consistent and be in tune with international system of units. It can be thought of as a correlative of Planck's constant, relating the velocity of the electron in the first Bohr orbit to the velocity of light: $e^2/(h \times c)$.

α is known as a dimensionless constant, because whatever units are used to calculate it, as long as they are applied consistently, the number obtained is the same. This of course, is not the case with *c*, the speed of light, which varies numerically according to the units used to measured it.

In MKSA units

$1/\alpha = 2(h/e^2)\ 1/\mu_0 c = 137.036.$

α has no dimensions.

$h = 6.626175 \times 10^{-34}$ joules/cycle.

$e = 1.6021892 \times 10^{-19}$ coulomb.

$\mu_0 = 4\pi \times 10^{-7}$ henrys/meter.

$= 4\pi \times 10^{-7}$ volts-sec²/coulomb-m

= permeability of free space.

Note that $h/e^2 = 25{,}812.8$ ohms is the fundamental Hall impedance and $\mu_0 c = 376.73$ ohms is the impedance of free space. The fundamental Hall resistance or impedance divided by the impedance of free space and that quotient multiplied by 2 is the reciprocal of the fine structure constant; that is, twice the fundamental Hall impedance, Z_H divided by the impedance of free space Z_{fs} is the reciprocal of the fine structure constant $1/\alpha = 2\ Z_H/Z_{fs}$ or $Z_H = 137/2\ Z_{fs}$. This seems to say an electron in a two-dimensional space of a thin semiconductor at 1.5°K has been restricted to 2/137 of the space of free space.

The relationship between the golden mean angle and the fine structure constant is established by taking 360° and dividing it by the approximation of the square of the golden mean, 2.618. It would seem arbitrary to introduce a calculation specific to degrees (rather than radian measure for example) in comparison with a dimensionless constant; however, it is the case that calculation by degrees is an abstraction from the relationship between the diurnal spin of the Earth and its yearly orbit. The number of revolutions the Earth makes in a year is 365.26, and when this is divided by the square of the golden mean, it yields 139.5.

Soldano's Derivation of α

Benny Soldano derives the fine structure constant as a relationship based upon shifts in the difference between ephemeral time (based upon the Earth's rotational orbit) and atomic time. The change in this ratio he ascribes to transformations in the gravitational binding energy, related to the shifting position of the Earth or other such factors that affect the macrocosm and the microcosm differently.

This difference, taken as a ratio of atomic time, is then compared to the Earth's angular velocity, which he corrects for the gravitational binding energy difference and then normalizes, by dividing the corrected figure according to the Earth's aberration angle. (The aberration angle is a calculation for the apparent position of distant stars.)

Soldano explained why he thinks that the discrepancy between the two forms of binding mass can account for the uncertainties of quantum theory as follows: "A fundamental difficulty with the universal law lies in the fact that Newton treated time as an absolute concept; that is, one could determine unambiguously the simultaneity of two events.

"This, however, requires that two observers be in instantaneous communication. Synchronization of the two clocks needed to measure simultaneity requires that the signal transmission time in one direction be measureable."

He then develops considerations traditional to relativity theory and states: "In a theory based on nonequivalence in gravitational binding, however, additional intervals of causal independence or acausality are required.

"This should not be a cause for concern, since our entire work demonstrates that time acausalities arising from mass nonequivalence in gravitational binding can be treated mathematically in a causal faction leading to solutions to fundamental problems in physics. Precedence for the use of time acausalities already exists in the Heisenberg uncertainty principle."

satellite constitutes an extremely sensitive 'laboratory' for quantifying some of the parameters required by explanations based on nonequivalence in gravitational binding." [A gravitational binding force is the attractive self-energy of a nucleus.]

From this, Soldano derives a definition of both inertial and gravitational mass. Lageos, NASA's geodynamic satellite, was placed in nearly circular orbit at approximately twice the radius of the Earth at approximately 110° inclination to the Earth's equator. This satellite is well above the Earth's ionosphere and is in a nearly perfect vacuum; nonetheless it is falling at a rate of 1.1 millimeters per day.

According to accepted theory, the satellite should not be falling. Furthermore, the plane of the satellite is rotating. Both of these otherwise inexplicable results, as well as the Fischbach results, are explained by Soldano's nonequivalence theory.

Soldano is able to derive the equation $V(r) = - G_{\infty} \frac{m_1 m_2}{r} (1 + \alpha e^{-r/\lambda}) = V_N(r) + \Delta V(r)$ from his own theory because he relates the term α to his gravitational correction factor (α, it should be noted, is the inverse of the fine structure constant) and, of course, plays an important role in quantum theory.

The problem inherent in Soldano's "revision" of quantum theory is located in the curious epistemological explanation of the gravitational binding force, which he accepts as a premise for his work.

This traditional, Newtonian explanation presumes an original condition in which the components of the nuclei of atoms float in empty space, presumably attracted to each other. The gravitational energy that brought them together is then supposed to be stored as a part of the binding energy holding the nucleus together.

The importance of his results would be greatly enhanced were he to recast his theory into the Keplerian mode.

Dr. Moon, professor emeritus at the University of Chicago, is editor-in-chief of the International Journal of Fusion Energy. *Carol White is editor-in-chief of* Fusion.

AN INTERVIEW WITH DR. BENNY SOLDANO

The Nonequivalence of Inertial and Gravitational Mass

Dr. Benny Soldano has taught physics for 15 years at Furman University in Greenville, S.C. From 1949 to 1971, he was a researcher in chemistry, physics, and engineering at Oak Ridge National Laboratory. For the past two years, he has been a Goddard summer research fellow, under NASA's physics research program. He is interviewed here by Dr. Robert Moon and Carol White.

Professor Benny Soldano: "The entire foundation of science depends upon the equivalence principle."

Question: Can you explain what you mean by the difference between gravitational and inertial mass?

There are only two properties of mass: first, that a given mass will attract all other mass, and that's called *gravitational mass*; and second, that mass resists change in motion, and this resistance to change in motion is called *inertial mass*. Now, these are two different properties of mass, but interestingly, when a substance falls, it can be "inerting" and "gravitating" at the same time.

Since these are two different properties, one would, without being told differently, assume that the values you would associate with inertial and gravitational mass would be different. The fact that—assuming they are in a vacuum—all things appear to fall to the ground with the same acceleration, is indirect proof that the inertial mass and the gravitational mass are one, and identically equal to each other.

Question: Is this what Galileo showed when he asserted that things of different mass fell to the Earth in the same amount of time?

He proved that the inertial mass and the gravitational mass properties appear to be identically equal to each other—which is contrary to reason, you would have thought. And Einstein, then, took this apparent equality, and he made it a principle—the so-called equivalence principle.

Question: How did you come to develop your theory of nonequivalence?

About 25 years ago, I concluded that the central difficulty which Einstein had run into when he attempted to unify physics, was the fact that General Relativity could not describe, surprisingly, gravitational binding energy—of all things. It could handle all other forms of energy, but it couldn't handle gravitational energy. It ran into such problems as apparent violation of conservation of energy at the microscopic level, and it required a special model of the universe in order to fit a series of complications.

I concluded, upon analysis of General Relativity's inability to quantitatively handle gravitational energy unambiguously, that this was a manifestation of a difficulty in the theory's fundamental assumption. In the gravitational binding-energy part of energy in general, which is a very small but very important part, the assumption that inertial and gravitational mass were identically equal to each other was false. This is very important for any unified field theory.

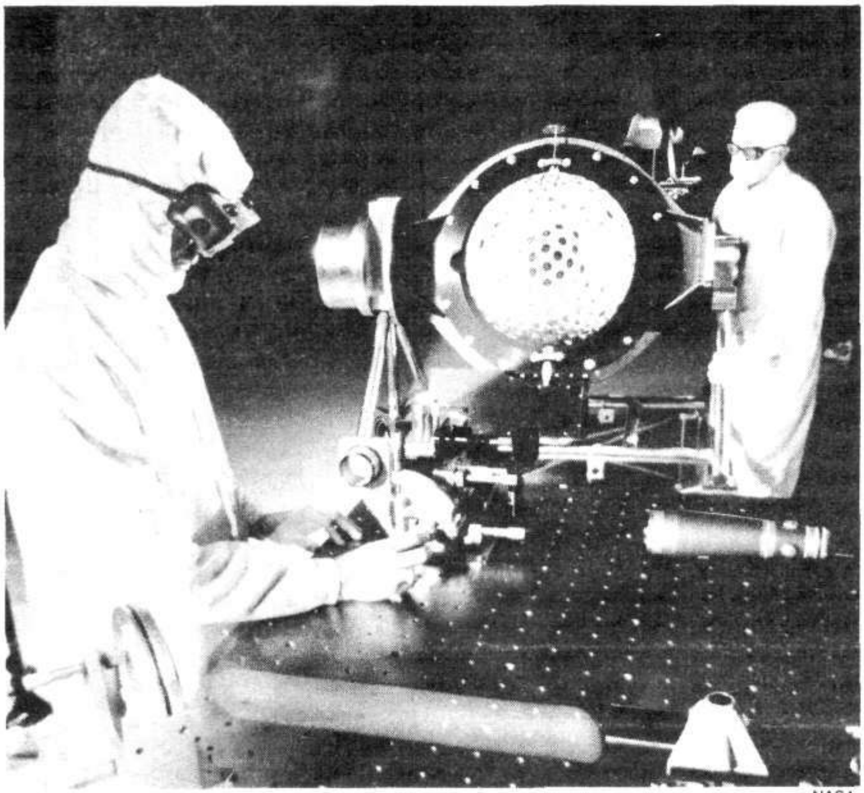
Question: What do you think of Fischbach's communication to the Jan. 6, 1986

***Physical Review Letters* suggesting a new "fifth force" to explain the discrepancy?**

The Eötvös experiment [on which the Fischbach work is based] measured the acceleration of an object relative to the Earth—how it falls. It can be done with pendulums, or by means of bending torsional fibers; but essentially you're looking at the acceleration, how things fall relative to the Earth. And contrary to the equivalence principles of Einstein and Galileo, the fact is, [the Fischbach group] found that in the Eötvös experiment, just by analyzing what he [Eötvös] had done 60 years ago, heavier objects (objects that had more nucleons associated with them) would fall just a little bit slower than substances composed of a smaller number of nucleons.

Question: Why hasn't anyone commented on this up until now?

I've had at least 42 abstracts and invited talks on the subject in the past 15 years, but the physics community was just not ready to listen, because the equivalence principle has almost become "theological." Because Special Relativity depends upon the validity of the equivalence principle, General Relativity depends upon the equivalence principle; the entire foundation of science depends upon the equivalence principle.



NASA

This Laser Geodynamic Satellite (Lageos), launched in 1976, is designed to provide a stable point in the sky to reflect pulses of laser light on its 426 special reflectors. By timing the return of the laser beam to an accuracy of about one ten-billionth of a second, scientists expect to measure the relative location of participating ground stations within an inch. Soldano has used the Lageos satellite as a laboratory for quantifying his hypothesis of nonequivalence.

Question: Why hasn't the equivalence principle been challenged before? Why do you think that there wasn't any question raised about the discrepancy that was found at the time when Eötvös did his experiment?

The experiment was considered so much more accurate and sensitive than anything up to that time, that they thought that this was a remarkable extension of the principle. And a whole body of literature has arisen—a massive amount—that always refers to the experiment and its modern variants as proof of the validity of the equivalence principle. And then one starts to construct theories like Special and General, which depend upon that single-minded assumption.

Question: What was the analytic technique the Fischbach group used?

Just curve-fitting, and using modern error-analysis and graphical techniques. They just went back and reexamined the data, and found, lo and behold, that the conclusion of the null hypothesis—that there is no difference between inertial and gravitational mass—really doesn't seem to hold up. The data actually fit the pattern that the more nucleons (that is protons and neutrons, the mass number) you have in any pair of atoms which you are comparing, the less acceleration will occur.

A fancy name for nucleon, which Fischbach and his group like, is "hypercharge." That gives you the idea, you're able to introduce quantum considerations, like strangeness; but in the Eötvös experiments, you're dealing with non-strange material, and nucleon number and hypercharge amount to the same thing.

Question: Can you expand on the fact that what is actually being compared are not densities as such but mass number?

It's not densities which you're comparing, but the number of nucleons, the number of protons and neutrons associated with the nuclei. If you could densify something, by some means, by compressing it, it would not necessarily be the case that it had the same mass number as something else which had an equal mass density. The mass number is called hypercharge in modern quantum physics.

Question: What is your objection to the so-called fifth force?

They evoke a fifth force, hypercharge force, which is repulsive. It will, they say, tend to repel the Earth as a substance falls, so that the substance won't fall as fast. This, I submit, is an attempt to save Special and General Relativity theory, which both depend fundamentally on the equivalence principle—the equality of inertial and gravitational mass.

They went to an equation which has

been evolving over the last 10 to 15 years, in which the general premise is that the Newtonian gravitational constant indeed is not quite a constant. There is a Newtonian gravitational constant at infinite extension from some reference frame, which has a larger value than the gravitational constant that you find when you make measurements in a laboratory. We're talking about a small difference, but it's real, it's measurable, it's come out of a lot of geophysical measurements: that the Newtonian gravitational constant really has a slight variation in it.

They say that a hypercharge effect can account for this disparity between the gravitational constant at infinity and a local gravitational constant. They say that these empirical constants, the constants of the equation, produce the new fifth force they're talking about. They think they've avoided the central question, but the equation they use already betrays them.

General Relativity is based upon strict equivalence, and in General Relativity, the Newtonian gravitational constant must remain constant under all conditions. General Relativity, based upon the equivalence principle, requires that the Newtonian gravitational constant remain an absolute constant; it can't vary. But here they're using an equation, based upon experimental data, that shows the constant varies! And they say the hypercharge explains it! Well, obviously, whatever the hypercharge is doing, it's inconsistent with General Relativity.

Question: How does this relate to your own theory?

The equation they're using to fit their data, is easily calculable according to my theory. In fact, the equation is actually referenced in the paper of mine which you are publishing [in the *International Journal of Fusion Energy*], and I am sending you an appendix which deals directly with Fischbach's conclusions. There are a lot of arguments which I go into.

Question: Can you explain this for a popular audience?

I can make it very simple. I can derive the empirical constants which Fischbach uses from my formula for the nonequivalence in gravitational binding. I show that a hypercharge-dependent nonequality between inertial and gravitational binding mass, one consistent with a nonnull Eötvös result, leads to a range-dependent Newtonian gravitational constant. The resultant explanation emphasizes the fact that Newton's universal law assumes the existence of an absolute time. Our explanation details the manner in which the three kinds of time currently used in physics—that is, universal, ephemeris, and atomic time—interrelate, thereby leading to the elimination of the Newtonian problem of absolute time.

The equivalence principle has almost become 'Theological.'

Question: So, according to the work you've done, in which you state the nonequivalence of inertial and gravitational energy, you can make your work cohere with the values they found empirically?

Absolutely. I can derive them theoretically. A fifth force tends to localize this difficulty being encountered by the [physics] Establishment. Nonequivalence in gravitational binding clearly shows that this effect appears at every level of physics. We handle the strong interaction, we handle electromagnetic force, we handle the weak force, and we handle gravitation. Because nonequivalence in gravitational binding *can't* be restricted; it appears at every level of interaction in science.

Question: What are the philosophical implications of your theory, that there is a nonequivalence in gravitational and inertial energy?

In my opinion, the weakest of the weak of all interactions, nonequivalence in gravitational binding, will provide the key to uniting all four levels of interaction in science. More important, it will provide an answer to the fundamental dilemma that's faced all of science for the last 70 years, namely: Does Planck's constant, on which the modern revolution in physics has been based, have priority over classical physics?

That is the central question. The answer is that nonequivalence in gravitational binding strongly indicates that classical physics, when modified by this nonequivalence idea, leads to a unit of action which mirrors all of the characteristics of the quantum itself. In principle, therefore, nonequivalence says classical theory ultimately has precedence over the dominant physics today, which is quantum mechanics.

Today, quantum mechanicians think that you start with Planck's constant, and from it you can derive the world. Nonequivalence says, you start with classical physics; *once you introduce nonequivalence in gravitational binding, you can arrive at the quantum itself*—which is the fundamental question of modern science.

Fusion Budget

Contined from page 15

development? No. The U.S. imploding liner R&D effort was killed in 1978 by Energy Secretary Schlesinger. The Soviets, however, apparently maintained a program on the scale of the overall U.S. tokamak effort.

Having such a cheap and readily accessible source for laboratory high-density fusion would put Soviet researchers in a vastly superior position. The cost of conducting full-scale testing, for example, could be reduced by as much as three orders of magnitude and the time span from conceptualization to actual test could be reduced from years to months.

Even more significant for the Soviets, such laboratory experiments are virtually impossible to detect, while underground weapons tests—especially in the United States—are easily discerned. In fact, the recent Soviet initiative to implement a comprehensive nuclear weapon test ban treaty may indeed be based on their ability to produce laboratory-scale undetectable "weapons tests."

Although this specific example has not yet been fully confirmed, it demonstrates how the proposed Reagan fusion budget cuts could immediately result in a major national security deficit.

Heussner/MPG

Klitzing with his experimental apparatus in the physics laboratory at the University of Würzburg.

German Physicist Demonstrates Quantum Hall Effect

The Nobel prize for physics was awarded in 1985 to Klaus von Klitzing for his experiments revealing quantization of the Hall resistance. Klitzing also has done a series of experiments that showed the quantization of the Hall effect.

Although this latter result was anticipated and then measured in the 1960s, Klitzing has succeeded in demonstrating the effect with great clarity. The fineness and precision of his experiment have, in effect, allowed him to replicate the first Bohr orbit, and in this way achieve a more precise determination of the fine structure constant.

Klitzing investigated the surfaces of semiconductors under extreme conditions—low temperatures and high magnetic fields. In these studies he used the Hall effect, discovered in 1879 by the American Edwin Herbert Hall. This effect is customarily employed to determine the conductivity of metals and semiconductors and to measure magnetic field strength.

The Hall effect appears as a new, transverse electrical potential, which is generated when an electrical current flows in a conductor that lies in a plane perpendicular to the magnetic field, as illustrated in Figure 1. It occurs as a result of the deflection of electrons passing through a magnetic field. The electrons are separated from the positive charges creating an electrical potential between them (the Lorentz force, $e\mathbf{V} \times \mathbf{B}$, where e represents the charge, **V** the rate of flow, and **B** the strength of the magnetic field). This effect is enhanced if the conductor is wide, thin, and long so that the electron gas is constrained to an approximately two-dimensional flow.[1]

The Hall effect can be thought of as a by-product of cyclotron frequency, if it is kept in mind that in the normal situation the full cyclotron rotation cannot take place because of the limitations of the conductor size. Therefore, the potential will build up between the edges, which are parallel to the direction of the current flow in the conductor. Electrons will be built up on one side of the conductor as they are driven over from the other.[2]

The Hall effect also occurs in the ionosphere, the Earth's "upper" atmosphere. Here the magnetic field is supplied by the Earth. The electrons will resonate with a radio field at the frequency of 1,414 kilocycles, well within the broadcasting band.

The key to the cyclotron, of course, is that the frequency of rotation of the electrons will be constant (within relativistic limits) in a given magnetic field. This frequency, normally denoted as

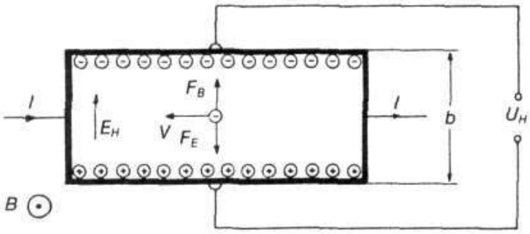


Figure 1
SCHEMATIC REPRESENTATION OF THE HALL EFFECT

Given a conductor through which the current I *is flowing and a magnetic field* B *perpendicular to the direction of the current and the plane of the current carrying transistor, the Lorentz force F_B will deflect the charged particles sideways. The particles will collect on the edge parallel to the electron velocity (when no magnetic field is present) and move from the opposite edge of the transistor.*

This charge separation leads to the buildup of an electrical field E_H (the Hall field). As soon as the resulting force F_E compensates for the Lorentz force, an undeflected current continues to flow. A potential difference U_H is created between these two edges.

ω, will equal the velocity, **V**/ 2 π *R*, where *R* is the radius. The point of the experiment in quantizing the Hall effect is to gradually increase the magnetic field, thereby raising the orbital frequency of the electrons in quantum jumps and determining that the buildup of the transverse electric potential, the Hall effect, occurs in a series of discrete jumps rather than smoothly.

In 1958, experimenters worked with the superconducting alloy indium antinomide, one of the alloys typically used in the manufacture of superconducting magnets, at temperatures of 1.7 degrees K. However, the temperature must be at least 77 degrees K in order for the Hall effect to appear, because of the dampening of the thermal kinetic energy that would otherwise obscure measurement. Another key requirement is for a sufficiently low space charge—that is, density of charge—in order that random collisions are minimized and the electric field is homogenous.

These experimenters were limited in 1958 by the semiconductor materials then available, which were too thick. Klitzing was able to take advantage of today's very thin transistor material in order to achieve his superior results. The extremely thin MOS field-effect transistors (MOSFET) he used are sketched in Figure 2.

The normal expectation is that a hyperbolic curve could be plotted showing the gate potential against the Hall effect. The number of charge-carriers e available to the current in these transistors grows proportionally to the gate potential U_G. The hyperbola shown in Figure 3 is what would be expected if U_H were plotted as a function of U_G. Contrary to all expectation, no such smooth curve exists. The curve shown in Figure 4, experimentally determined by von Klitzing, deviates from the curve shown in Figure 3 by its characteristic plateaus.

The Quantum Hall Effect

The experiment was performed under very strictly determined conditions. The MOSFET was cooled to about 1.5 degrees K (−272 degrees C). At this low temperature, the kinetic energy of the electrons in the conducting layer of the transistor is so small, that the electrons are unable to move perpendicularly to the electrical field. This condition of restricted degrees of freedom of electron oscillations is termed a two-dimensional electron gas.

Klitzing also used an unusually strong magnetic field in his experiment—180,000 gauss. This is about 400,000 times the strength of the Earth's mag-

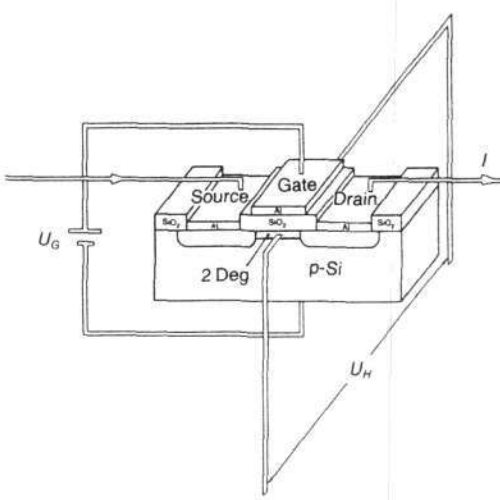


Figure 2
MOS FIELD-EFFECT TRANSISTOR

The transistor is supplied with current through the source and drain contacts. In the presence of a conducting channel U_G, a conducting layer is formed between the semiconductor and oxide. Under certain physical conditions (2° K), a two-dimensional electron gas is formed in this layer. MOSFET elements are contained in many of today's electronic circuits.

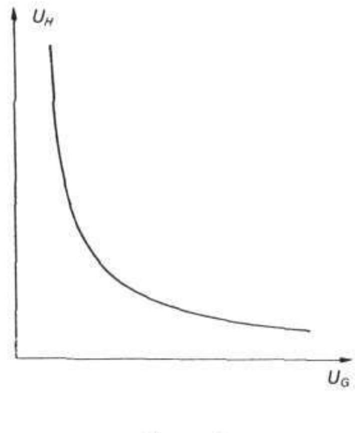


Figure 3
THE THEORETICAL PREDICTION

This is the hyperbolic correspondence that one might expect between the grid voltage U_G, and the Hall voltage U_H.

netic field and almost the same order of magnitude as is found in the atom. This strong magnetic field forces the electrons of a two-dimensional electron gas into closed paths. Just as in the atomic nucleus, only a definite number of rotational states are possible, and only a definite number of electrons can belong to the same state. (The rotational state is called the Landau level, whose maximum number of electrons is $n_L = e \cdot \mathbf{B}/h$, where h is Planck's constant.[3] If p Landau levels are occupied, $n_p = p \cdot e \cdot \mathbf{B}/h$. In this case, the Hall resistance is $R_H\,p = 1/p \cdot h/e^2$.)

In addition to the Hall effect, which measures the transverse potential developed between the two edges of the semiconductor, there is also the Hall, or magneto, resistance, which in effect is a lengthening of the path the electron must travel to reach the boundary of the conductor. The resistance increases as the magnetic field is increased (by introducing an added degree of rotational motion to the electron around the field lines) and it decreases with increased electron density. If the magnetic field is increased sufficiently, ultimately the electron flow will simply be cut off.

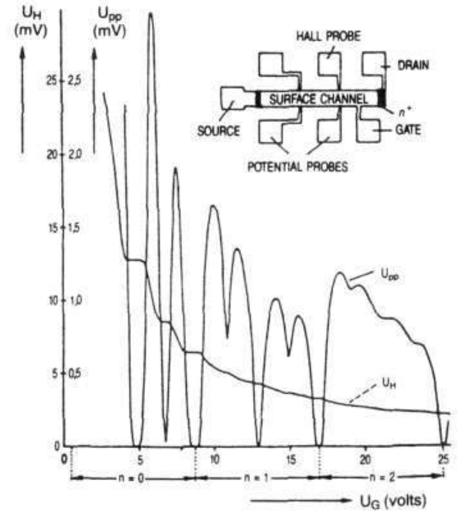


Figure 4
KLITZING'S EXPERIMENTAL CURVE
This is what the grid voltage U_G versus the Hall voltage U_H actually looks like, according to Klitzing's experiment. The plateaus in the Hall voltage can be seen clearly. U_{pp} is the longitudinal voltage, which becomes zero when the plateaus appear. Klitzing first published these results in 1980 in Physical Review Letters.

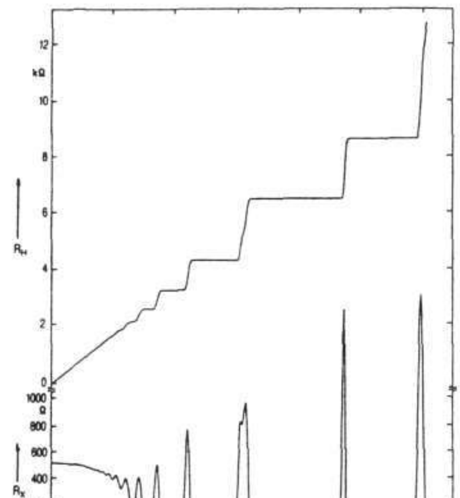


Figure 5
THE SAME EXPERIMENT WITH A VARYING MAGNETIC FIELD
The plateaus from Klitzing's data in Figure 4 become even more exaggerated here where the concentration of charged particles was held constant and the magnetic field was varied. These data are from an experiment carried out by E. Braun at the Federal Physical-Technical Institute.

Klitzing was able to determine that there is a "natural resistance," which is solely determined by the ratio of Planck's quantum of action divided by the square of the electron charge. This figure, 25,813 ohms, when divided by the Landau level exhibits very sharp quantum plateaus.

His very sharp experimental result, showing the quantization of the Hall resistance, was possible because he was working with an extremely thin transistor and with a high magnetic field. He was able to demonstrate that when the electrons are restricted to a plane, electrical conductivity depends solely on two elementary physical constants, Planck's constant and the charge of the electron.

This simple result came as a great surprise, since it had been assumed until now that the conductivity of a two-dimensional electron gas in a magnetic field would depend on a number of constants, such as the magnetic field strength, the characteristics of the semiconductors used, and the geometry of the design of the experiment.

Instead, one finds only a "natural resistance" that appears in the characteristic interval of $R_H\,p = 25{,}813/p$ ohm,[4] whenever the concentration of charge-carriers is increased in a fixed magnetic field or the magnetic field is increased in a fixed concentration of charge carriers. Figure 5 shows the results of an experiment carried out by the Federal (West German) Physical-Technical Institute in Braunschweig. In this experiment, the magnetic field was varied, unlike Klitzing's original experiment (Figure 4), and the "steps" of the plateaus of the quantum Hall resistance are brought out very beautifully.

It is also surprising that the value of the quantum Hall resistance (except for the factor of the speed of light) is the same as the fine structure constant, α, first determined by physicist Arnold Sommerfeld in Munich in 1916. Sommerfeld introduced the constant α in an attempt to remove some of the cruder inadequacies of Niels Bohr's planetary model for the atom. Bohr's model corresponds neither to the line spectrum of atoms with large atomic numbers, nor to the splitting of the spectral lines in the so-called double-lines. His model allows only circular orbits for electrons. However, since

Kepler's time, such an assumption for the motion of a particle around a central body must be seen as totally arbitrary.

Sommerfeld came upon the concept for the electron motion in the general Keplerian orbital form of the ellipse, in which the orbital velocities reached in the vicinity of the nucleus make a relativistic correction necessary. This has the consequence that the orbits are no longer closed ellipses, but become rosette-curves when rounding the perihelion. This model gives a nearly exact interpretation of the experimental doublets.

Thus, the fine structure constant is of crucial importance for the entire concept of quantum physics. Its value is about 1/137, which is also the ratio of the velocity of an electron at the lowest level in a hydrogen atom, to the velocity of light. Using von Klitzing's method, α's value can be measured now to the millionth place.

This is an adaptation of a longer article written by Ralf Schauerhammer in the German-language Fusion *magazine.*

Notes

1. With b as the width of the conductor in the direction in which the electrostatic field $\mathbf{E_H}$ is generated by the Hall effect, and $\mathbf{V}$ for the velocity of the electrons, the force acting on the electron is $\mathbf{F_E} = e \cdot \mathbf{E_H}$, and $\mathbf{F_B} = e\,\mathbf{V} \times \mathbf{B}$. *The magnitude of* $\mathbf{V}$ *is given by the strength of the current, since* this is exactly the number n of charges e, which flow through a cross-section of the layer of width b in a unit time. Thus, $I = n \cdot e \cdot b \cdot \mathbf{V}$ and $\mathbf{V} = I/(n \cdot e \cdot b)$. This expression results directly in $\mathbf{U_H} = b \times \mathbf{E_H} = \mathbf{B} \cdot \mathbf{F_E}/e = \mathbf{B} \cdot \mathbf{F_B}/e = b \cdot \mathbf{V} \times \mathbf{B} = \mathbf{B} \cdot I/(n \cdot e \cdot b) \cdot \mathbf{B}$.
2. The constancy of the cyclotron frequency is determined by equating the Lorentz force with the centrifugal force, where m equals the mass, e the charge of the electron, $\mathbf{V}$ the velocity, R the radius, $\mathbf{B}$ the magnetic field, and ω the angular frequency. Thus, $e\mathbf{V} \times \mathbf{B} = m\,\mathbf{V}^2/R$. $e\mathbf{B} = m\mathbf{V}/R$; $eB/m = \mathbf{V}/R = e\mathbf{V} \cdot 2\pi$. This gives the result $eB/2\pi \cdot m$ = Frequency. For this effect to be sharply measurable it is necessary to have a strong magnetic field, but also to work within a sufficiently narrow radius so that the quantization of the velocity is large enough, relative to the velocity, to be measurable. Since Klitzing concluded his experiment, other experimenters have obtained similar results by etching circuits of a fraction of a micron diameter, even in thin copper. This would be like a minute washer.
3. It is n = state of density times energy interval, whose state can be reduced to a Landau level. Thus, $n_L = m/(8 \cdot \pi^3 \cdot h^2) \cdot 2\pi \cdot h \cdot \omega$, where $\omega = e \cdot \mathbf{B}/m$, which is the cyclotron frequency.
4. The value of 25,813 ohms is easily calculated. It is $h = 6.625 \cdot 10^{-34}$ Jsec and $e = 1.6020 \cdot 10^{-19}$C. J sec/$C^2$ = J/C · A results exactly in the ohm unit.

AN INTERVIEW WITH KLAUS VON KLITZING

The Quantum Hall Effect

EDITOR'S NOTE

Klaus von Klitzing, who won the Nobel Prize in physics in 1985 for his work on the quantization of the Hall resistance, has been a member of the governing faculty at the Max Planck Institute for Solid State Physics in Stuttgart since January 1985. He received his doctorate in 1972 under the direction of Prof. Gottfried Landwehr at the University of Würzburg, and after a research stay at Oxford University he joined the faculty at Würzburg in 1978. From 1980 to 1984, he was associate professor at the Technical University in Munich.

Here are excerpts from an interview Nov. 14, 1985 conducted by Hans Horeis and Ralf Schauerhammer, editors of the German-language Fusion *magazine.*

Klaus von Klitzing

Question: Can you tell us what is so unique about your discovery of the quantum Hall effect?

We are dealing with something very fundamental, which in solid state physics exists only in the case of superconductivity. Superconductivity is a fundamental phenomenon in which the difficult components of solid bodies no longer appear, but we are confronted with a quite clear phenomenon. The same is true for the so-called quantum Hall effect.

In researching semiconductors, under specific conditions, you get results that depend only upon fundamental constants, on natural values. The significance of this is the same as someone discovering that the speed of light is a velocity that nature has preassigned.

In the same way, there is a kind of natural resistance that always has the value of 6453.2 ohm and that depends only on fundamental constants, Planck's quantum of action and the elementary charge. When you find such a result, then you are dealing with deep physical phenomena. You learn very much from that about solid bodies and about new quantum phenomena in solid bodies.

Question: The subject of quantum physics is about 50 years old. How did it happen that you found something totally new?

I think that anybody could have found it. Everybody who reads the literature has seen the graphs that lead to this quantum Hall effect. He or she could have seen and could have analyzed it.

The curves with these extreme plateaus, which now are key, had been published before. Therefore, all you needed was essentially only some experience and the idea at the right moment. I have had the advantage of being able to do research with different samples for 10 years, and then I had the insight that something fundamental is at hand here.

Certainly, this was only possible because I could participate in research work on a long term. Others, who only have looked at the curves, had a certain line of thought. We have been misdirected somewhat by these theoretical conceptions.

I once wrote a diploma thesis dealing with the quantum Hall effect. We

Continued on page 64

Experimental Results Surprise Quantum Theory

A group of scientists at the Institute for the Study of Heavy Ions at Darmstadt University in West Germany have observed that, contrary to theoretical predictions, positron-electron pairs are created in nuclei with high atomic numbers, in the Z range from 180 to 188. (Z is the the number of protons.)

The interest in their results, however, does not occur in the confirmation of the deviation from the "theoretical" predictions that pair production would occur where the atomic number was a reciprocal of the fine structure constant, $Z = 137$. This deviation had already been predicted. Rather, the interest lies in the occurrence of a quantized positron kinetic energy peak at 300.

The results were covered extensively in the November 1985 *Physics Today*.[1] However, author Bertram Schwarzschild fails to note their most remarkable feature: The Darmstadt results lend substance to the contention of nuclear physicist Erich Bagge that the traditionally accepted symmetries in positron-electron emission do not exist and, therefore, there is no need to posit the existence of the neutrino.

The highest known nuclear charge does not have a Z as high as 137; however, the experimenters at Darmstadt were able to simulate a "supercritical" nucleus with a Z above 173 by colliding uranium nuclei, or other similarly high atoms. Walter Greiner at Goethe University, Frankfurt-on-Main, West Germany, led the group of experimenters who achieved these results, and in the Soviet Union Yakov Zel'dovich proposed a similar idea.

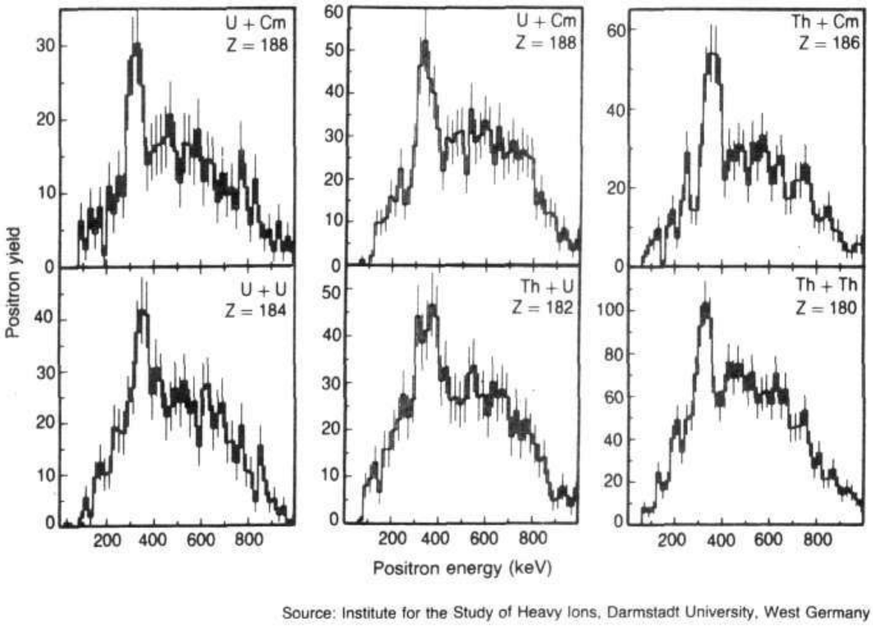
For theoretical reasons to do with the bound state of the electron, it might have been predicted that production of positron-electron pairs would occur only at atomic number $Z = 137$, (the integer closest to the reciprocal of the fine structure constant), producing a pair from a vacancy in the lowest-lying electron orbital level in the electron shell.

However, it has been generally assumed, from a so-called realistic experimental point of view, that in fact this would occur not at 137 but at $Z = 173$ or greater. This has to do with the actual finitude of nuclei, and the particles that make it up, which in quantum physics are treated as point particles rather than as having a finite volume.

Prior to the work at Darmstadt, this positron-electron emission was never verified experimentally. Eight years ago, Greiner and his colleagues produced heavy nuclei by colliding heavy ions with each other. For example, thorium hitting tantalum produced a fused nucleus as high as $Z = 163$. Since 1981, the group at Darmstadt has been producing heavy nuclei in a still higher range, as high as $Z = 188$, and they have hopes of reaching higher ranges still.

Quantum electrodynamic predictions say that that peak production of positron-electron pairs should be very sensitively correlated to Z. The surprise in the Darmstadt result is that this pair production has occurred over a broad range of Z, while the energy of the positron-electron pair remained very constant at about 300 keV irrespective of the colliding energies as well as of the Z.

In the case of heavy nuclei, which have a high charge, there is a very strong electrostatic field at the lowest lying level. With normal elements, the chemical bonding at the valence shell is in the range of 8 to 10 eV, whereas with heavy nuclei the charge is in the range of 1 million eV. (The shell, of course, will be much closer to the nucleus because of the extremely high charge of the nucleus.) It is from this high field that the paired particles are produced. The energy required to produce an electron ($E = mc^2$) will be approximately 511,003 eV, and both a positron and an electron are created at $2 \times 511,003$ eV.



Source: Institute for the Study of Heavy Ions, Darmstadt University, West Germany

QUANTIZED POSITRON KINETIC ENERGY PEAK

Contrary to theoretical predictions, positron-electron pairs are created in nuclei with high atomic numbers in the Z range from 180 to 188. The quantized positron kinetic energy peak occurs at 300. Shown are experimental results for the Darmstadt experiments.

Conventional Wisdom?

Like the fifth force people (see article, page 22), conventional wisdom is already looking for the decay of a previously unknown *boson* to account for these findings. And this new boson should be, in their view, only about three times the mass of the electron. Others are looking to quark theory for an explanation.

Results such as these point to the need for major revision in quantum theory. One place to look is the crucial experiment conducted by Erich Bagge that showed that the production of a positron-electron pair from a gamma ray had an energy spectrum in effect opposite in distribution to that predicted by the Bethe-Heitler theory.[2]

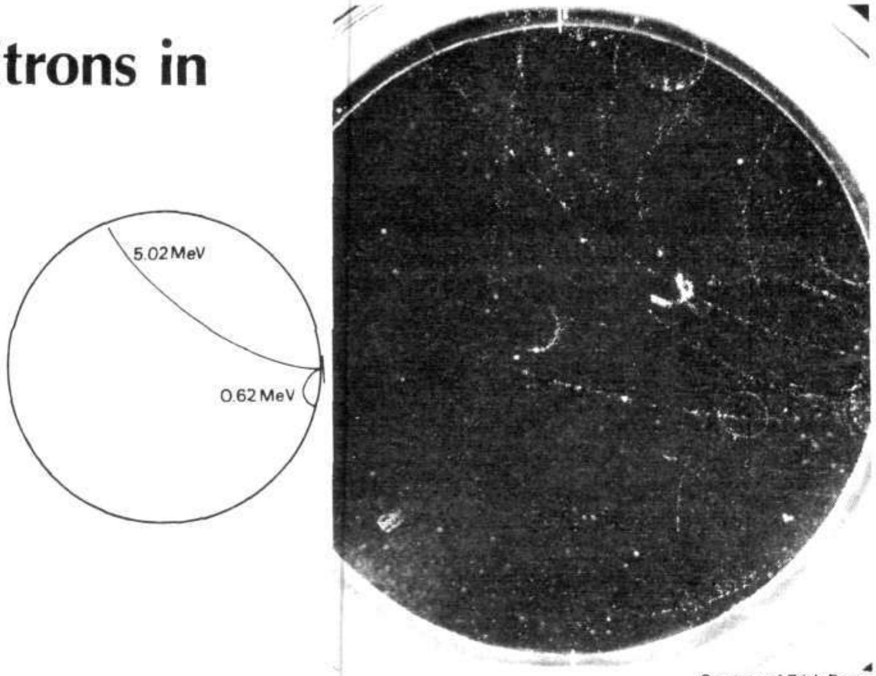
Bagge conducted this experiment as a crucial demonstration that the theory behind the Bethe-Heitler prediction was incorrect, in particular because it depended upon the posited existence of the neutrino to prevent violation of energy conservation laws. Bagge's own theory accounts for the apparent loss of energy, by denying the existence of a vacuum and substituting instead a fundamental "negative energy" state, in which the positron normally exists and from which it must be torn away.

—*Carol White*

Notes

1. "Puzzling Positron Peaks Appear in Heavy Ion Collisions at GSI," by Bertram Schwarzschild, *Physics Today* (Nov. 1985), p. 17.
2. See the accompanying note by Bagge and also his article "Why Neutrinos Don't Exist: What Really Happens in Pair Production and Beta Decay," in *Fusion* (Nov.-Dec. 1985), p. 29.

Low-Energy Positrons in Pair Creation



Courtesy of Erich Bagge

TRAJECTORIES OF AN ELECTRON-POSITRON PAIR

In this photograph of one of Bagge's experiments in a Wilson cloud chamber, the electron exits upward, with energy of 5.02 MeV, while the positron exits downward with energy of 0.62 MeV. According to the Bethe-Heitler theory, the two energies were supposed to be nearly equal.

In the November 1985 issue of *Physics Today*,[1] Bertram Schwarzschild reports on "puzzling positron peaks appearing in heavy ion collisions at the Society for Heavy Ion Research at Darmstadt in West Germany (GSI)." There is also a discussion of experiments to explain the intensity peaks of positron energies between 300 and 400 keV.

Erich R. Bagge, Ahmed Abu El-Ela, and Soad Hassan have reported in several places,[2] on measurements of pair creation of positrons and electrons that were triggered by gamma quanta of 6.14 MeV at their passage at nuclei of gold atoms (atomic number or Z = 79). It was also established that the positrons predominantly receive low kinetic energies, generally around 270 keV.

There is a great probability that both the GSI measurements and those done by our group at the University of Kiel are based on the same effect. If one conceives of the impact of a uranium nucleus (atomic number = 92) of 6 MeV energy per nucleon on another uranium nucleus of the same type at rest as being a pair-producing process, as if the Fourier-analysed Coulomb fields of the 92 impacting protons would be fields of light quanta, then these trigger electron-positron pairs in the Coulomb field of the nucleus at rest. In these pairs—in accordance with our observations and their consequent interpretations—mainly positrons are created, densely compacted at the surface of the Dirac Sea; that is, with practically zero energy. These positrons are then discharged through the Coulomb field of the uranium nucleus at rest.

Since the positrons must be looked at as wave packets of minimal extension h/mc, they can, by means of this discharge process, gain the energy:

$$E^{+}_{\text{kin}} = \frac{Ze^2}{\hbar c}mc^2 = 92/137\ mc^2$$
$$= 343.2 \text{ keV}.$$

This is just about the energy found at GSI in the maximum intensity peaks, during six experiments using various actinic impact partners. The results of the experiments our group conducted at Kiel show the same interpretation in the case of the gold nucleus, with omewhat smaller average energies:

$$E^{+}_{\text{kin}}\text{ (Kiel)} = E^{+}_{\text{kin}}\text{ (GSI)} \cdot 79/92$$
$$= 294.7 \text{ keV}.$$

—*Erich H. Bagge*

Notes

1. "Puzzling Positron Peaks Appear in Heavy Ion Collisions at GSI," by Bertram Schwarzschild, *Physics Today*, (Nov. 1985), p. 17.
2. Erich R. Bagge, *Fusion* (German-language edition), (Dec. 1985), p. 11; and *IJFE*, (Jan. 1985), p. 53; Ahmed Abu El-Ela, Soad Hassan, Erich R. Bagge, *Atomkernenergie/Kerntechnik*, **47** (109), 1985; **45** (208), 1984; *Fusion*, (Nov.-Dec. 1985), p. 29.

Curing Lung Cancer With Laser Light

by Ned Rosinsky, M.D.

Recent developments in medical technology will soon make it possible to cure the majority of patients with lung cancer: first, by detecting the tumor early while it is less than 1 millimeter in diameter and has not yet spread; second, by definitive treatment of the small tumor with laser light to destroy the cancer without harming normal surrounding lung tissue. This latter technology, based on optical biophysics, will save more than 100,000 lives in the United States annually.

Lung cancer is the leading type of cancer in men and will soon be the same for women, accounting for approximately 130,000 new cases in the United States annually, and an equal number of deaths. Current treatments are nearly always ineffective, with a five-year survival rate after detection of the tumor that is under 5 percent.

Until now, the main problem in treatment has been early detection. Once the tumor is large enough to be seen on chest X-ray or CT scan—it has to be approximately 1 centimeter in diameter—in more than 75 percent of cases the cancer has already spread so far that it is inoperable. Further, there are no effective chemotherapy or radiation therapy treatments that have more than a short-term palliative effect.

The detection problem has been significantly improved recently with the development of better screening for the presence of cancer cells in sputum samples. In the past five years, this technology has been brought up to a level comparable with the PAP test for cervical cancer, which itself has made a dramatic improvement in cervical cancer survival rates.

The sputum test involves breathing in a mist aerosol, then coughing up a sample of bronchial mucous. This is then examined for cancer cells that have sloughed off a tumor in the lung.

The innovator of this technology, Dr. Geno Saccomanno at St. Mary's Hospital in Grand Junction, Colo., stated that the technique can pick up lung cancers several years or more before they show up on a standard X-ray, while they are still in the size range of 1 millimeter. At this smaller stage, there is much less likelihood that the cancer has spread by metastasis to other lung areas, or has invaded neighboring tissues.

As with the PAP test, the sputum test can be done easily on a mass scale in an outpatient setting and is harmless to the patient. Saccomanno states that routine screening of the population would pick up more than 100,000 of the 130,000 new cases of lung cancer annually, at this early treatable stage.

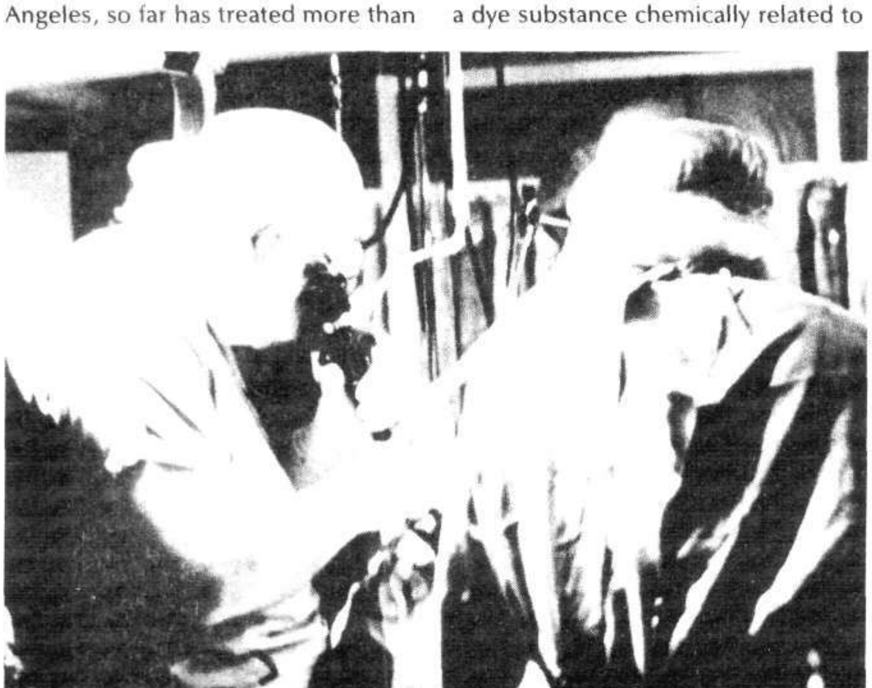
Optical Biophysics

The second component of the therapy, precise localization of the tumor, as well as the third stage, definitive treatment, are both made possible by laser biophysics. This new modality is termed *photodynamic therapy* (PDT). Dr. Oscar Balchum, a pioneer in this area who is the head of pulmonary medicine at the University of Southern California School of Medicine in Los Angeles, so far has treated more than 200 patients—with an apparent cure rate of 100 percent for localized tumors.

Although these patients have been followed after treatment for up to several years with no recurrence, Balchum cautions that the proof of long-term efficacy will require an additional five to ten years of follow-up monitoring, as in any treatment modality used in fighting cancer.

The localization of the tumor is difficult for several reasons. Although 95 percent of lung tumors start in the lining of the airway tubes, the bronchi, and are therefore accessible by a fiberoptic bronchoscope (inserted through the mouth and down the airway tube), the tumors in the early treatable stage are small and difficult to distinguish from normal tissue. This problem is compounded by the large area of possible locations, the entire series of branching bronchi in both lungs.

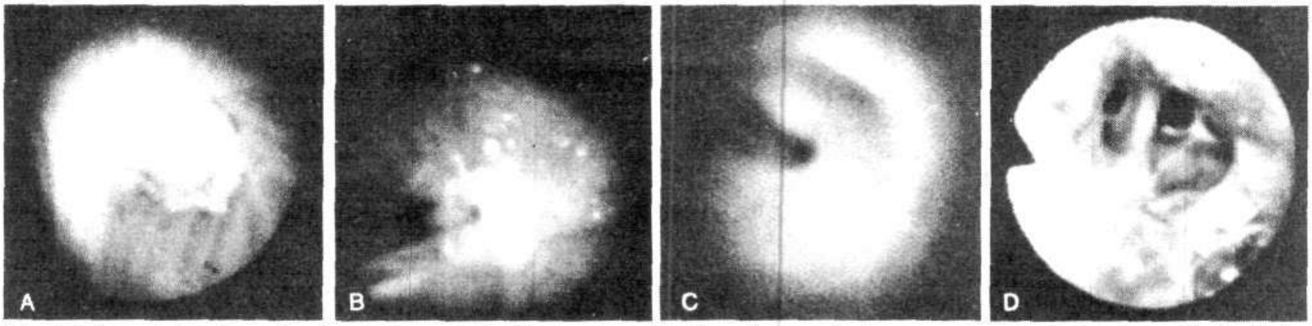
To improve the visualization of the tumors, Balchum has the patient take a dye substance chemically related to



Courtesy of Oscar J. Balchum, M.D.

Broncoscopy for photodynamic therapy. The conducting fiber, center, is inserted through the channel of the bronchoscope.

Source: "Photoradiation Therapy of Endobronchial Lung Cancer: Large Obstructing Tumors, Nonobstructing Tumors, and Early-Stage Bronchial Cancer Lesions," by Oscar J. Balchum, M.D., Ph.D. and Daniel R. Doiron, Ph.D, in Clinics in Chest Medicine, Vol. 6, No. 2, June 1985, p. 264.



The left lower lobe bronchus is totally occluded by a tumor (a). The photoradiation treatment with the tiny cylinder tip is shown in (b), and the intense complete diffusion of red light (white light off) throughout the tumor is shown in (c). After the cleanup, the left lower lobe bronchus is fully opened up to its walls.

the heme portion of hemoglobin, termed *photofrin II* (abbreviated HpD), which selectively localizes in tumor cells.

To increase the visibility of the dye, he illuminates the bronchi with a blue laser fitted into the fiber-optics of his bronchoscope. This makes the HpD-laden cells fluoresce in the red region of the spectrum, so they stand out clearly against the background tissue. The source of the blue light is a krypton ion laser. Balchum reports that the HpD technology can find the tumor in 60 to 70 percent of the cases where the patient's sputum shows cancer but none can be seen on normal light bronchoscopy. It is not yet fully understood why cancer cells take up the HpD dye more than normal cells. However, the dye, like its closely related heme group in hemoglobin, can be readily involved in oxidation/reduction chemical reactions. It is possible that the abnormal metabolism of cancer cells, particularly the frequent finding of the use of metabolic pathways that do not use oxygen (the reliance on glycolysis for energy rather than the use of oxidative phosphorylation), may account for this selective uptake of the dye.

Definitive Treatment

The third component of therapy is definitive treatment. Once the tumor is located in the sights of the bronchoscope, Balchum switches to another laser frequency, produced by a red ruby laser, and focuses the laser on the tumor. This frequency is differentially absorbed by the HpD-containing tumor cells many orders of magnitude more than by normal surrounding tissue.

The red light does not kill the tumor by heating it, but actually causes the HpD dye to photo-excite, which then causes a variety of excited oxygen states (termed singlet radical states) in the cancer cell that interfere with normal cell membrane and mitochondrial activity and slowly kill the tumor.

This method is in contrast to the use of lasers at higher powers in surgery, where the laser heats the tissue to produce the desired effect. Thus, there is little likelihood that the HpD technique will harm normal tissue. Again, normal tissue does not significantly absorb either the HpD dye or the red laser light.

Because 95 percent of all lung cancers begin in the lining of the bronchi, and because the cure rate is 95 to 100 percent when the tumor is surgically removed in its early stages (by taking out the entire lobe of the lung where the tumor is located), the PDT approach, which uses only local treatment, should have a comparable cure rate to early surgery. That is, it should cure the great majority of cases.

The PDT technique demonstrates the great power of optical biophysics in creating procedures that are specific to particular states of tissues. The major problem in treating cancer is that although the cancer tissue is obviously different from normal tissue, nearly all of the chemicals that are poisons to cancer are also poisons to normal tissue; there is a problem of creating the specificity needed in the treatment.

In contrast, for example, bacteria are far more different from normal human tissue than is cancer, so it is relatively easy to find substances, such as the many antibiotics commonly used, that will kill bacteria and not harm humans.

Thus far, biochemistry has failed to produce the required specificity needed for the fight against cancer. However, the biochemical specificity developed in the case of the HpD dye, for example, can be complemented and enhanced with the extreme specificity of laser frequencies in order to get the required overall specificity needed to selectively kill the cancer without harming the patient.

Letters

Continued from page 5

225 gift subscriptions of *Fusion*. This magazine will enhance the educational instruction at Satellite and be enjoyed by many.

We felt a tremedous loss over the tragedy of Challenger 7 and its crew, but this memory will live on through the thoughtful contributions of your supporters.

Rita Galbraith
Assistant Principal
Satellite High School
Satellite Beach, Florida

The Dream Is Alive

To the Editor:

The omnivision movie on the Space Shuttle, "The Dream Is Alive," is a fantastic story! [See review in Jan.-Feb. 1986 *Fusion*, p. 63.]

The Omni theater in St. Paul, Minn. began showing this movie ironically the day of the Shuttle tragedy. . . .

The response of the public has been overwhelming. The performances have been sold out. They have even added performances on the weekend. The American population is hooked on the space program.

Andy Olson
Heron Lake, Minnesota

The Wonders of URANUS

Voyager 2 Opens Up An Unusual New World

by Marsha Freeman and Jim Everett

NASA

After traveling 3 billion miles and 8½ years, Voyager 2 has provided us with the first close-up views of Uranus. Retooled along the way to provide maximum data, the remarkably successful Voyager is a symbol of the U.S. space program's mission to extend civilization throughout the universe.

After a 3-billion mile journey taking more than eight years, on Jan. 24, the Voyager 2 spacecraft made its closest approach to Uranus, the seventh planet from the Sun. For the first time, mankind had a close look at this very unusual body in the solar system and found out that indeed this giant planet does have a magnetic field, differentiated rings, at least 15 moons, and a very unusual climate and weather system. We report here on the Voyager 2 findings just a few days after Jan. 24.

No longer a mystery, the rings of Uranus are revealed here as a continuous distribution of small particles. Voyager took this image Jan. 27 while in the shadow of Uranus, at a distance of 147,000 miles and a resolution of about 20 miles.

Uranus has long been an enigma. Rotating on its side and with only featureless cloud tops, not even the length of its day was known. The veil was lifted when Voyager 2 flew past the planet with all instruments working perfectly. In only a few hours, Voyager revealed not only the length of the Uranus day, but a strangely tilted magnetic field, a new family of rings made of dust, and moons with a bizarre hybrid of geologic features not seen anywhere else in the solar system.

The most striking and indeed unique characteristic of Uranus is the fact that it is inclined 98 degrees on its axis of rotation. Rather than lying perpendicular to the plane of the ecliptic, its axis lies close to the plane, dipping slightly below it, as seen by the approaching Voyager spacecraft.

Data from Billions of Miles

The Voyager that arrived at Uranus on Jan. 24, 1986 was not entirely the same spacecraft that left the Earth on Aug. 20, 1977. Although the 11 scientific instruments and cameras onboard the spacecraft were the same, scientists and engineers had reconfigured the equipment and enhanced its capabilities on Voyager and on the ground in order to get a quality of data at Uranus comparable to the earlier encounters with Saturn and Jupiter.

The Voyager spacecraft, originally called the Mariner Jupiter/Saturn mission, has performed beyond all expectations of the scientists who planned this mission more than a decade ago. Since the dawn of the space age, man had dreamed of taking sophisticated instruments to parts of the solar system that man cannot get to yet himself, to see what is there and to discover more about the evolution and development of the solar system within which the Earth is placed. Voyager 2 has lived up to that dream at Uranus and will now go on to meet up with Neptune in 1989.

When Voyager arrived at Uranus, it was twice as far away from the Earth than it had been at Saturn. The strength of the radio signal used to transmit its photographs and other data to Earth was, therefore, greatly diminished. Due to the greater distance, the signal was spread out, or dispersed, to a much greater extent. Therefore, to collect a signal that was strong enough to carry substantial data and could be distinguished from background noise, engineers had to greatly increase the data collection area on the ground.

This was accomplished by connecting together, or arraying, the antennas that receive the Voyager's radio signals. NASA operates three complexes in its Deep Space Network—in California, Spain, and Australia. Because of the geometrical relationship between the position of Voyager and Earth at the time of the Uranus flyby, the signals collected in the southern hemisphere traveled through less of the Earth's atmosphere, increasing the strength of the signal. Therefore, the antennas in Australia played the major role in collecting the Uranus data.

At Jupiter, the spacecraft had a data transmission rate of 115,200 bits per second (bps). At Saturn, the rate had dropped to 44,800 bps. And at Uranus, if no changes had been made in the system, the rate would have been about one fourth that at Saturn. Without arraying the antennas on Earth, fewer than half the observations planned at Uranus could have been performed and the data returned to Earth.

The 210-foot diameter NASA antenna dish near Canberra, Australia, was linked with the Parkes radio astronomy antenna of the same size, 200 miles away, to increase the collection area of Voyager's signals, in effect doubling the aperture size. At NASA's other two sites, the smaller and larger existing antennas were arrayed.

When the antennas are arrayed, the same data are received at a number of antennas and electronically combined to increase the signal strength. This allowed a data rate of 21,600 bps at Uranus. The data rate determines the degree of resolution of the objects the spacecraft is observing and the number of images that can be relayed to Earth.

It takes nearly three hours for signals from Uranus to reach the Earth. During the precious six hours Voyager was to be close to the rings and moons of Uranus and to the planet itself, scientists wanted to squeeze as many images as possible out of the onboard systems. During its previous encounters, Voyager had transmitted eight bits of data for each picture element, or pixel. Each pixel contained 256 levels of gray, to show the finest possible detail. These images were then computer-enhanced to show colors.

At Uranus, instead of transmitting the full eight bits of data for each image, only the difference between the brightness of successive pixels was transmitted. This image compression was accomplished by programming one of the six onboard computers to preprocess all the imaging data, prior to transmission to Earth, to send only the differences in brightness. This image data compression, which has been developed in the years since the Voyager was launched, resulted in a 60 precent reduction in the number of bits needed per image, or a 40 percent increase in the amount of new information able to be transmitted.

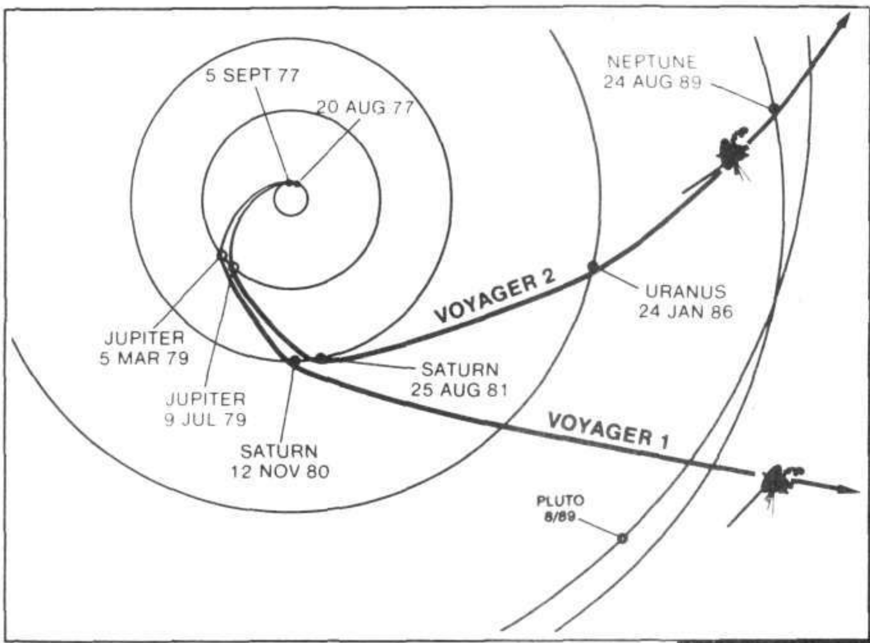
This general technique is also being developed for Earth-orbiting remote-sensing systems, where data onboard that are not useful, such as views of Earth shrouded in clouds, could be preprocessed, sorted out, and perhaps stored, but not transmitted to Earth.

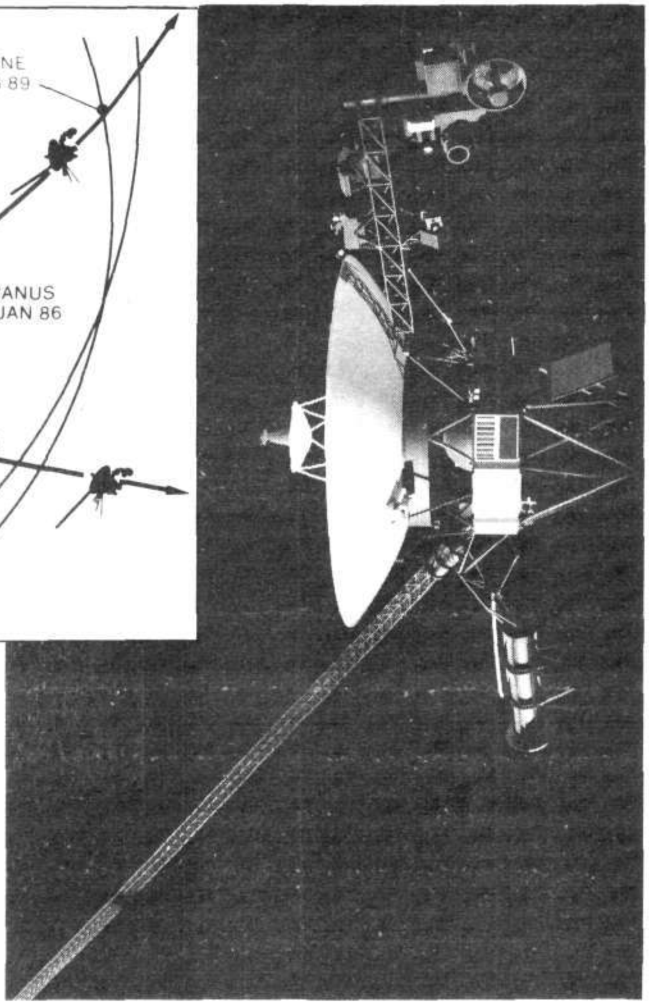
Another major change made in Voyager was done aboard the spacecraft itself. Because of the very low light levels in the outer reaches of the solar system, scientists knew that long exposures would be necessary to get the required signal-to-noise ratios needed to make the images. But the exposures became so long—as much as 96 seconds at Uranus—that the motion of the spacecraft itself would begin to smear the object in the image (when Voyager arrived at Uranus, it was traveling at about 45,000 miles per hour). It is similar to the problem of taking a photograph of the scenery from a fast-moving train, without blurring the image.

To compensate for this motion and allow the cameras to track the object with the camera shutters open, it was necessary to move the scan platform holding the cameras in a direction to compensate for the motion. The scan platform worked only partially, and Voyager compensated by using on-board rockets to slew the entire craft. This image motion compensation procedure had been tried experimentally during the observation of one of the moons of Saturn and was used successfully at Uranus.

The Grand Tour of the Solar System

Only once in 177 years do the outer planets of the solar system line up in such a way that a spacecraft sent from Earth could possibly visit more than two of these planets on one journey. This once-in-a-lifetime possibility was described by NASA mission planners as a "grand tour of the





NASA

Voyager 2 and its predecessor Voyager 1 are the most sophisticated robotic spacecraft ever flown. Their brief encounters with Jupiter, Saturn, and Uranus have provided more knowledge of the planets than has been learned in the last 200 years of astronomy.

solar system." That is why the Voyager mission was—and had to be—launched in 1977. As Dr. Bradford Smith, head of the Voyager imaging team, put it, "the last President who had an opportunity to do anything like the Grand Tour was Thomas Jefferson." Therefore, although NASA budget cuts were mandated by the Nixon administration in the early 1970s, scientists were determined not to give up the first chance in the space age—and the only opportunity in their lifetimes—to make such a grand tour.

The attraction of the grand tour is not just that man could visit four planets with one spacecraft. An additional motivation was that a trip only to Uranus at any other time would take about 30 years, leaving from Earth and going directly to Uranus, since the planet is 1.8 billion miles from Earth and the spacecraft has a limited initial speed because of the propulsion systems available.

(Of course, there were some myopic mortals on whom these facts made no impression. When Voyager made its closest encounter with Saturn on Aug. 25, 1981, Senator William Proxmire commented on the television show "Nightline" that the Voyager mission was not necessary. "The planet will be there for a long, long time," he stated. We have "fiscal problems," and "we don't have to do it in our lifetimes. It can be done over years.")

The strategy of the grand tour was to employ a method suggested by German space pioneer Hermann Oberth in the 1920s—a gravity assist. This involves sending the spacecraft on a trajectory to each planetary flyby so it is positioned precisely when it gets there to pick up a "push" that will propel it on to the next planet.

For example, when the Voyager spacecraft left Jupiter after its flyby in 1979, the push it got from passing close to that vast planet was equal to the velocity boost it had obtained at launch. From there, it continued on to Saturn, where it arrived in 1981. In 1989, Voyager will arrive at Neptune, but in order to get the best gravity assist to send it on its way, Voyager had to fly on a trajectory that took it within 30,000 miles of the Uranian moon Miranda, making it one of the closest flybys of the entire mission.

In its 8½-year lifetime, Voyager 2 has shown us many firsts—the first evidence of active volcanism outside of the Earth, on Jupiter's moon Io; the thin ring of dust and ice around that planet; new moons; and the atmospheric structures of the mysterious Titan and Jupiter's red spot. At Saturn, Voyager revealed a breathtaking array of countless rings, still-unexplained structures and changes in them, and again, more small moons.

Extending Human Knowledge

Voyager's major scientific and communications systems, designed for a 5-year, two-planet mission, have performed perfectly at Uranus, 8½ years after launch. The scientific instruments aboard Voyager have been investigating both planets and satellites during its brief encounters as well as the interplanetary environment in between flybys.

One class of instruments is the optical scanners, which must be movable and are mounted on the spacecraft's scan platform. They have narrow fields of view and must be accurately pointed. The spectral information they collect includes radiant energy in the visible wavelengths, infrared emissions, ultraviolet light, and polarized light.

The photopolarimeter, which observes the way light is polarized by the chemicals and aerosols in planetary atmospheres, has provided data on the composition of the clouds and surfaces of the planets and their satellites. Measurements in the infrared also reveal chemical compositions, as well as the temperature and heat balance of the objects under observations.

Two television-type cameras mounted on the scan platform provide the magnificent photographs produced by the mission. The images are sent to Earth in shades of gray and then color is added through computer enhancement. A second general class of instruments aboard the spacecraft has the job of sensing magnetic fields and fluxes of charged particles as Voyager passes through them. They are fixed to the body of the spacecraft, unlike the optical scanners, and by combining their data, information on planetary magnetic fields, Sun-planet interactions, and planet-moon interactions have been measured. Two of the four magnetometers carried on Voyager are located on a boom to separate them from the spacecraft's magnetic field. The other two, which are higher field instruments, are mounted on the spacecraft body. The total weight of the magnetic fields investigation package, which has revolutionized our knowledge about the magnetic structures around the giant planets, is 12.3 pounds.

A third family of scientific instruments concerns radio astronomy and plasma wave experiments and uses a long antenna to listen for planetary emissions. Radio signals from the spacecraft are used to gather information on the ionospheres and atmospheres of planets and their satellites and to track data to chart gravitational fields that affect Voyager's course.

Voyager sends all of its data to the waiting scientists on Earth via nuclear-powered radio transmissions. These radio signals allow scientists to make precise measurements of the spacecraft's trajectory as it passes near a body. Postflight analyses then determine the mass of a body, as well as its density and shape.

The rings of Saturn and Uranus were explored by radio signals from Voyager, as scientists measured the scattering of the signals as they traveled through the rings, from behind the planets. These provided crucial data on the ring mass, particle size distribution, and ring structure. Plasma studies are investigating the properties of the solar wind with increasing distance from the Sun, as well as the magnetospheres of the giant planets.

Voyager has performed masterfully over its 3-billion mile journey. Just a year after launch, and before any of its encounters, the spacecraft's computer-command subsystem automatically switched to the back-up receiver, when a problem arose in the primary system, and it has functioned on that back-up since that time.

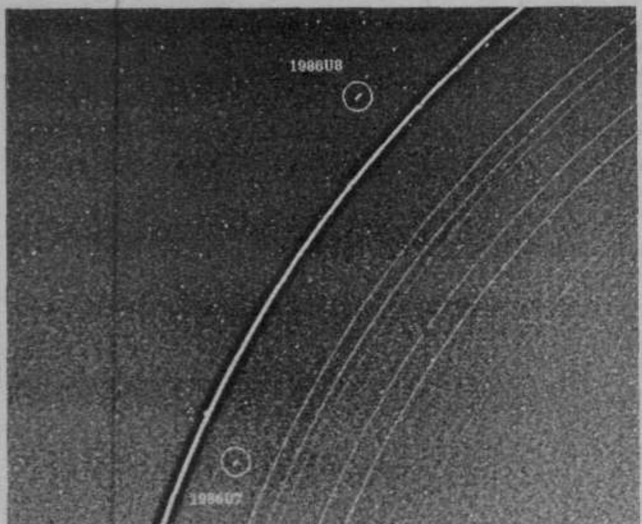
The only significant problem encountered by the spacecraft was during its flight behind Saturn in 1981. The scan platform jammed in one axis, preventing further pointing of the instruments. After two days, the platform apparently corrected itself and was again movable. The spacecraft is programmed so that if it has any potentially life-threatening failures, it automatically puts itself into a "safe" mode and awaits commands from Earth.

The Surprises of Uranus

Scientists had hoped to find clues to Uranus's keeled over spin axis by observing its moons. According to a widely held theory, Uranus tilted after a collision or near collision with an Earth-sized body. But the Uranian moons bear no scars of this early trauma.

The moons. In the days prior to the flyby, much attention was focused on the prediction that at least 18 moons would probably be discovered around Uranus. The source of this rather exact prediction was the theory that planetary rings, of which Uranus was known at the time to have nine, maintain their structure with the help of small "shepherding" moons. As was known from before the Voyager 2 flyby, the rings of Uranus are extremely narrow. Without some active organizing action, one might expect the particles to randomly hit each other, causing the rings to smear out into an undifferentiated plane. Two shepherding moons would keep a ring intact by forcing the particles into a zone between the moonlets; thus, the prediction of 18 moons for the nine rings.

Shepherding moons were in fact found around the epsilon ring, the largest and outermost ring. But no other shep-



This Jan. 21 image of the rings of Uranus was taken at a distance of 2.5 million miles and a resolution of about 22 miles. Two small moons can be seen on either side of the bright epsilon ring. As with the rings of Saturn, one of the hypotheses was that each ring would have two shepherding moons to keep it in line, but this has proven to be false. The ring structures of both planets cannot be understood simply by looking at the interaction of the individual components; scientists will have to look at the global geometry of the planet.

herding moons have yet been found around either the eight previously known rings or the newfound tenth ring. Perhaps some will be found as the ring photos are processed and enhanced, but Uranus has another family of rings whose dynamics will not be explained with embedded moonlets.

The rings. After the close flyby, Voyager turned its cameras back toward the ring system to see how they would look backlit by the Sun. By measuring the interference caused by the rings to Voyager's radio signals, scientists determined that the average particle size of the 10 rings is about 1 meter. This is a much bigger particle than found in Saturn's rings. Surely there were smaller particles than this, but repeated attempts to photograph dust in the rings failed. Finally, with the angle of sunlight just right and with a 96 second exposure that made the background stars streak, a host of dust rings were observed.

These Uranian rings more closely resemble the rings of Saturn. A continuous sheet of dust is organized into numerous rings. Most unexpected was that on first seeing the dust rings, no one could match them up with the 10 large rings. It is as if there are two distinct populations of rings superimposed on each other. The magnetic field of the planet may play a role in stripping the dust from the 10 large rings and shaping it into a ring system.

In other ring discoveries, the epsilon ring was found to have two components. There is so far no evidence of kinks or "braids" as there are in Saturn's outer "F" ring. Beyond the epsilon ring several ring arcs were seen. It is not now known if these are part of the dust rings.

The magnetosphere. Until the Voyager's flyby, no one knew if Uranus had a magnetic field. At a distance of 320,000 miles from the planet, Voyager passed through Uranus's bowshock, the region of impact of the million mile an hour solar wind on the planet's magnetic field. The solar plasma stops abruptly, with some of the plasma leaking into the magnetosphere, but most of it sliding around it.

Unlike any other planet in the solar system, the magnetic poles of Uranus are inclined an incredible 55° to the axis of rotation. On Earth this would be as if the north magnetic pole were over Los Angeles, and the south magnetic pole over the Indian Ocean near Madagascar. The strength of the magnetic field is about 15 percent less than that of the Earth.

Not only the orientation but also the source of Uranus's magnetic field is a mystery. According to the generally accepted theory, a planet's magnetic field is generated by a dynamo in the planetary interior. On Earth, for instance, large-scale convective motions of molten metals in the core generate electric currents across a primordial magnetic field, thus amplifying the magnetic field. Without some kind of dynamo, the primordial field would have long ago dissipated.

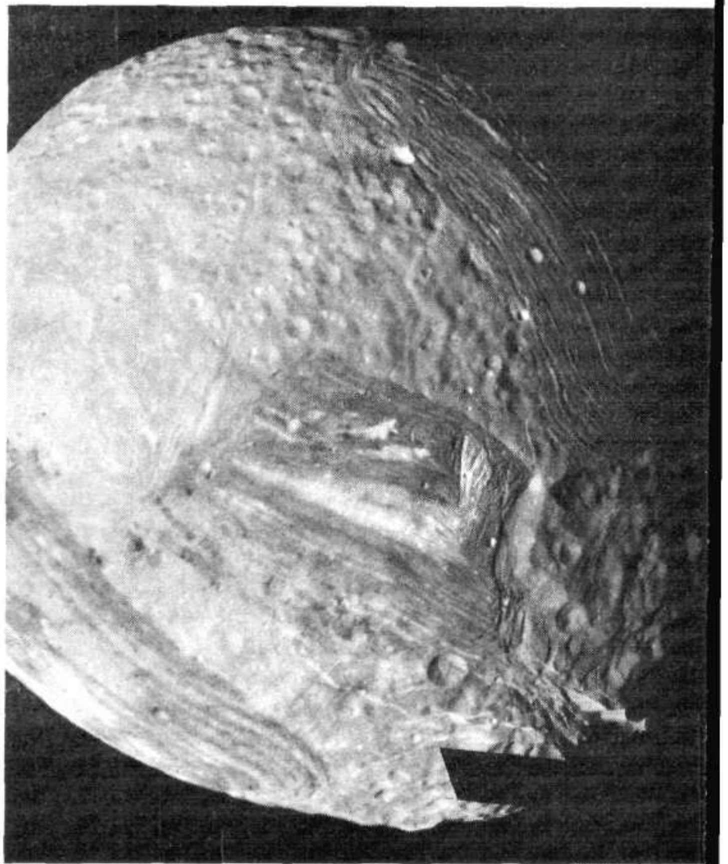
Uranus does not appear to have enough internal heat to support a molten metal dynamo in the planetary core. An ocean of liquid methane, ammonia, and water probably lies over the solid core of Uranus. If there is no dynamo in the core, could there be one in the oceans? Dynamo theorists, with the help of organic chemists, will explore possible models in the coming months.

A model of the trailing magnetic field will take time to

The Moons of Uranus

With the exception of Umbriel, which is unusual in a number of respects, the moons of Uranus show less geological activity with increasing distance from the planet. The case of Umbriel, surprisingly, illustrates the point. Voyager 2 passed nearest to the inner moon, Miranda, which has the most varied landscape of any moon so far observed in the solar system. Mission geologist Harold Masursky noted that one might hypothesize that the tamer surface features seen on the outer moons might be a camera-resolution effect. But Umbriel, which has the blandest surface, is the middle of the five moons, and the outer moons, Titania and Oberon, show some tectonic activity. So camera resolution is not a factor here.

Umbriel is unusual primarily in that it is out of character with the other large moons. True, it has an exceptionally dark surface, reflecting only 15 percent of the sunlight striking it. Like the dark material of the rings and other lunar surfaces, we are probably seeing an organic compound whose parent is methane. But Umbriel's surface is otherwise what planetary scientists had expected all the moons to look like. It has an "old" surface; that is, it shows a record of ancient meteor bombardment. Geologists call this a good



NASA

crater population, with large craters from the period of the early days of the solar system and a dwindling number of smaller craters added over time. There are a few young, crisp, walled craters.

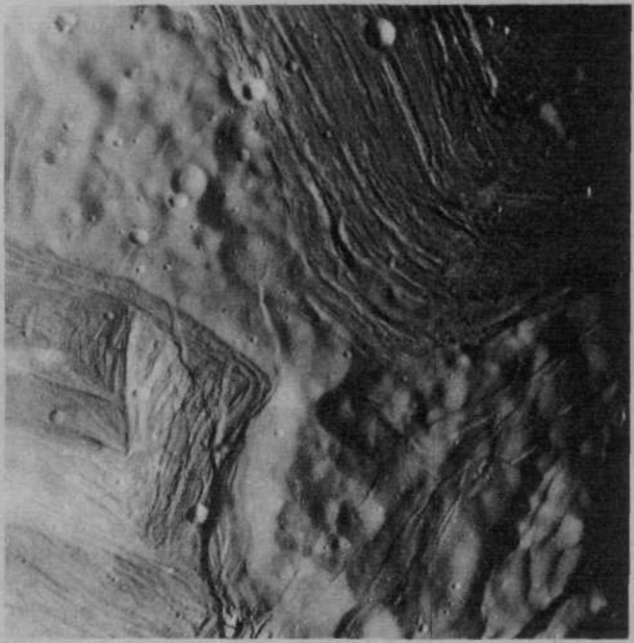
Only in one small region does Umbriel show kinship with its neighbors. On the limb of the moon, almost out of view, sits a large, anomalously light, ringlike structure. Perhaps it is volcanic, but that is out of keeping with the rest of the surface. Perhaps it is a large meteor crater, but no other of its craters are light colored. So, for the time being, the ring remains a mystery.

Titania, the most distant of the moons, has a fairly standard crater population, but the surface has other features that show a more active history. A great rift valley system runs for hundreds of kilometers. At one point it is about 75 km wide. Its sunlit wall shines unusually bright. Perhaps the forces that created the rift also released water vapor that formed frost on the cliffs. One large crater has a valley running across it, thus dating the fault after the impact.

Oberon has a mountain six kilometers high and a large crater flooded with a dark, probably organic material. Ariel similarly shows evidence that it has not been a dead body for all its existence.

The real surprise, however, is the surface of Miranda. No other body in the solar system has as rich a collection of scarfs, rifts, layered terrain, flow patterns, and craters. Being the closest of the large moons to Uranus, one naturally suspects that the source of energy for this activity lies in gravitational interactions between the outer moons and Uranus. Recall that Jupiter's closest large moon, Io, was found to have active volcanoes driven by tidal heating. But Io is a much larger moon than Miranda, and Jupiter is a much larger planet than Uranus.

No one really expected much in the way of geologically active surfaces on the Uranian moons because, first, they are relatively small and thus must have cooled long ago, and second, their tidal interactions would be minimal. This combination of unexplained energetics and surfaces of presumably organic compounds will make them an exciting subject of inquiry over the coming months.



(a)

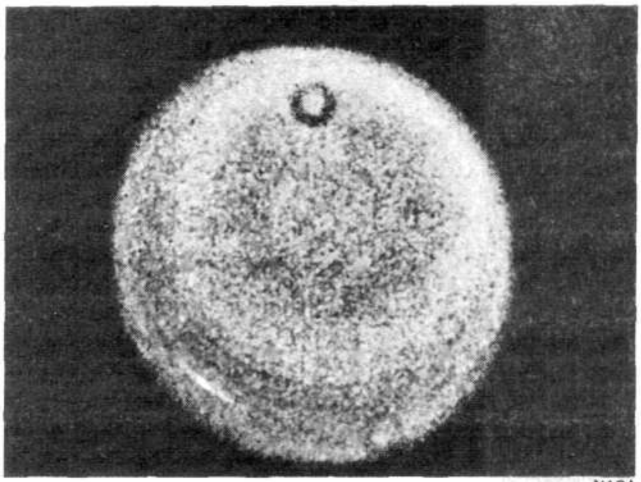
(b)

Miranda (left), the innermost moon of Uranus, is roughly 300 miles in diameter with a varied geologic terrain. This is a computer-assembled mosaic of many of the high-resolution frames obtained by Voyager 2 at a distance that ranged from 18,730 to 25,030 miles at a resolution that ranged from 1,840 to 2,430 feet.

On Miranda, the ridges and valleys of one province are cut off against the boundary of the next province. Probably compressional (pushed-together) folded ridges are seen in curvilinear patterns, as are many extensional (pulled-apart) faults. Some of these show very large cliffs, ranging from .3 to 3 miles in height—higher than the walls of the Grand Canyon on Earth. The missing piece of the composite will be inserted into the image once the complicated processing can be completed.

Photo (a) is a high-resolution closeup of the "chevron" area. Cutting across the bands are sinuous scarps, probably faults. Superimposed on both types of terrain are many bowl-shaped impact craters less than 3 miles wide. The entire closeup area is 140 miles across.

Photo (b) shows a bewildering variety of fractures, grooves, and craters, as well as features of different albedos (reflectances). The grooves reach depths of a few miles and expose materials of different albedos. The great variety of directions of fracture and troughs and the different densities of impact craters on them signify a long, complex geologic evolution of this satellite.



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This Voyager picture of Uranus shows a discrete cloud (lower left) that looks like a bright streak. The picture is a highly processed composite of three images obtained Jan. 14, when the spacecraft was 8 million miles from the planet. This cloud is the most prominent feature seen in a series of images designed to track atmospheric motions. The occasional donut-shaped features are shadows cast by dust in the camera optics, which are exaggerated because of the processing necessary to bring out the faint features on the planet.

construct from the enormous amount of data transmitted. (Voyager stayed in this region for three days after the flyby.) An early hypothesis is that the magnetic field behind the planet rolls up on itself, according to Voyager Project scientist Ed Stone, "like a sausage."

An aurora was observed over the magnetic pole on the unlit side of Uranus. This was detected with Voyager's ultraviolet sensor. This sensor also detected a new type of light emission from the atmosphere called electroglow. The atmosphere can absorb sunlight and reemit it as "airglow." Electroglow emission is stronger than could be caused by the absorption of sunlight. Yet it is only evident in the sunlit portion of the planet, so sunlight must play some unknown catalytic role.

The Atmosphere. The infrared spectrum of the atmosphere fits very closely to a model containing 10 to 15 percent helium. Methane is a major component of the atmosphere, and combined with other organic compounds in the presence of sunlight has created high-level haze and smog that block a clear view of the lower clouds.

The temperature spectrum of the clouds is bizarre. At thin, high altitudes over the sunlit pole the temperature is 750° K (850° F), as measured by the ultraviolet spectrometer. Over the unlit pole, which has not been exposed to sunlight for 20 years, the temperature is 1,000° K (1,340° F)! Clearly, there is some energy source in the planet not directly dependent on the Sun.

The lower, primary cloud temperatures are a cold 50 to 65° K (−370 to −343 degrees F). The temperature structure is surprising here, too. The equator and the poles are both about 65°K, and the midlatitudes are the coldest, at 50°K.

Even in high resolution closeups, the visible surface of Uranus remained rather featureless. One cyclonic feature resembled those of Jupiter and Saturn. Scientists at the Jet Propulsion Laboratory, the headquarters for the Voyager Mission, were able to track a few cloud features through several rotations. The rotational speed varied with latitude but averaged about 16 hours.

The winds are prograde, meaning that they turn in the same direction as the planet spins, which is highly unusual. The wind speeds are more than 200 miles per hour, twice that of Earth's jet streams. The high speed prograde winds led to an initial underestimate of the length of the Uranian day. The actual value of 16.8 hours was determined by measuring radio periodicities in the revolving magnetosphere.

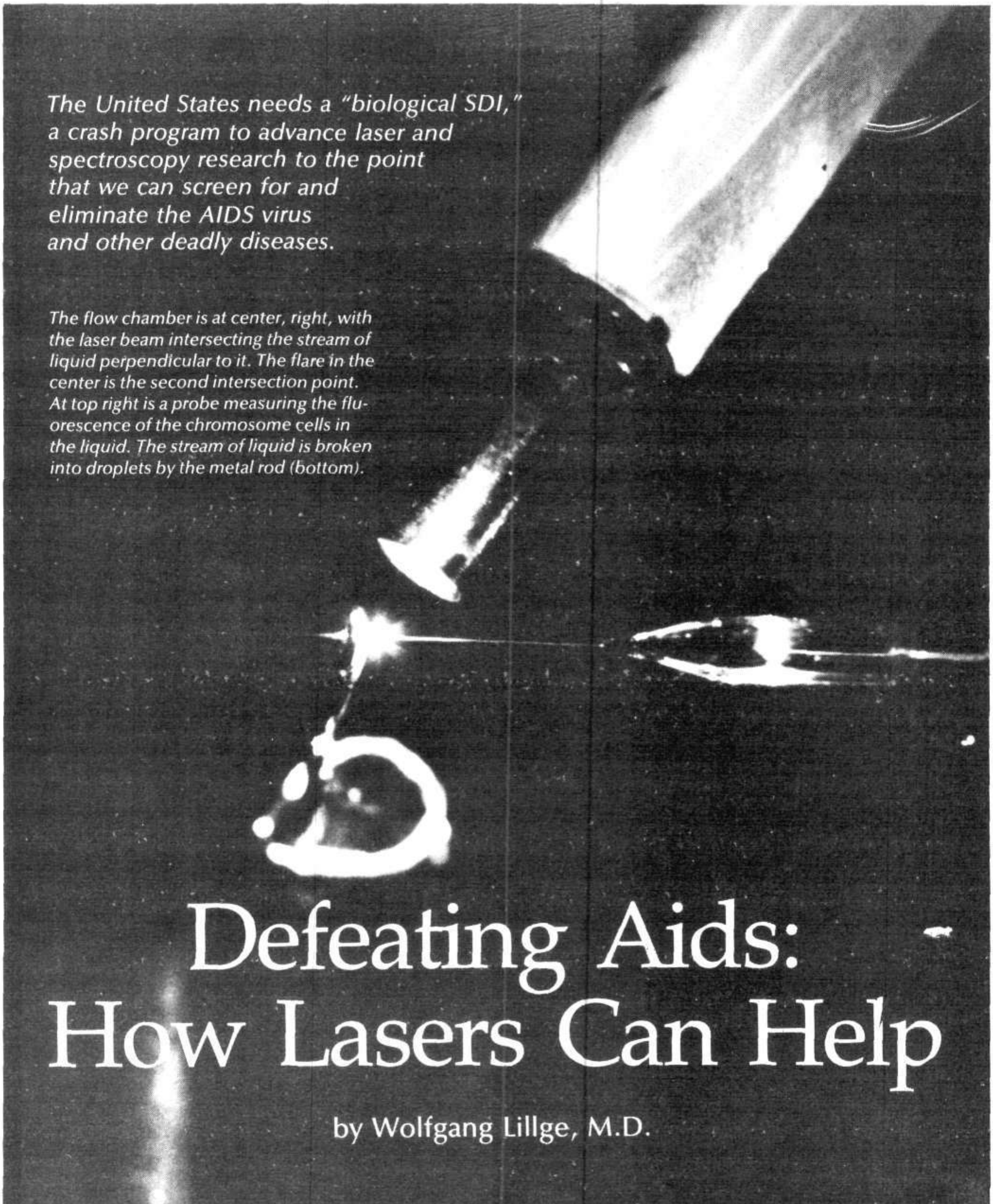
What would Uranus look like if you were there? Floating on the cloudtops of Uranus, you would see a sky where the Sun would tightly circle the north pole, never setting, just as our North Star never sets at night. It would circle the sky once every 16.8 hours, but at the pole, daylight would extend for 42 years, half of the 84 years it takes Uranus to orbit the Sun.

Uranus: Known to Man Only 105 Years

Because of its great distance from Earth, Uranus was the first planet discovered with the use of a telescope; the others were known to ancient astronomers who observed them with the naked eye. First thought to be a comet by its discoverer, William Herschel, in 1781, Uranus remained a mystery for decades. It was not until nearly a century later that its rings became known. In 1977, a group of astronomers aboard the Kuiper Airborne Observatory noted that when they viewed a star as it disappeared behind the planet, the star "blinked" five times before reaching the planet's surface.

From this evidence, it was concluded that Uranus had slight rings around it, and the number was later defined as nine. These rings have been described as the darkest objects in the solar system. As an example, the outermost epsilon ring reflects only about 5 percent of the incident light from the Sun.

Uranus's discoverer Herschel continued to build bigger and better telescopes, and in 1787 he discovered its moons Titania and Oberon; Ariel and Umbriel were found in 1851 by English astronomer William Lassell. (Herschel's son John named all of moons after figures in English literature.) It was another hundred years before the next moon was discovered: Miranda was observed in 1948 by American astronomer Gerald Kuiper. And before Voyager reached Uranus, scientists had observed five other small moons, the largest approximately 1,000 miles in diameter.



The United States needs a "biological SDI," a crash program to advance laser and spectroscopy research to the point that we can screen for and eliminate the AIDS virus and other deadly diseases.

The flow chamber is at center, right, with the laser beam intersecting the stream of liquid perpendicular to it. The flare in the center is the second intersection point. At top right is a probe measuring the fluorescence of the chromosome cells in the liquid. The stream of liquid is broken into droplets by the metal rod (bottom).

Defeating Aids: How Lasers Can Help

by Wolfgang Lillge, M.D.

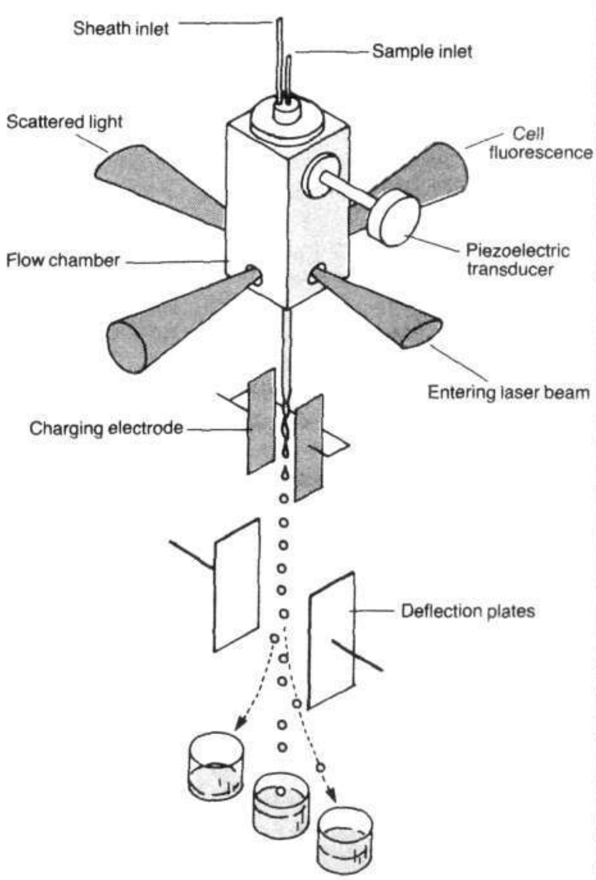


Figure 1
SCHEMATIC OF A FLOW CYTOMETER

Cells strained to identify a particular cellular property, such as the amount of DNA, enter at the top. The cells are dispersed into a single-cell suspension in the conducting medium (normally a saline solution). An electrically conducting sheath fluid is added at the top to insure precise sample location in the flow cell. The laser beam enters the chamber from the right and is focused into an elliptically shaped slit of light to excite each fluorescently stained cell as it passes through the laser beam. The fluorescent light is analyzed to measure the amount of fluorescent dye in each cell. As each cell passes through the laser beam, it also causes a scattering of the laser light that can provide additional information on cellular properties. The piezoelectric transducer is coupled mechanically to the flow chamber and tuned to about 40,000 hertz to vibrate the chamber and break the emerging stream into uniform droplets at a rate of about 40,000 droplets per second. The electrode can be charged rapidly to 75 volts so that droplets can be electrically charged as they break off from the main stream. The charged droplets are deflected by an electrical field supplied to the deflection plates. Thus, a group of droplets can be charged either positively or negatively and separated from the uncharged stream.

A year ago, we wrote that spinoffs from the laser defense program, along with other recent advances, had brought medical science to a point where man can now conquer many of the leading killer diseases and significantly extend the productive human life span.[1] Specifically, we mentioned the flow cytometer/circular intensity differential scattering technique (CIDS), developed by Los Alamos National Laboratory, a unique machine to identify viruses, bacteria, and other microorganisms with high specificity and maximum speed. CIDS has the potential to detect retroviruses, like AIDS (acquired immune deficiency syndrome), that have become amalgamated to the cell structure.

Today, as AIDS threatens to decimate the world population, the development of CIDS and other advanced medical technologies is a question of life and death. We need a strategic defense initiative for biology and medicine, similar to President Reagan's SDI, whose fundamentals are based on the same type of technologies needed to shoot down incoming missiles or to control a fusion plasma—namely, lasers and spectroscopy.

Translated into the scientific language of AIDS research, this means that we need instruments capable of identifying—and possibly also killing—the deadly AIDS virus. The AIDS virus is a particularly effective killer because it has found a way to overwhelm the immune system (the body's defense against disease) and can hide inside the B-lymphocytes, nerve cells, and also lung cells. Scientists have to find out exactly how the virus is capable of doing this and then identify the virus reliably, in whatever form it may camouflage itself. To do this, the flow cytometer/CIDS technology will have to be upgraded to a high-resolution capability, especially to root out the the AIDS virus after it is integrated into the human genome.

A Revolution in Diagnostics

The CIDS system involves advances in two new technologies developed at Los Alamos National Laboratory in New Mexico. In the flow cytometer, cells or individual molecules are suspended in liquid, stained with dye, and passed through a flow chamber at rates of up to 20,000 cells per second. As they pass through the chamber, the cells are hit by laser beams of one or different frequencies. A computer then records the absorption or scattering of the laser light (the fluorescence signal intensities of molecules excited by the lasers) for each individual cell. The flow cytometer can measure cell size, DNA content, the permeability of cell membranes to particular molecules, the movement of receptors on a cell surface, chemical reaction rates within cells and more.

In conjunction with another emerging technology—an instrument called the angular-scanning CIDS spectrometer—the flow cytometer can identify particular bacteria and viruses in an order of minutes. CIDS uses left and right polarized laser light to identify a specific "signature" of the microorganism being processed through the flow chamber.

In addition to their unique application to AIDS research, these two technologies will revolutionize all microbiology testing relevant to clinical use. Infectious diseases are still a major cause of death, largely because no present method of microbial identification is rapid and specific enough to enable the physician, at the very onset of the infectious disease, to begin a specific antimicrobial treatment of the patient. There are several infectious diseases in which early and specific intervention can save the life of the patient; for example, the viral disease herpes simplex encephalitis. Treated early, more than half of those afflicted with this disease can be saved; when diagnosis is delayed, even the most intensive care comes too late.

The Problem of AIDS Testing

Scientists at Los Alamos National Laboratory are only beginning to apply this technology to AIDS virus identification. If successful, this would be a giant step forward in the effort to begin a mass screening of the population, yielding accurate figures on the spread of the disease and a specificity of detection that would permit reliable identification and precise study of even small genetic changes of the virus genome.

The several different AIDS tests that have been in use for about two years are all merely *indirect* tests; they are based on the identification of antibodies against the HTLV-III/LAV virus that the immune system has produced after it has been exposed to the AIDS disease. Although useful as a rough preliminary routine measure to identify AIDS antibody carriers and to screen blood banks, these AIDS antibody tests have several problems that are unique to this disease:

(1) The AIDS virus's protein coat, against which the immune system produces antibodies, mutates 100 times faster than the influenza virus; hence, the test may not have sufficient "resolution power," since it is tuned to a class of antibodies that the patient may no longer be producing.

(2) Recent findings indicate that the number of AIDS carriers who have no antibodies at all is much higher than heretofore suspected. Such persons would appear in the antibody test as "false negatives."

(3) On the other hand, in order not to produce too many "false positive" results, the test must be highly specific and purified, which again is possible only with advanced microbiological techniques.

The new technology of the flow cytometer/CIDS overcomes these drawbacks. With CIDS, it will be possible to identify the presence of the AIDS virus directly in blood sera, and possibly even intracellularly. In current methods of detection, the identification of the virus itself is only the last step after a series of different antibody tests (ELISA, Western blot, and so on), and can be performed only by growing the virus in a cell culture. This is not only very costly and time consuming, but, more important, the procedure might turn out not to be specific enough.

How the Flow Cytometer and CIDS Work

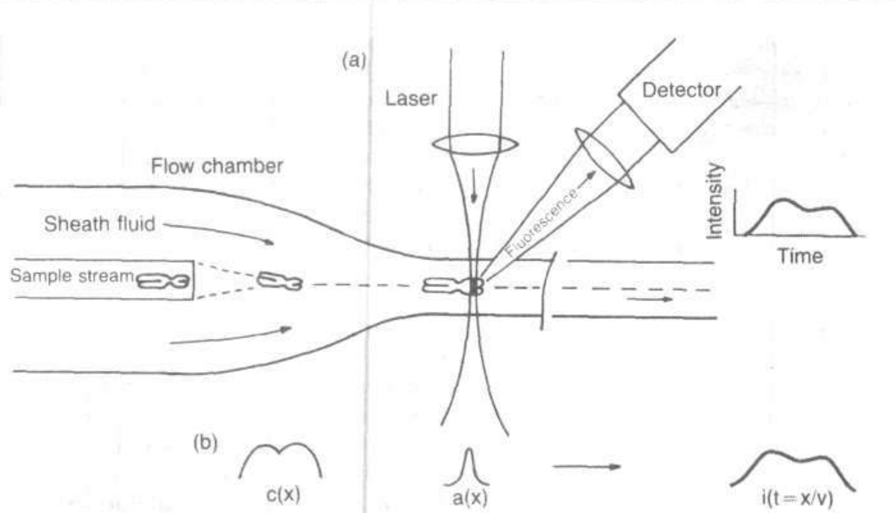
Los Alamos work with the flow cytometer began in the 1960s to study the effect of radiation on cells, and then was broadened to include study of cancer and the immune system. Over the years, its precision and speed have been vastly improved (Figure 1).

Circular intensity differential scattering, an even newer technology, is one of the few really new approaches to microbial identification in the past several decades. The method takes only minutes and processes approximately 5×10^5 organisms per milliliter. According to the scientists working on the project at Los Alamos, further modifications soon could increase the sensitivity of the instrument by at least an order of magnitude.

As of mid-1985, several future generations of CIDS instruments were planned. The first machine was a static instrument, designed to identify bacteria in pure culture or viruses in typical clinical specimens in a static cuvette system. A second-generation machine, now operational, employs the same principle with the addition of a flow cytometer, so that organisms can be examined one at a time. A schematic of an angular-scanning CIDS spectrometer is shown in Figure 2.

Light from a laser or any other appropriate source passes through the polarizer and then through a photoelastic modulator, which modulates the polarization at a selected

Figure 2
ANGULAR-SCANNING CIDS SPECTROMETER
The chromosomes in the sample stream pass lengthwise through the laser beam. The deflector collects the fluorescence that is emitted, and then the profile of the chromosome is convolved with the laser profile. The resultant signal is outputted at the detector.



frequency. This alternately left and right circularly polarized light then impinges on the sample in a cuvette, and the light is differentially scattered. The detection arm rotates under computer control, stopping at the specified angle and taking data for a specified length of time. The detector also contains a photoelastic modulator, a polarizer, and a photomultiplier tube, in order to measure the intensities of the scattered left and right circularly polarized light.

The key feature of the CIDS technology is its use of left and right polarized light. This has two basic potential applications: First, *circular dichroism,* which is based on the differential *absorption* of left and right circularly polarized light and occurs only at a specific absorption band of the molecule in question; and second, in contrast to this, the differential *scattering* of left and right circularly polarized light (CIDS), which occurs throughout the spectrum, rather than only at absorption bands. CIDS was first observed as an artifact of circular dichroism measurements of large particles because it produced long tails in the circular dichroism spectrum that extended from the absorption bands in the ultraviolet to the visible part of the spectrum.

CIDS is given, then, as the amount of light scattered when the incident beam is left circularly polarized minus that scattered when the incident beam is right circularly polarized, divided by the total amount of light scattered by the object (that is, the virus or bacterium). Identification of microorganisms has been tried before by way of total light scattering, depending only on the size, shape, and average refractive index of microorganisms. However, this approach has not proven useful in the laboratory. In contrast, CIDS uses right and left circularly polarized light to hit the microbial sample; the scattered light is thus enriched, and changed in several components, creating a specific "signature" of the sample.

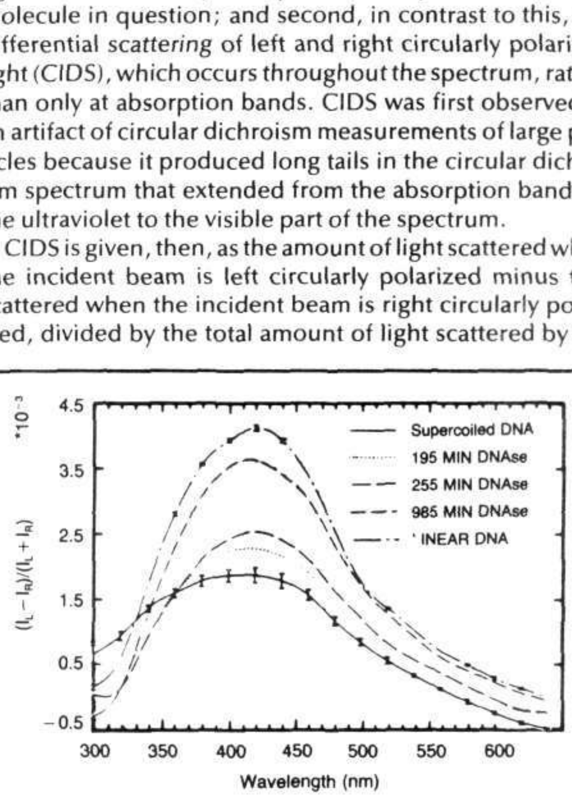


Figure 3

SPECTRA OF SCATTERED LIGHT FROM DNA

The spectrum of scattered light at a 90° scattering angle as a function of wavelength for highly supercoiled DNA from a plasmid, a tiny piece of DNA material (bottom curve). The three middle curves show the spectra after treatment with the enzyme DNAse (which dissolves the bonds of the DNA, and thereby decreases the coiling) for various periods of time (in minutes). The spectrum of calf thymus DNA (short fragments) is shown for comparison(top curve). The vertical axis shows the amount of light scattered when the incident beam is left circularly polarized minus that scattered when the incident beam is right circularly polarized, divided by the total amount of light scattered by the object.

Source: Gregg et al. *Rapid Methods and Automation in Microbiology and Immunology*, p. 187, Habermehl, ed. Springer-Verlag, Heidelberg, to be published.

Preliminary knowledge exists about the physical basis of these measurements. According to C.T. Gregg of Los Alamos National Laboratory, CIDS measures "the three-dimensional 'packaging' of helical molecules, largely that of the microbial genome." What is also known is that the CIDS spectrum depends upon the pitch and the radius of the scattering helix.

A typical CIDS spectrum is shown in Figure 3, taken with highly purified and supercoiled plasmid DNA as a function of wavelength (lowest curve). The upper curves represent the same DNA treated for different time intervals with DNAse, which uncoils the helical structure of the molecule. These results are finally compared with the CIDS spectrum of calf thymus DNA (top curve), which is used in the laboratory for short, linear fragments of DNA.

The real potential of this new instrument must be seen in the fact that one microbial sample yields a varying amount of data, depending on the wavelength of the laser light used, the scattering angle, and so on. So far, only a tiny fraction of this potentially highly specific signature of a virus, bacteria, or an organic macromolecule can be obtained and processed.

The procedure for expressing the CIDS signature for any particle sent through the machine is as follows: All the different measurements can be expressed mathematically as elements of a so-called Mueller matrix, which consists of 16 elements, and each of these matrix elements can be determined by measuring different frequencies in the output signal. Essentially, all polarization properties of the light beam at each point of the instrument are describable by the Mueller matrix; that is, the scattering of light from an object at a particular angle and wavelength.

In effect, CIDS itself is only one component of what should be described as multiparameter light scattering, which reflects 16 different polarization elements. These include combinations of polarization, circular polarization, angles of scattering, upshifts and downshifts of frequencies (Stokes and anti-Stokes lines), and so on. These are entered into the Mueller matrix to define the signature for a particular virus or bacteria.

The first-generation CIDS machine, the one on which the Los Alamos scientists have carried out all the published experiments, is based on only one single element of the Mueller matrix; yet, even so, very clear results have been obtained. This shows the unique potentials inherent in this technology. As soon as scientists learn to master all 16 elements of this "spectroscopic language," we will have a lexicon of all the different viral, bacterial, or molecular signatures that serve as references to identify any mixture of microbial samples in any laboratory in the world.

On the basis of only one element of the Mueller matrix,

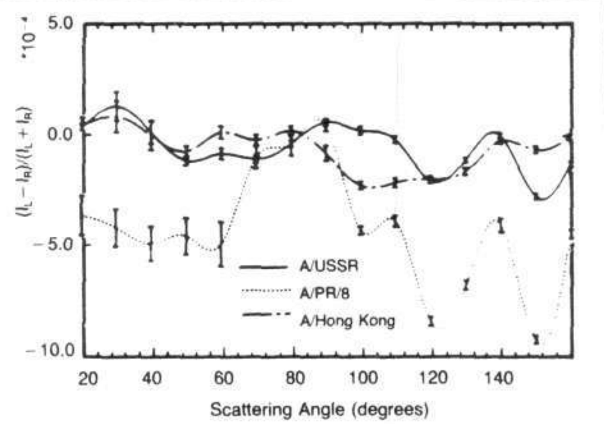


Figure 4
SPECTRA OF SCATTERED LIGHT FROM FLU VIRUS
These are spectra of three type A influenza virus vaccine preparations as a function of a scattering angle at 488 nm. Good discrimination is obtained among these three virus preparations around 60, 110, and 150°.

Source: Gregg et al. *Rapid Methods and Automation in Microbiology and Immunology*, p.189, Habermehl, ed. Springer-Verlag, Heidelberg, to be published.

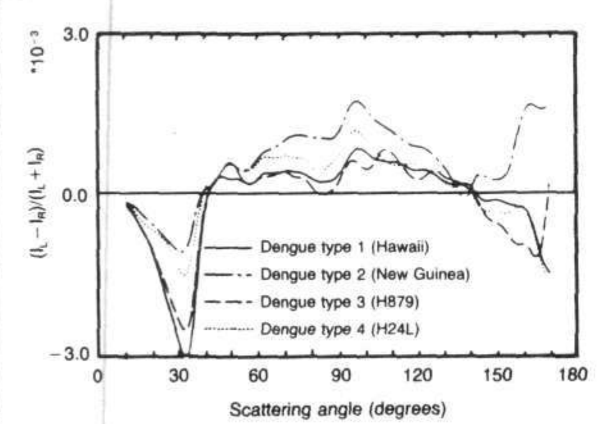


Figure 5
SPECTRA OF SCATTERED LIGHT FROM DENGUE VIRUSES
These are spectra of four types of dengue fever virus vaccines at 360 nm. The best resolution among the four viral vaccine types is obtained near 30°.

Source: Gregg et al. *Rapid Methods and Automation in Microbiology and Immunology*, p. 190, Habermehl, ed. Springer-Verlag, Heidelberg, to be published.

C.T. Gregg and his colleague G.C. Salzman have already demonstrated the DNA spectra shown in Figure 3. With this same relatively "primitive" technology, they even succeeded in producing different signatures from three influenza virus strains with a running time of about four minutes for each virus preparation (Figure 4).

Other published data from successful experiments showed a clear differentiation between four types of dengue fever virus vaccines (Figure 5) and four types of encephalitis virus vaccines (Figure 6). In all these cases, at a specific scattering angle, a very clear resolution can be obtained.

Another use of the flow cytometer, with longer-range implications, is a project of Los Alamos and Lawrence Livermore National Laboratory to collect a complete library of the human genome. The library would be a stockpile of complete genes and such fragments of genes that determine specific metabolic processes in the cells, tissues, or organs. The fragments are separated in the flow cytometer and then genetic engineering is used to insert them into bacteria and produce quantities of the gene product. In the future, it might be possible with this method to cure hereditary metabolic diseases that often lack the functioning of one single enzyme, or to artifically insert genetically engineered cells into a diabetes patient to produce the necessary insulin.

These preliminary findings have an immediate practical significance. In the clinical laboratory, for example, it is very difficult to distinguish serologically between St. Louis encephalitis virus and dengue fever virus. The CIDS spectra of the vaccine preparations as they were generated by the Los Alamos scientists, however, are very different. The array of possible measurements with the fully developed CIDS method provides a "resolving power" for microbial identification whose potential is just beginning to be tapped.

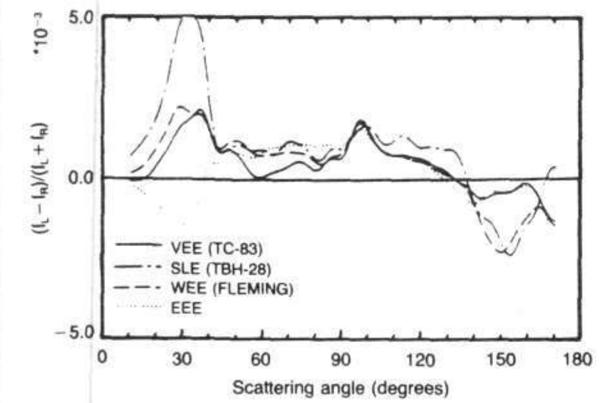
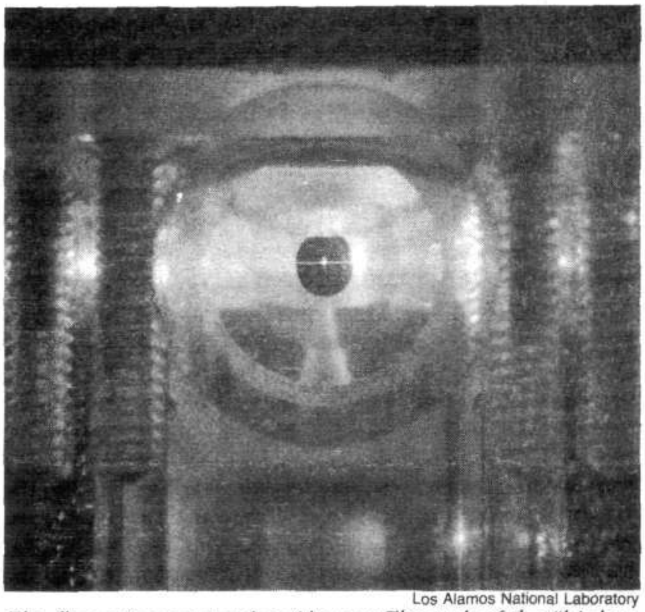


Figure 6
ENCEPHALITIS VIRUS
These are spectra for four types of encephalitis virus vaccines. The region of maximum resolution is again about 30°.

Source: Gregg et al. *Rapid Methods and Automation in Microbiology and Immunology*, p. 191, Habermehl, ed. Springer-Verlag, Heidelberg, to be published.

Now, Salzman at Los Alamos is building a CIDS machine that will allow measurement of up to 8 of the 16 Mueller matrix elements, each of which provides additional information for microbial information.

An especially critical question that is not sufficiently resolved is the choice of the right wavelength of the incident laser beam. It seems that the range of 633 nanometers from the helium-neon laser that Gregg has been using does not produce ideal results. However, using laser light of too short a wavelength, down to the 350 wavelength region,


Los Alamos National Laboratory

The flow cytometer at Los Alamos: The task of the "biological SDI" is to develop this technology quickly to defeat the AIDS virus.

would damage the sample in terms of photopolymerization or photodepolymerization. Dr. James Frazer of the Houston Medical Center, an expert on spectroscopic questions, has suggested use of lasers in the range of 430 nanometers because of their interference with key molecular systems in the cell.

Spectroscopy and Biophysics

After fusion research and the development of directed energy technologies (lasers), the next most significant field of science is spectroscopy of living processes. Furthermore, it will be progress in basic biological and biophysical research that will have the greatest impact on laser and plasma technology. When we understand better how DNA or a living cell works, we will be able to develop a better military laser defense and open up the unlimited energy source of fusion.

A "biological SDI," which explores how living organisms use energy—that is, how electromagnetic action is used in a highly efficient manner—will produce the same kinds of spinoffs and breakthroughs as the defense SDI.

The fact that CIDS uses left and right circularly polarized light coheres with the way nature itself is organized. The great Louis Pasteur first discovered that living organisms are predominantly organized according to a left or right asymmetry. Key molecules in life processes, like amino acids and proteins, are used in nature only in one of their two asymmetric forms. The reason that is the case may very well be found in the different spectroscopic behavior of these chiral macromolecules.

A highly significant aspect of any spectroscopic tool like CIDS would be not only to detect an AIDS particle in the DNS genome, but, ultimately, to destroy it using the right frequency and intensity of input radiation. Nuclear Magnetic Resonance (NMR) technology might also be appropiate for the same purpose. NMR could be fine-tuned in the radio or microwave region of the spectrum to couple into harmonic characteristics of spectroscopic features of the AIDS particle.

NMR spectroscopy creates spectral images of specific molecular patterns in tissues, depending on which frequency (radio, microwaves, and so on) is used to trigger the signal. Potentially, NMR spectroscopy can be employed in all those fields of biophysical research that call for insights into metabolic changes, molecular interactions, and so on. Frazer, who recently used NMR spectroscopy to identify differences in the glycoprotein structures of tumor cells with varying degrees of malignancy, is convinced that NMR spectroscopy will also play an important role in AIDS research.

All the technologies mentioned, including the flow cytometer, CIDS, and NMR, will provide spectral signatures of molecules or particles only from a relatively small band of the entire electromagnetic spectrum (ranging from long wavelength radio waves, radar, infrared, and the visible region through ultraviolet and the short wavelength X-rays and gamma rays). In order to evaluate the qualities and properties of any individual molecule, however, scientists *must be able to obtain the total emission in all these spectral* ranges of such a molecule.

One of the main problems of biophysics, in general, is that researchers are technically unable, at the moment, to measure all of the field information emitted from any surface of a molecule, cell, or particle. Lacking this total overview, we look at the real characteristics of molecular events, in effect, only through a tiny slit.

It is an established fact that light of various wavelengths plays a key controlling role in cells. We also know some of the basic processes that lead to the creation of very weak electromagnetic fields in living organisms. For instance, any long polymer that consists of charged particles has definite vibrational modes, which result in infrared emissions. Other conditions and motions result in emissions of different wavelengths. These are obligatory events that occur universally in any living organism. In fact, once one rejects the simplistic building-block notion of molecular biology that, unfortunately, has dominated scientific thinking in the last decades, a huge new field of research opens up: the biology of light.[2]

The flow cytometer/CIDS is an important step in the right direction, even if this machine represents only a small portion of the fields emitted by any molecular species. In terms of spectroscopic technologies, the immediate task is to run microwave interferometry, infrared interferometry, ultraviolet-visible interferometry, and so on at the same time.

Currently the equipment for such a test is not available. However, this is exactly what the "biological SDI" must begin to develop in order to defeat the AIDS virus.

Wolfgang Lillge is on the biology staff of the FEF.

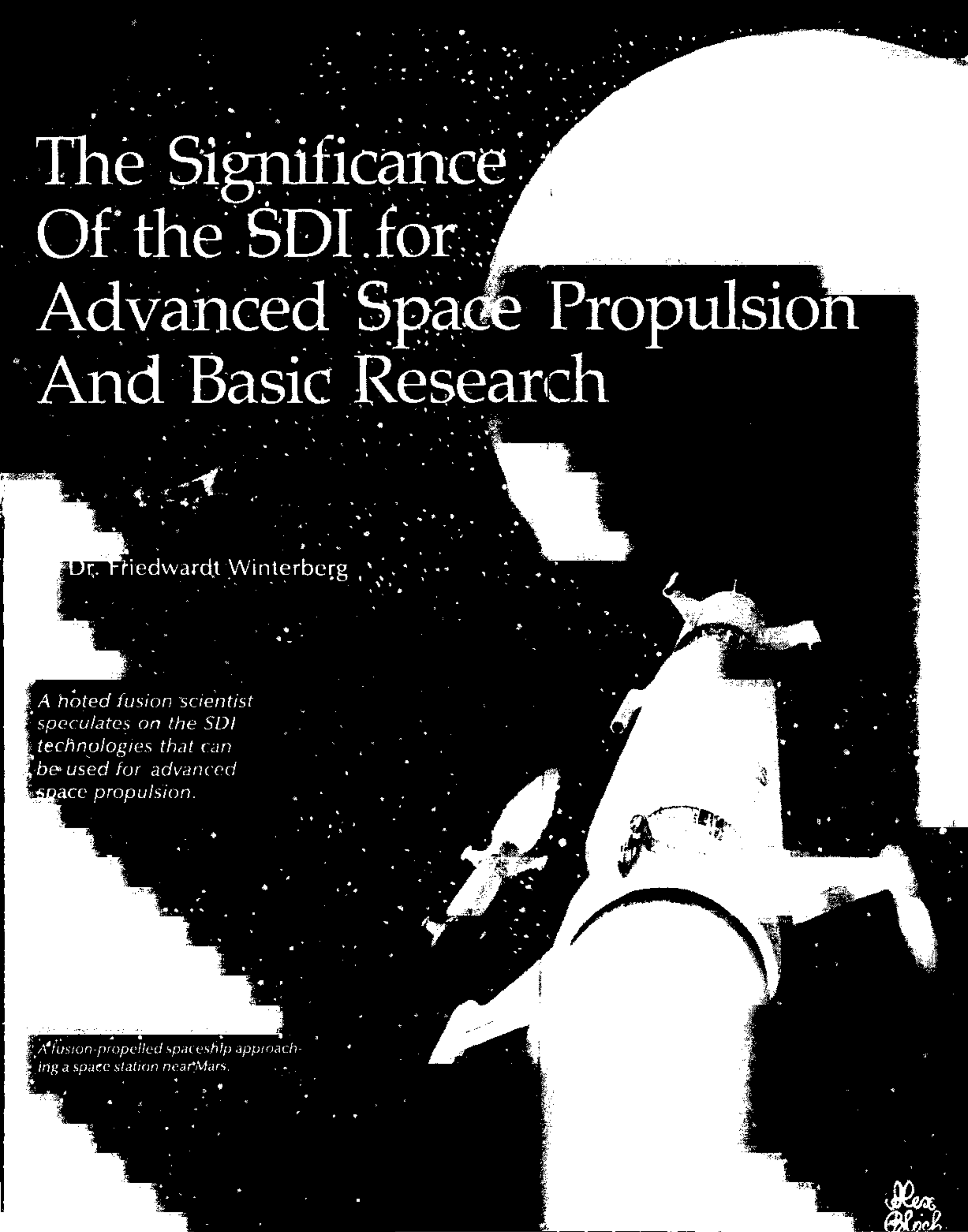
NOTES

1. See "The Medicine of the Future Is Here Now," by the author and John Grauerholz in *Fusion*, March-April 1985, p.28.
2. See the author's article, "'Optical Biophysics': The Science of Light and Life," in *Fusion*, March-April 1986, p.31.

The Significance Of the SDI for Advanced Space Propulsion And Basic Research

Dr. Friedwardt Winterberg

A noted fusion scientist speculates on the SDI technologies that can be used for advanced space propulsion.



A fusion-propelled spaceship approaching a space station near Mars.

There are two great frontiers of science: first, the *quest to reach ever-greater distances in space; and* second, the study of ever-smaller dimensions of space and time. Both quests—the first still being done with space rockets, and the second with high-energy particle accelerators—require ever-larger energies.

How far we can go depends upon a very important conjecture. (A conjecture, of course, is not a theorem, it only *might* be one.) This conjecture is called the "physical-technical conjecture"; it states that the laws of nature have a structure that permits a technology making all these laws explorable. It is by no means obvious that this is true, and at the moment it is only a *conjecture*. However, until now, this conjecture has been proven to be true. In mathematics, we have conjectures like the famous Riemann conjecture regarding the zeros of the zeta function, which determines the distribution of the prime numbers. The Riemann conjecture has been shown to be true for the region of the zeta function, explored for example with computers, but we do not know if it is true for all regions up to infinity. However, it probably is true since it has held true in that many cases. It is hard to accept that mathematics, which is in some way a part of nature, should suddenly go an odd way.

Likewise, in physics, it is hard to believe that the experience we have had so far would abandon us, and that certain parts of nature turn out to be unexplorable. Therefore I would say that everything that can be explored, not only *will* be explored, but that every part of nature *can* be explored, which is something quite different. Saying that everything that *can* be explored will be explored does not necessarily mean that everything that is unexplored, *can* be explored. Current technology could limit what can be explored *now*. However, the "physical-technical conjecture" merely says that everything that is explorable can be explored eventually. Therefore I would like to speculate on what these technologies might be by which all laws of physics can be explored.

Colonizing the Galaxy

The successful completion of NASA's Apollo program established beyond a reasonable doubt that exploration of the solar system, of the surfaces of planets, is possible. Eventually, we will have the technology to explore the surfaces of all of the planets of our solar system. Furthermore, there cannot be the slightest doubt that we will eventually master the technology of controlled fusion, because actually we have already mastered it in the hydrogen bomb. This is not enough; we also must miniaturize it so that this energy source will enable us to reach nearby solar systems.

The next step, then, would be to go to a nearby solar system, maybe 10 light years away or even 100 light years away. If it is habitable, and if we then colonize it for a thousand years and then keep on going farther, hopping from one solar system to another, a simple calculation shows that the entire galaxy could be colonized in about 10 million years. The exploration of our solar system, of nearby solar systems, and finally of all solar systems in our galaxy, is clearly feasible with fusion propulsion.

I want to stress here the importance of the physical-technical conjecture because only if this conjecture is true, will we really become masters of our universe.

But we are not just interested in exploring surfaces and planets and colonizing them; we would also like to know—using a phrase by Goethe—the forces of nature that are holding together the innermost parts of the universe. In physics, this means the nuclear and subnuclear forces. And if we are interested in the laws of life, this means the laws of microbiology.

This is where the Strategic Defense Initiative (SDI) comes in, because the implementation of the SDI will give us new tools; tools that represent a kind of supertechnology, as yet *unheard of*, which will permit us, eventually, to explore all of the laws of nature. Before I review some of the ideas of the SDI—at least those concepts that indicate how such a defense system could perhaps be built—I would like to reflect back to some ideas that space pioneer Hermann Oberth outlined in a letter he sent to a publisher in 1924. Oberth asks:

> Here is another problem; is it perhaps possible that one can propagate, in space, beams [he thought about cathode rays or ion beams] which remain parallel over arbitrary distances? Such beams, then, could serve, in a certain sense, as tracks in space, which could be used by spaceships to receive energy, and also could be used to give the spaceships some kind of material hold. . . . It is quite conceivable, in fact, that one could use such beams as tracks—for example, between two parallel beams, to make the analogy complete, of railroad tracks.

This was before the laser was invented, so Oberth visualized two beams, one made up of positively charged particles and the other of negatively charged particles, which of course, would be necessary to provide a return current. In the case of an uncharged laser beam, we would only need one beam, or one track (a monorail).

Then Oberth raises another question: If a spaceship were helped by such beams, could it come close to the velocity of light? Thus, in 1924 Oberth raised questions that decades later are still attracting science fiction writers. According to Einstein's special theory of relativity, everything in the spaceship—and that includes life—would go slower. Oberth expressed the view that there cannot be the slighest doubt, in spite of contradicting views at that time, that Einstein's prediction is true. When Oberth put this on paper, the time dilation effect predicted by Einstein was still unconfirmed. Today, it has been confirmed by the decay of mesons, and more recently by atomic clocks carried in planes.

The SDI Breakthrough

One very important breakthrough in the SDI was made a few years ago—the X-ray laser. A laser requires some kind of energy source to pump a medium. The medium consists of atoms, which all oscillate in a coherent way and emit a beam in one preferred direction only. The X-ray laser concept developed by the Lawrence Livermore National Laboratory undoubtedly is a direct thought-child of the famous

Teller-Ulam configuration, or, more accurately, the Teller-Ulam-Guderley configuration. Teller invented this famous configuration by combining the unrelated ideas of Ulam and Guderley.

The Teller-Ulam configuration appears in Figure 1. An atomic bomb is positioned in one focus of an ellipsoidal cavity (it can be egg-shaped), and in the second focus is a ball of liquid deuterium. The diameter of the U-235 bomb is very small compared to the deuterium ball at the right, which is about 1 meter. In the last moments of the explosion of the fission bomb an enormous amount of soft X-rays is emitted with the velocity of light, well ahead of the explosion wave. This fact is utilized in Ulam's idea.

According to this idea X-rays can be confined by solid walls. Therefore, the X-rays confined inside the ellipsoidal cavity will hit the deuterium ball, giving it a surface temperature of 10 million degrees; that will launch into the ball a convergent Guderley shock wave, named after the aerodynamicist Kurt Guderley.

The famous theory says: If you have a convergent shock wave, you get about a 30-fold compression in the center of the deuterium ball and the temperature rises; in this case, with a meter-sized ball of liquid deuterium, temperature rises from 10 million degrees at the surface of the ball to 1 billion degrees. Then you get ignition in the center, and a thermonuclear propagation wave moves outward. The hydrogen bomb exploded in the Bikini Atoll, called the "Mike" Test, must have looked like this.

In the X-ray laser shown in Figure 2, the ellipsoidal cavity of Figure 1 becomes a long pipe. Inside the pipe is a wire that is the laser rod; it is bombarded with the X-rays, and it becomes, incidentally, what laser physicists call a continuous wave or CW laser. The laser transitions in the X-ray domain are very, very short-lived, but the X-ray bombardment, before the whole thing disintegrates by the explosion wave of the fission bomb, lasts long enough to pump up the atoms many, many times, producing a continuous beam of X-rays.

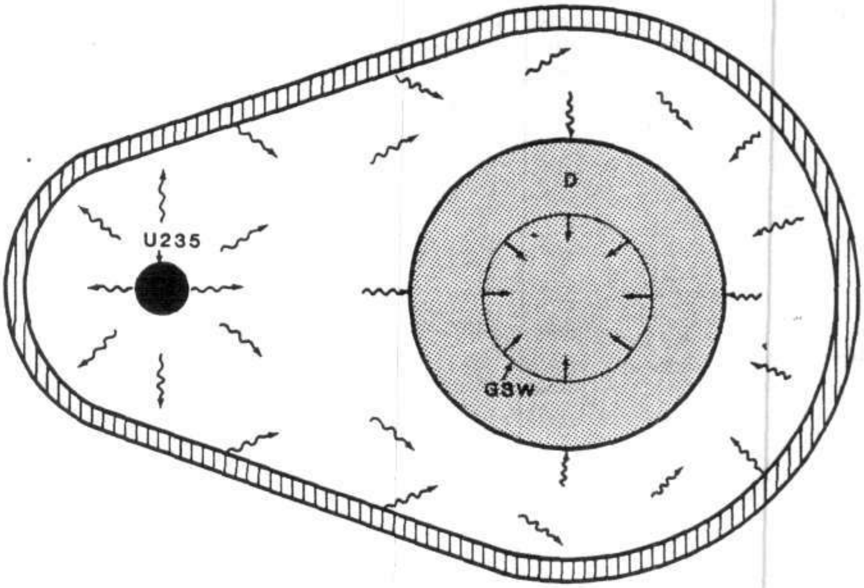


Figure 1
TELLER-ULAM CONFIGURATION FOR A THERMONUCLEAR EXPLOSION
An enormous amount of soft X-rays are emitted in the U-235 chain reaction, imploding the liquid deuterium ball (D) with a Guderley convergent shock wave.

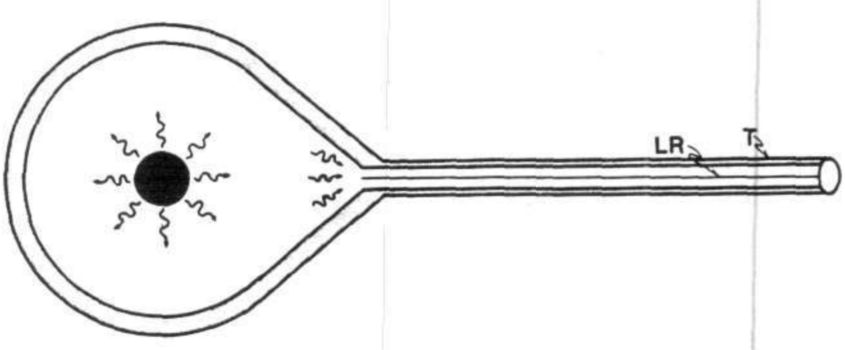


Figure 2
X-RAY LASER CONFIGURATION
Deforming the Teller-Ulam configuration into a long pipe with a wire inside, produces a continuous wave X-ray laser.

Recently Lawrence Livermore National Laboratory reportedly made a breakthrough, producing a type of optical cavity with such X-ray lasers. If true, then the beam reaches such coherence that it no longer spreads out. In Figure 2, the beam would still spread out, because the pipe, or the wire has a finite thickness, is not infinitely thin. (If it were too thin, then *no* radiation would come out.) The spreading of the beam depends on the ratio of the diameter of the wire, divided by the wavelength, so the beam initially spreads out slightly; yet over several thousand kilometers, this can be quite significant.

If the breakthrough reported at Livermore proves true, the laboratory succeeded in making an optical cavity for X-rays. To make it possible, a concept known as zone plate, invented by the famous 18th-century French physicist Augustin Fresnel, most likely was used. In this case then, the X-ray laser beam not only can be made much, much stronger, but also can be kept together. This of course will have tremendous implications for Oberth's idea of beam tracks. If we can really make such an X-ray beam and keep it together, then we can propel a spacecraft over tremendous distances.

There is another, very important application of the X-ray laser. As you know, there are tremendous efforts under way to miniaturize hydrogen bombs to such an extent that the explosion can be controlled in a chamber. In other words, we would have an explosion motor, where miniaturized explosions would take place (like the explosions in an automobile engine, which do not destroy it since they are controlled). With a different kind of trigger to replace the atomic bomb trigger, we could have thermonuclear microexplosions.

One very promising candidate to replace the atomic bomb trigger would be intense ion beams. Sandia National Laboratories has made a tremendous breakthrough recently with these ion beams, which are produced by magnetically insulated diodes. Sandia can now focus these ion beams, almost as if with an optical lens, to a spot less than a millimeter in diameter. This was totally unpredicted, and it is theoretically poorly understood, because the beam behavior is highly nonlinear, but by trial and error, lab researchers found out it works. Before that only laser beams could be focused that well. This therefore poses a very big challenge to the Livermore laboratory, which put its bet on a laser having much less energy because they thought only laser beams could be focused. Sandia could afford a megajoule ion beam machine because ion beams are much cheaper to produce, therefore, Sandia is ahead of Livermore by a factor of about 10 to 100.

Spinoff Applications

If we can produce thermonuclear microexplosions, then we could also make an X-ray laser for the laboratory. And then, by a certain technique called holography, we could magnify living tissue, including living cancer cells, perhaps a million times, without killing the cancer cells. This could be much better than an electron microscope where the cancer cells being looked at are killed. We could make such enormous magnifications of cells without killing them, because X-rays are much less destructive than the electron beam rays in an electron microscope. Magnifying a cancer cell that much could show scientists exactly which molecule is moving from here to there, and give us a very clear idea of how to explore the cause of the abnormality in cancer.

Of course, cancer research would not be the only area to benefit. The X-ray laser as a tool could also be used to explore the cause of many other diseases. And in genetic engineering, we could really determine, which "piece" we must move from over here to over there. In fact we could

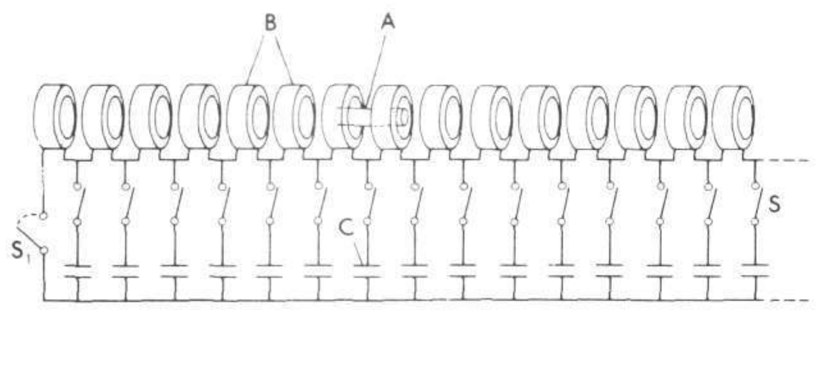


Figure 3
MAGNETIC ACCELERATOR
Many coils energized by capacitors produce the traveling magnetic wave to drive the projectile. But the capacitors can be replaced by a sequence of thermonuclear microexplosions as shown in Figure 4.

eventually be able to read the genetic code like a book, a very beneficial spinoff of the SDI. Most important, we could retard the aging process. Our life now lasts—what does the Bible say?—70 to 80 years, and it's reaching 90 (for example Hermann Oberth is 91). Since we need about 30 years to get educated, that means we work another 30 years and then we are thrown away.

How long does it take to produce a car? A day? If the car then moved around for one day and after that it went to the junk dealer, this obviously would be very inefficient. Since our life is comparatively short, I hope that with genetic engineering we could one day make the necessary changes to reach a lifespan of say 1,000 years. (I personally would, if I could, like to live forever!) But at least if we could, with genetic engineering, increase lifespan by a factor of 10, that would be a breakthrough in everything. Our education, which lasts 30 years, could then be much more efficiently utilized.

Thus you can see what kind of side effects the SDI may have, side effects that are very difficult even to predict at this time.

Interstellar Travel

Another very important milestone in the SDI would be a magnetic accelerator reaching very large velocities (Figure 3). Ultimately, such magnetic accelerators could be driven by thermonuclear microexplosions. There are several chambers where small nuclear explosions take place; each chamber produces a fireball that presses against the magnetic field, and an enormous electromagnetic pulse is produced.

With such a microexplosion-driven magnetic accelerator, we could launch very large payloads from the surface of the Earth into Earth-orbit. Furthermore, we could use particle beams and laser beams to make a channel through the atmosphere, heating the air to several thousand degrees (or perhaps 10,000 or even 100,000 degrees) and making it much thinner. Of course, the channel would have to last only for a very short moment, only long enough to let the fast projectile through the channel with very little air resistance.

Figure 4 shows how that works in the framework of the SDI. Huge electromagnetic guns would be located in northern Canada, or Alaska, or one of the Arctic islands. If ICBMs are launched from the Soviet Union, the X-ray laser would be lifted very rapidly above the horizon to destroy them in their boost phase. Ordinary rockets may not be fast enough to lift the X-ray laser above the Earth's atmosphere. However an electromagnetic gun which could generate in a very short moment a velocity of about 30 kilometers per second, then, of course, in less than a minute, or maybe a hundred seconds, the X-ray laser would be at the right altitude to fire

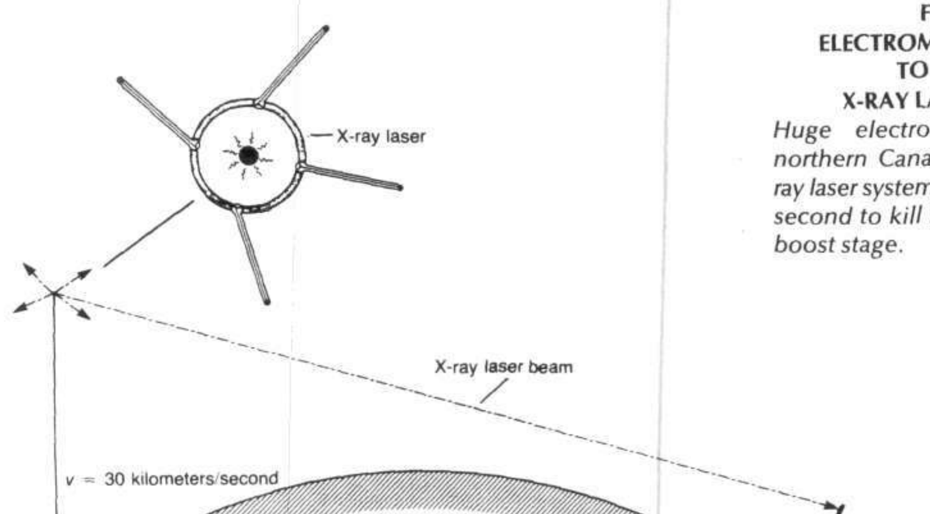


Figure 4
ELECTROMAGNETIC GUNS TO LAUNCH X-RAY LASER SYSTEMS
Huge electromagnetic guns in northern Canada could pop-up X-ray laser systems at 30 kilometers per second to kill Soviet rockets in the boost stage.

and destroy the boosters.

There has been a lot of talk about so-called fast-burn boosters being able to escape the X-ray laser, because they rapidly reach a very high velocity. (The MX is one type of fast-burn booster.) The Russians do not have a fast-burn booster yet; with present boosters the whole payload of warheads and decoys is released in a relatively high altitude—roughly 200 kilometers. A fast-burn booster could reach that velocity at 80 kilometers altitude; and then, the X-ray laser beam could be absorbed. However, the reported breakthrough by Livermore scientists may have changed this.

In this case, very powerful X-ray laser beams could be produced that spread out much less. Then the laser would simply burn a hole through the atmosphere and could destroy the fast-burn booster. The X-ray laser, therefore, in combination with an electromagnetic gun, has to be taken *very seriously. We can also use an electromagnetic gun* as a zero-stage for a rocket, and there may be some combinations that will turn out to be optimal.

Figure 5 demonstrates some idea of how we can use the electromagnetic gun technology to reach interstellar distances, maybe a trip to a nearby solar system. What is suggested here is an electromagnetic gun with many capacitor coils. Of course, we could also use thermonuclear microexplosions instead of these capacitors.

Suppose before a spaceship starts, we launch a large number of nuclear explosives ahead of it, with an electromagnetic gun. This would form a chain in space, a "road" moving ahead of the spaceship. Like a ramjet, the spaceship would ignite the nuclear explosive just after it passes it. This nuclear explosive, then, with characteristics of a shaped charge, would give the spaceship a big push.

If we make a very, very long "road" of such nuclear explosives, and the spaceship comes and sets off the nuclear explosive shells, it could attain velocities of 3,000 kilometers per second. The configuration for such a thermonuclear-shaped charge capable of reaching this velocity is shown at left in Figure 5. To produce velocities close to the speed of light, we would utilize a different kind of shaped charge, *shown at right in Figure 5.*

The latter design gives you about three times higher velocity than the nuclear explosive products move. (In a thermonuclear explosion you have approximately 10,000 kilometers per second versus 30,000 kilometers per second; *but in the other type we could come close to the velocity of* light.) We would have to shoot many, many such atomic bombs, or rather hydrogen bombs, ahead of the spaceship, and that spaceship would use all of the explosives already placed there as a sort of rail. The energy and the recoil mass are already put ahead of the spaceship.

Many years ago, someone proposed a nuclear ramjet using interstellar gas. That would not work, because the density of interstellar gas is much too thin, and there is not enough thermonuclear fuel in it. With the thermonuclear miroexplosions, of course, the fuel is placed into space as a kind of road, a nuclear road to the stars.

Gamma-Ray Laser Beam Propulsion

Figure 6 is a new concept that I hope will be a new area of research. There has been a renewed interest in an old idea first described by Willard Bennett around 1930—the pinch effect. This idea of using a pinch was popular in the early days of the fusion program. One pioneer on the pinch research, Dr. Winston H. Bostick still believes in the pinch, and a lot of people are starting to look at it again in an

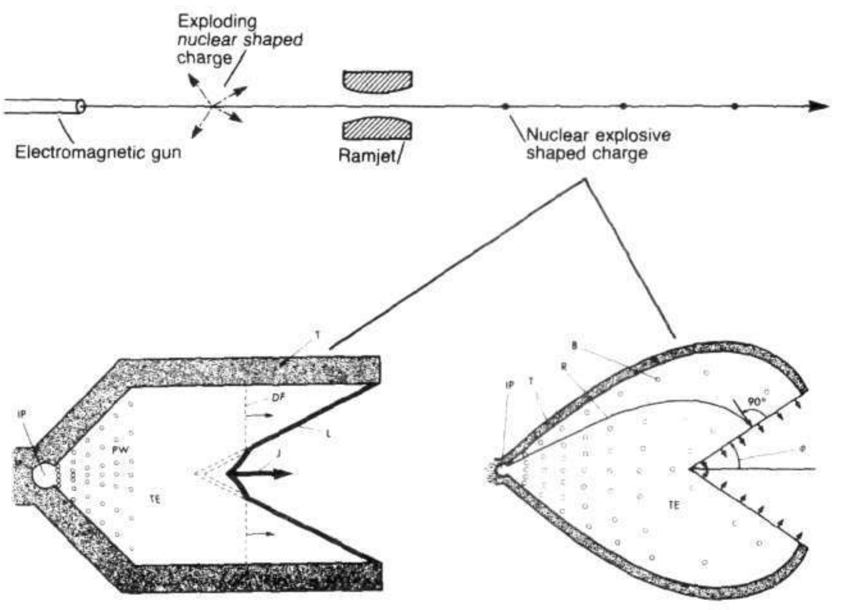


Figure 5
A NUCLEAR ROAD TO THE STARS
In this configuration an electromagnetic gun projects a "road" of nuclear explosions into space. The spaceship detonates the explosions, which then propel the vehicle forward.

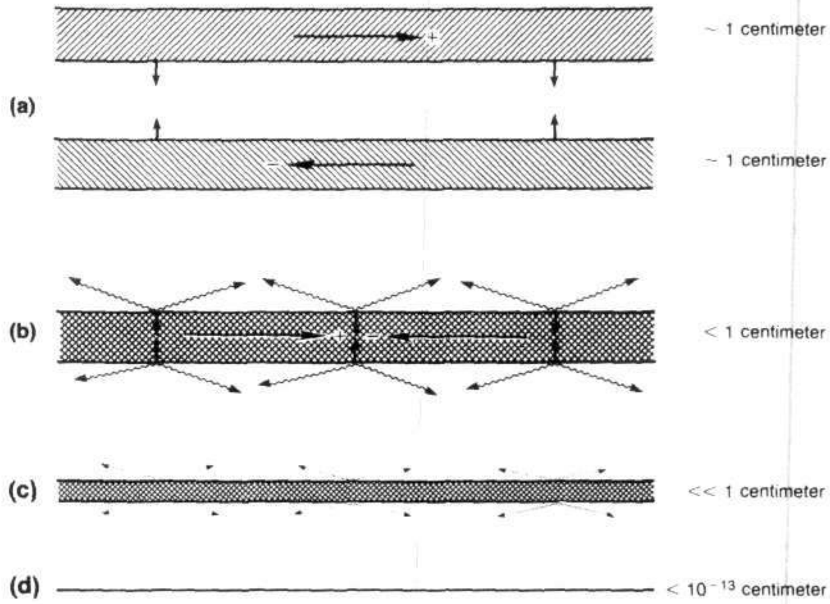


Figure 6
SCHEMATIC FOR RADIATIVE COLLAPSE OF AN ELECTRON/POSITRON PLASMA TO NUCLEAR DIMENSIONS
In this concept, a large number of positrons are created, accelerated to relativistic energies, and coalesced with a similar beam of electrons into a relativistic electron/positron plasma of counterstreaming beams. This beam will collapse to a diameter of nuclear dimensions, or perhaps smaller, creating an entirely new state of matter.

entirely new light.

There is a most unusual kind of pinch, for which, however, we have to first produce a very large number of positrons. To produce this very large number of positrons, we will need a plasma like hydrogen plasma that does not consist of electrons and protons, but rather of electrons and positrons (matter and antimatter). To make this plasma, we need to produce a very large number of positrons, which are electrons except that they have an opposite charge. And if a positron meets an electron, they annihilate each other into gamma radiation.

In the first step, we can produce a very large number of positrons with an ultraviolet laser. In the second step, we would have to accelerate the positrons to relativistic energies and make them form an intense relativistic positron beam; then we would do the same thing with electrons, except that we would accelerate them into the opposite direction. (We would not have to produce the electrons because they are readily available.) In the third step, we would make the electron and positron beams coalesce into a relativistic electron-positron plasma of counterstreaming beams.

Imagine that the beams occupy large rings or racetracks that can be many, many kilometers long. One beam goes in one direction and the other goes in the opposite direction (Figure 6a). Then both beams are oppositely charged, so they attract each other electrostatically and also magnetically. They would then coalesce into one electron-positron plasma. The electron-positron plasma would be electrically neutral, because the positive charges of the electron would be compensated by the negative charges of the positron-electrons. Opposite charges compensate each other and we get the positron-electron plasma shown in Figure 6b.

Such an electron-positron plasma would have a unique fate. First, if the particles move toward each other they collide. This collision of particles results in heating, so the electron-positron plasma gets hotter, an effect that would tend to blow up the electron-positron plasma. However, there is another effect acting in the opposite direction. Because the beams are relativistic, the particle oscillations perpendicular to the beam axis, produced by the particle collisions, lead to the emission of intense radiation that cools the electron-positron plasma. There are some situations where the plasma loses more heat this way, and loses it faster than it can produce by collisions. If the cooling exceeds the heating, then, the electron-positron plasma will collapse to a diameter of nuclear dimensions, and under some circumstances to an even smaller diameter (Figure 6). Therefore, we would have an entirely new state of matter, which exists in the universe only in neutron stars or in stars that are closely related to black holes. In neutron stars such densities are created in the nucleus by gravitational collapse; but here they are created by radiative collapse of a relativistic electron-positron plasma. Just prior to the collapse to its final state, the electron-positron plasma forms a fantastically narrow filament. Because of this, it would send out an enormous burst, not of soft X-rays, but of gamma rays, and that means very hard gamma rays.

What can we do now that we have a many-mile-long, racetrack-like relativistic electron-positron plasma? It would not only produce a gamma-ray beam of fantastically high coherence, because it shrinks down to nuclear dimensions, but also it would have an enormous energy release because it is a pinch of nuclear density. So we could use this gamma-ray beam to give energy to an interstellar spaceship, as Professor Oberth envisioned it (Figure 7).

We could project such highly coherent gamma-ray beams over immense distances, because the beam is so highly coherent and therefore so highly parallel.

Proton Decay

Let me return to the "physical-technical" conjecture again. Chemistry, which is the science of dealing with the outer electron shells of atoms, needed only the relatively small energy of a few electron volts. This posed no serious technical problems. In order to get to the megavolts needed to explore the atomic nucleus, particle accelerators were needed, and with them nuclear reactions became explorable.

According to Einstein's equation $E = mc^2$, nuclear reactions release only about 1 percent of the energy stored in matter. Fusion releases somewhat more than fission, but even at best only a few percent, so we never get out 100 percent of the energy. If one day, however, we develop machines that produce much higher particle energies, we may get into a situation where the decay of protons could be greatly increased.

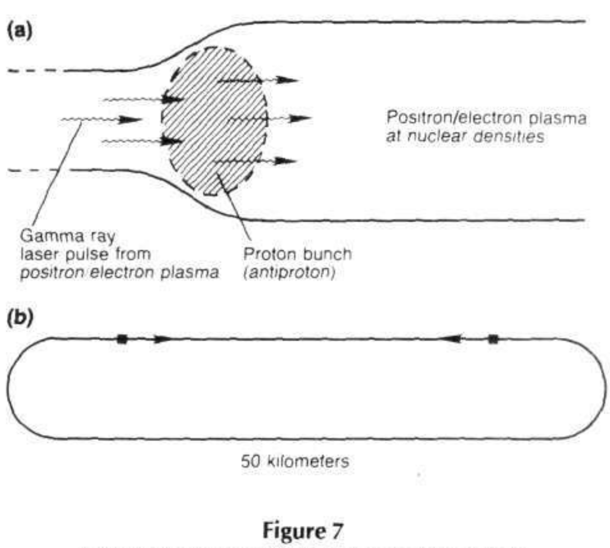


Figure 7
GAMMA RAY LASER ROAD TO THE STARS
A many-mile-long racetrack-like relativistic electron–positron plasma would produce a highly coherent gamma-ray beam of enormous energy. This beam could then be used to give energy to a spaceship, as Professor Oberth had envisioned it.

Physicists now are wondering if protons do indeed decay, since the evidence is not conclusive for or against. That does not mean they cannot decay. Radium decay was not easy to detect, requiring certain, very delicate measuring equipment. In the neutron-induced, nuclear chain reaction, however, the radioactive decay was enormously amplified, and the same may be possible with the proton decay, with a still-to-be-discovered effect. It is quite conceivable that protons also eventually decay through an interaction that becomes significant only if you have reached extremely high energies—many, many orders of magnitude larger than the largest particle energies reached.

More precisely, we need energies about a *trillion* times larger than the energies encountered in nuclear physics. There is some speculation that at this energy level, the strong and weak electromagnetic interactions are unified, and there may be another energy even a thousand times higher at which the ultimate unification with gravity may happen.

Conventional accelerators would be completely unsuitable for this purpose, because to reach these energies they would be many light years long. The only hope ever to reach these energies is the invention of entirely new technologies. It is here, where the collapsed electron-positron plasma may enter. We could, for example, make some sort of laser accelerator, in particular a gamma-ray laser accelerator shown in Figure 8. There the acceleration would take place with gamma rays, in the very highly dense matter, and enormous particle energies could be reached. If it is 50 kilometers long, it could reach the energy needed to make the proton decay.

For the SDI, of course, the development of such ultra-intense gamma-ray beams would be of great importance because they could easily puncture holes through the air and destroy incoming missiles.

Dr. Friedwardt Winterberg, a pioneer in inertial-confinement fusion, is a research professor at the Desert Research Institute, University of Nevada, and author of The Physical Principles of Thermonuclear Explosive Devices. *He is considered the father of impact fusion for his early work on thermonuclear ignition by hypervelocity. He has long been at the forefront of research on the implementation of nuclear energy for spaceflight. Born in Berlin, Germany in 1929, Dr. Winterberg received his doctorate in physics under Werner Heisenberg and helped design the research reactor of the Society to Advance Nuclear Energy for Naval Propulsion in Hamburg, West Germany.*

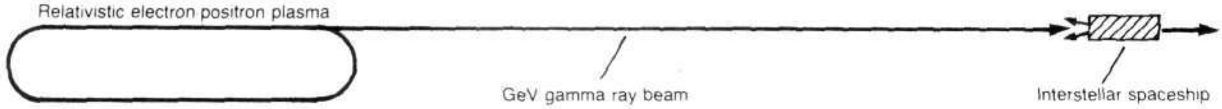


Figure 8
THE GAMMA RAY LASER PLASMA WAVE ACCELERATOR
Two bunches of protons or antiprotons would be launched from the opposite sides of the straight section of a long racetrack, hitting each other head-on.

An Interview ith 'Teachernaut' Judith Garcia

Teacher-in-space finalist Judith Garcia accepting a model of the aerospace plane from President Reagan Feb. 7.

'The Frontier of Space Beckons Irresistibly to Us'

Judith M. Garcia, a teacher of French and Spanish at the Thomas Jefferson High School for Science and Technology in Fairfax, Va., was one of the 10 national finalists to be NASA's first teacher in space. She is interviewed here by Joseph Cohen, a week after the Space Shuttle accident.

On Feb. 7, President Reagan visited her high school to present the first model of the "Orient Express" aerospace plane, the aircraft that can fly from Washington, D.C. to Tokyo in a little more than two hours. In accepting the model for the school, Mrs. Garcia talked about the challenge of space to teachers and to youth. "The frontier of space beckons irresistibly to us to explore its planets and moons. . . . The courage and dedication of the Challenger crew of seven will serve to inspire and guide us as we continue their journey to the stars."

Question: What sparked your interest in the space program?

I've been interested in the space program since the Soviet satellite Sputnik went up in 1957. However, at that time I was in high school, and as we began developing our own space program, a woman didn't dare dream of being a part of it. We could be interested in it, we could be curious about it, but we really weren't able to take part in it.

So I followed our trip to the Moon as a bystander, with anxiety, and hope, and all the emotions that every American and every other person in the world felt as the Apollo mission succeeded. I never lost my interest in the space program. Also I was very much affected by my first airplane ride.

Question: How old were you then?

I had my first airplane ride when I was 19. I was in Brazil, and I flew from Victoria to Rio in a Piper Cub. We went into a storm and the plane was between clouds, where I could look up above me and see sunshine and blue sky, beside me clouds, and beneath me the land and the sea. It was incredible. I could see lightning strike from one cloud to the other, and I could see riplets of silt going out across the white sand into the sea, and the sea changing color.

All at once my whole perception of everything came together, and from that new perspective I was no longer able, ever again in my life, to look at anything by itself. I've always felt that moment taught me that there is a whole picture of everything that we do. I've always tried to pull myself out of any situation and capture what that whole picture might be in any given situation.

I've really loved aviation. I've only recently had an opportunity to work on my pilot's license. I have a friend who has a plane and I have started taking lessons with him.

I got five hours' flight time in August, but I've been very busy since then and haven't kept up with it. It's a love that I have, though, and will continue.

Question: What we generally get from the media—apart from the good things they wrote about the Challenger—in an undertone and even directly, is that civilians are not ready for space flight and don't realize the dangers of it.

That's not true at all. The teachers who applied to NASA's program to be the first teacher in space weren't naive. They entered this program because they were interested in it. The NASA selection process weeds out all but those who are absolutely dedicated to doing their best in succeeding in this program.

The application itself was an unbelievable ordeal: 15 pages of essay questions. And by the time you went through the application and selection process, and NASA's briefing, if you didn't have an idea of what the space program was all about, its strengths and its weaknesses, you didn't belong in that group.

I feel that all of the 114 teacher applicants received a very, very good background on the development of the Shuttle, what its good points were, what we hoped would be improved later on, and so forth. Also, after we were selected, Commander Dick Scobee talked with the 10 finalists at length, discussing what we were facing. He very openly talked about the fact that it was a very dangerous thing. He said, of course we build the program on safety, but there's always that margin of risk involved, and the risk is very great.

If there is an accident, he said, it will be a very serious one. There really aren't small things that can happen. When you are in a launch procedure, there are many, many factors that go into that launch, and each one has critical points. Each and every one of us knew this.

Question: So the press was wrong on this question of risk?

They were absolutely wrong. To the contrary of saying the program is not ready, I think that the finalists felt that the Shuttle system had already proven itself trustworthy and safe; this was an accident. It's the kind of accident that has occurred with commercial flight, which is really a much simpler type of aviation. I think what we have to do is put all this in perspective.

It was a terrible tragedy, and it was unfortunate that it occurred with the first civilian in space. However, I don't feel that because we've suffered this tragedy, we should stop sending civilians in space. My feelings are so strong on this point that I can't emphasize it enough. We are not sending only our technology out in space, we are sending human beings out in space.

We are planning our first permanently manned space station. We are looking toward Mars. We are looking toward the Moon. What we're looking at in the very near future is a permanent presence of mankind in space. We've got to realize that they are human beings that we're sending out there, and with human beings you are sending up a culture, a civilization. That means we're going to have to have all kinds of people out there. And I believe that the civilians who are sent will play a major part in molding the way our future course is planned in space.

Question: How were the finalists trained and what sort of activities did you have?

We were given lengthy workshops and briefings as a group of 114 in Washington over a period of five days. These workshops gave us insight to the history of the space program, where we were, where we are, and hopefully where we're going. That in itself was a very, very comprehensive picture of the space program. Then as a group of 10 we were taken to Houston where we went through medical and psychological exams. They measured us in ways that are not done in a normal medical exam. For example, we had a dental examination that involved taking actual photographs of our teeth and the inner part of our mouths. Thorough laboratory tests were also run, and the cardiovascular systems received a great deal of attention.

The psychological exam was lengthy, and also very thorough, including a 2½ hour discussion with the psychiatrist.

We also had classes where we were taught about flight, the physiological changes that occur at different altitudes, and what we could expect and how to deal with it. We went through the physiological certification in the hypobaric chamber, where we took our oxygen masks off for a period of time so that we could experience symptoms of hypoxia.

We also flew in the KC-135 stratotanker [the military version of a 707] to experience weightlessness. We did 27 parabolas, [dive/climb maneuvers where zero gravity or weightlessness occurs when the centrifugal force pulling upward equals gravitational force pulling downward] which took over two hours to complete. In general, we were given every consideration I felt that we should have been given up to that point in our training.

We all had a taste of what it would be like. We all knew that we were physically and mentally able to deal with what would be before us. When the selection was completed and Barbara Morgan and Christa McAuliffe were selected as 1 and 2, they went to Houston to undergo far more training than it was necessary to give the rest of us.

Question: Can you tell us more about their training?

They went up in the T-38 as a preview of the accelerated flight that they would necessarily experience during launch. They also went through what you would call more serious in-depth training on how to handle themselves on the Shuttle during launch, reentry, and the time spent on the orbiter.

They were trained in detail as to what would be expected of them during each moment of the time they spent on the orbiter; what their duties would be, where to stand out of the way when they needed to, and where to take part when they should. They went up in the KC-135 again, I believe three times, to test the hardware that they were going to deal with.

Christa told me that there were times when she felt she was being overtrained, in that you repeat, and you repeat, and you repeat. And when I last saw her she said, "I know that you think that the training probably was one exciting moment after another, but in reality it often became very repetitious, very tedious. Now I can appreciate why we have to do this," she said. "I really am not concerned about thinking about what I'm going to do because I really feel now I can simply do it."

Question: What would you say to young people who want to be astronauts? What should they study? How should they prepare themselves for the future?

This is a question that many young people have been asking me. Basically, I have been telling them to prepare, but never close any doors before you reach the thinking that this is absolutely the goal you want to achieve in your life. Of course, anyone who wants to become a part of the space program knows and realizes there is a heavy need for engineers, scientists, researchers, doctors, biologists. In other words, there's a great need for people in science and technology.

I would encourage them to dig into their math studies, their sciences. I realize that these are not the easiest fields to take up, and often they might have to forego having a good time to study; this is a sacrifice that will have to be made for them to be outstanding in these areas. I believe that in our space program we're going to have to choose the most oustanding men and women to take up and lead us forward.

Again, I would advise them not to close their eyes to the humanities. Going back to the point I made before, we're *human beings* going up in space, and we can't lose sight of our humanity. I would encourage them, while they are studying science and math, to study the humanities for sensitivity about the role that the sciences will play in the history of mankind. Then they will be able to grasp a complete picture of the direction they are taking, a sense of purpose.

As far as looking to the space program in view of the recent accident, I would ask them not to take risks that are foolish risks, but to realize that in the exploration of any frontier there is an element of danger to be faced. Above all, we should always consider human life and protect it.

Question: This is how the United States was settled, isn't it?

That's exactly right, and as we moved West we lost many of our people. And as we've gone into many other endeavors, we've also lost many of our people. When you think of the Civil War, the American Revolution, and so forth, we've lost people who chose to fight to work toward a goal; they looked at the situation as it truly was, and accepted the possibility that they might lose. In a sense they haven't lost, though, for because of their sacrifices, we have now built a great country and a strong country, and we are now

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Probing Inside a Comet Tail

by Jim Everett

The International Cometary Explorer, known as ICE, passed through the tail of comet Giacobini-Zinner, only 4,880 miles from its nucleus, on Sept. 11, 1985. Moving at a speed of 12.8 miles per second, ICE safely zipped through the cloud of dust and plasma. All instruments worked perfectly and they transmitted important details of the comet's structure.

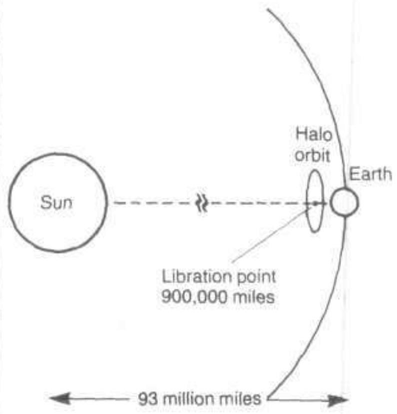


Figure 1
THE 'HALO' ORBIT
The so-called halo orbit is centered on a libration point, the place where the gravitational pull of the Earth balances that of the Sun. The satellite traces out a halo over the Earth.

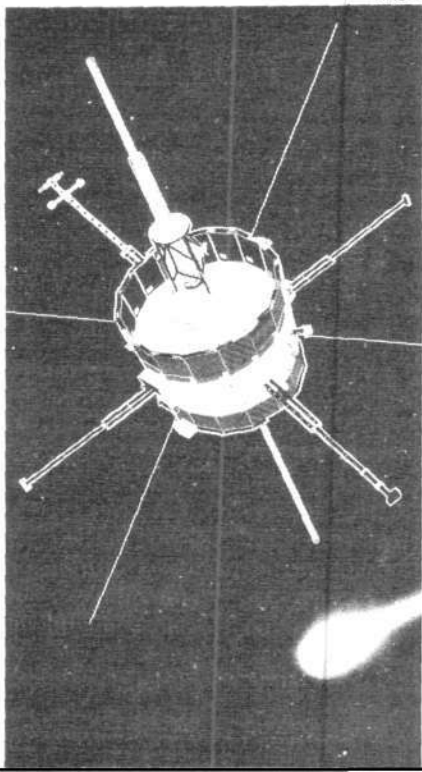
The ICE satellite was launched in 1978 with a different purpose and a different name. It started as a solar wind monitoring satellite called Interplanetary Sun-Earth Explorer or ISEE 3. NASA placed ISEE 3 in what is known as a halo orbit, so that it always stayed between the Earth and the Sun (Figure 1). The center of a halo orbit is the so-called libration point, the place where the gravitational pull of the Earth and the Sun are exactly balanced. Thus the satellite traces out a "halo" over the Earth.

Richard Farquhar, the mission's flight director, began exploring the possibility of moving ISEE 3 from its halo orbit to probe a comet even before it was launched. "I knew once in the halo orbit that the spacecraft could be moved all over the place," he said. When it became evident that NASA would not have enough funds in its budget to send a special comet satellite to meet Halley's Comet, Farquhar began to persuade solar wind scientists to give up their experiments in exchange for a comet mission.

Comet Giacobini-Zinner (G-Z for short) provided an ideal target. G-Z reaches perihelion (the orbit point closest to the Sun) near the Earth's orbit, making it possible to redirect the spacecraft with available on-board rockets and some help from the gravitational fields of the Earth and the Moon.

On June 10, 1982, ground controllers directed the satellite's rockets to fire, sending it out of the halo orbit and toward an intricate series of interactions with the Earth and Moon. After six more rocket boosts and five lunar passes (the last being only 60 miles above the surface of the Moon), the by-now-named ICE was on track for a rendezvous with G-Z.

NASA



The International Cometary Explorer is only 5.8 feet wide, but its antennae stretch 302 feet across.

ICE left the Earth-Moon system in January 1985, and it finally caught up with G-Z nine months later, on Sept. 11. The onboard instruments had not, of course, been originally designed for probing a comet. But the original solar wind experiments involved measuring magnetic fields, plasmas, and ion composition—just the stuff that makes comets so interesting.

No spacecraft had ever before visited a comet. In designing the experiments to be performed during the flyby, therefore, the ICE team had to rely on theoretical models. They expected that ICE would cross a well-defined "bow shock" before passing through the comet's tail. The bow shock is a region where the solar wind is deflected and decelerated by the plasma surrounding the comet.

Instead of finding a sharp boundary layer, ICE detected plasma waves gradually increasing in strength 84,000 miles before passing through the tail and again 60,000 miles later.

Inside the Tail

As a comet approaches and is heated by the Sun, it sublimates water, carbon dioxide, ammonia, and other gases, which are then ionized, or charged, by the solar wind. The Sun's magnetic field lines, which radiate radially, like the spokes of a wheel, were expected to "drape over" the cometary plasma, something like cooked spaghetti (Figure 2).

In this case, the theory proved correct. As ICE moved across the tail, it detected first magnetic polarity in one direction, then a neutral sheet, then magnetic field lines of opposite polarity, confirming the theoretical model. The presence of these draped field lines helps explain how comets keep their long tail so thin.

Inside the plasma tail ICE detected a sharp drop in protons, the main constituent of the solar wind, and a dramatic rise in electrons, 100 times more plentiful here than in the solar wind. One surprising feature of the plasma tail is its kinetic energy temperature of only 10,000 to 20,000 degrees, compared to the solar wind temperature of about 200,000 degrees. Also unexpected was the rapid changing of magnetic polarity and intensity inside the bow shock, indicating turbulence between the solar wind and the cometary plasma.

The ICE was equipped to measure the content of the comet's tail, but its instrumentation was not adequate for definitive results. It detected charged water molecules, some carbon monoxide ions, and an unknown ion of atomic mass 23 or 24, possibly sodium or diatomic carbon. The measuring time for this instrument was 20 minutes, which was just the time ICE was in the heart of the tail.

As ICE approached G-Z, some members of the research team worried that cometary dust would damage the spacecraft's sensors and possibly coat the solar cells, cutting off energy to the satellite. In fact, there was neither damage nor a drop in energy during the flyby. The plasma wave instrument actually detected less than one tenth the dust particles predicted.

The ICE mission is not over yet. It will twice cross the orbit of Halley's Comet, and NASA scientists hope to measure changes in the solar wind.

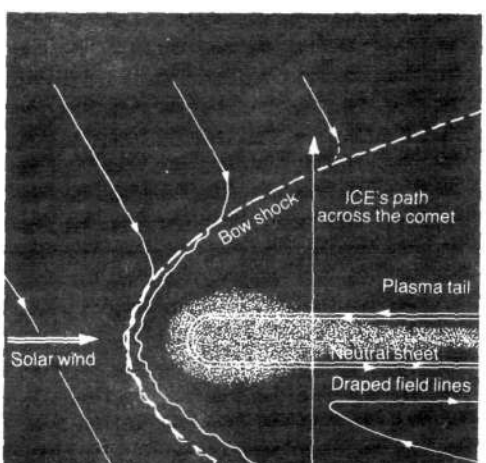


Illustration not drawn to scale.

Figure 2
MOVING THROUGH THE COMET TAIL
As scientists had predicted, when the ICE satellite had its rendezvous with the tail of the Comet Giacobini-Zinner, the spacecraft found the magnetic field lines of the Sun draped over the comet's plasma tail like cooked spaghetti. As ICE moved across the tail, it detected magnetic polarity in one direction, then a neutral sheet, and then magnetic field lines of opposite polarity. It is thought that these draped field lines keep the comet's tail thin.

Interview with Judith Garcia

Continued from page 59

building a great, strong space program.

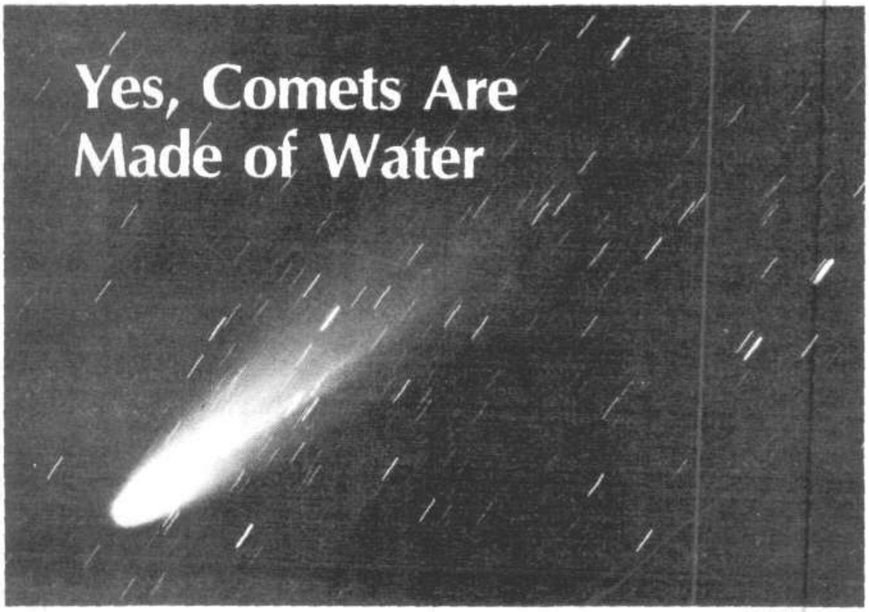
I would want the young people to understand that any risk that they ever take should be a calculated risk that they understand thoroughly and then go forward as courageously as the Challenger crew went forward into the future.

Question: You mentioned that this is for all humanity. Do you think it might help other parts of the world, such as Africa, to have the goal of sending an astronaut into space?

Are you saying that we could use space to create peace on Earth? I think that an African would be a marvelous person to select. Again, I really feel that what we're doing up there is creating another area where mankind is going to have to live and work together.

Space is not going to be a monolingual area, nor an arena for just one nation. We're all going to see that our space program requires international cooperation. Sharing the space experience with people of all nations would be a way of creating an understanding of this new frontier that would only enhance the ability of mankind to deal with problems on Earth—as well as to avoid the same problems in space.

Yes, Comets Are Made of Water



Lick Observatory

Comet Halley in a time-exposure taken with the telescope at the Lick Observatory at the University of California in Santa Cruz. The streaks are stars as the camera records their motion over 20 minutes.

Since 1951, scientists have tried to prove astronomer Fred Whipple's theory that comets were "dirty snowballs." Until December 1985, all they had was indirect proof from observing fragments that showed that the major ingredients of comets are ice and water.

Direct proof came from a telescope sent up by NASA in an aircraft, flying at an altitude of 41,000 feet, that measured the infrared spectra of Halley's comet. A modified C-141 aircraft, operated by NASA's Ames Research Center in California and fitted with a special 36-inch diameter telescope from the University of Arizona, operated way above any ground-based telescope, Dec. 21-23. At that height, scientists in the Kuiper Airborne Observatory were able to make the first direct observation confirming water in a comet.

Using the Infrared Spectrum

These recent observations used the special instrumentation and telescope developed by scientists Harold Larson, D. Scott Davis, and Michael Williams from the University of Arizona. Before this, scientists were able to detect only the by-products of the postulated underlying ice. These by-products consisted of oxygen and hydrogen atoms, molecules like OH (one oxygen and one hydrogen atom), and positively charged water molecules.

The recent discovery stems from a new theory on spectroscopy, presented at a March 1980 conference by Dr. Michael Mumma of the NASA Goddard Space Flight Center. Mumma suggested that the parent molecules, in this case water, can best be detected by measuring their infrared fluorescence spectrum when stimulated by sunlight.

His theory, which has been confirmed independently by scientists in France and Japan, predicts in precise detail the wavelengths and relative intensities of infrared spectral lines emitted by gaseous water and other parent molecules that should be present in comets.

The use of an airborne telescope was necessary to get beyond Earth's atmosphere, because the water vapor in our atmosphere will absorb some of the spectral lines under observation. Using this airborne method, spectroscopic studies done by the scientists at the University of Arizona detected water in Jupiter's atmosphere 10 years ago.

Over the past 20 years, scientists first tried to confirm the presence of water in comets using radio astronomy telescopes. Later they used satellites, like the International Ultraviolet Explorer. But these instruments did not show the presence of water, according to Dr. Harold Weaver of Johns Hopkins, because water "does not fluoresce in the ultraviolet, and the new theory shows that water's radio spectral lines are too weak to be seen."

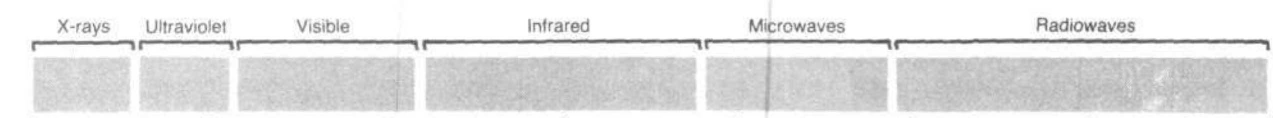


Figure 1
THE ELECTROMAGNETIC SPECTRUM

The light we see is the visible part of the electromagnetic spectrum of energy, which ranges from the very long wavelengths of heat to the very short wavelengths of ultraviolet light and X-rays. Infrared waves are too long for our eyes to see; microwaves and radiowaves are even longer.

The Arizona spectrometer can detect the particular wavelengths emitted by the comet when it is stimulated by sunlight. Similarly, scientists use satellite-based spectrometers in order to find the infrared "signatures" for different kinds of plants or rocks on Earth.

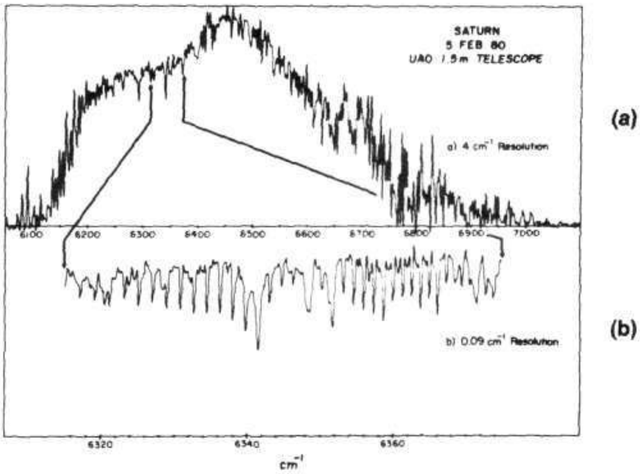


Figure 2
MAPPING THE SPECTRA OF THE PLANET SATURN

The new spectrometer developed at the University of Arizona greatly increases the resolution possible. Shown in (a) is a section of the spectral signature of the planet Saturn's atmosphere taken in 1970 with a resolution of .4 centimeters. The present high-resolution instrument produced the detail shown in (b), at .009 centimeters.

The Results

Mumma's theory of infrared fluorescence of water predicted accurately the presence of 10 spectral lines of water in the cometary coma surrounding Halley's nucleus. Observations Dec. 21 showed 4 of the 10 predicted lines; then on Dec. 23, all 10 were seen.

These differences were attributed to changes in the comet itself. According to Weaver, "the brightness of the water lines, across the board, increased by a factor of 3" between the observations. "Finding such dramatic variability in the comet's behavior was a surprise in itself," he commented.

Until now, scientists worked backward, observing only the fragments of the comet, to try to understand the dynamics of these celestial bodies that produce such magnificent comas and tails as they approach the Sun. Now they have a powerful tool for direct measurements and identification of the parent molecules.

The NASA/Arizona University team is planning to observe comet Halley again from March 21-27 flying the Kuiper Airborne Observatory in the southern hemisphere near Australia. They will be looking for both water and methane in the comet, hopefully compiling the first complete map of a cometary coma for these two substances.

—Marsha Freeman

'Trailmaster'

Continued from page 21

gimes. This can most immediately be seen in the fact that simply irradiating material with long wavelength infrared electromagnetic radiation does not directly lead to the generation of nuclear transformation, no matter how intense the irradiation; while short wavelength gamma ray electromagnetic radiation will induce nuclear transformations in a wide range of materials, at even extremely low levels of irradiation.

Trailmaster provides an economical, readily accessible, and versatile means of exploring the widest range of high energy, energy dense physical regimes and will vastly expand the existing frontiers of basic science and applied technologies.

Superphenix

Continued from page 11

ious commonly used moderators, capture sufficiently few neutrons to make a chain reaction possible in natural uranium.

Although fast neutrons are not very efficient in splitting U-235 nuclei, they can do other things that make them very attractive in the breeder. First, they can split U-238, which since it is more common, means that between 10 and 15 percent of all fissions in a fast breeder are from fast neutrons. Therefore, fast neutrons are responsible for that amount of the energy produced.

More important, the neutrons hitting uranium-238 have a high probability of being captured and creating uranium-239, which rapidly decays into neptunium-239 and then into the more stable plutonium-239. Fast neutrons are very efficient in fissioning plutonium, so by converting unproductive uranium-238 into the highly fissile plutonium-239, the neutrons produce energy.

The breeder requires two neutrons per fission—one to produce the plutonium and one to split it—whereas conventional thermal reactors require only one neutron per fission. This need for two neutrons per fission is offset to a large extent by the fact that when a fission is triggered by a fast neutron, it releases more neutrons than when triggered by a thermal neutron. When fissioning U-235, for example, each fission releases on average 2.05 neutrons in a thermal reactor and 2.46 neutrons in a fast reactor; when fissioning plutonium, each fission releases 1.96 neutrons in a thermal reactor and 3.03 in a breeder.

Criticality is easier to reach in the breeder because its core can be more dense than that of a conventional reactor, since it needs no moderator.

In order to have a reactor breed—regenerate fissile material from nonfissile material—fast breeders utilize covers, called fertile blankets. These are made of depleted uranium, a "waste product" of enrichment plants, and they capture neutrons that normally escape from the core. The fuel in the core is slowly depleted in fissile material, but the blankets are progressively getting enriched at a quicker rate, and thus breeding more fuel than the breeder consumes.

Several plans are in the works to follow-up Superphenix. The original plan was a concept called Rapides-1500, a plant with two reactors akin to Superphenix, but optimized to a power of 1,500 MWe. The lack of determination by the managers of the program, however, has delayed any decision on this concept. The economic crisis also has sharply reduced the energy consumption expectation for the decades to come; therefore, creating the perception that breeders will not really be necessary for 20 to 30 years. Because the electricity produced by Superphenix is more expensive than usual nuclear electricity (though it is still much cheaper than fossil-fuel power plants), the current idea predominant in the industry is to "just keep the concept alive," instead of going for a bold development program.

Such thinking forgets that Superphenix is an industrial prototype, and therefore understandably more expensive than a conventional nuclear plant. If future breeders were constructed at the same pace as conventional nuclear plants have been built in France, the price per kilowatt hour would fall to levels similar to or just slightly above the current nuclear electricity prices.

After the Superphenix

Discussions are going on now about the construction of only one other Superphenix, perhaps just slightly improved in terms of optimization, thus bringing the power for a reactor of the same dimensions to 1,500 MWe. There are also discussions about building this second reactor in West Germany, but officials are unenthusiastic about this option, because they fear that the German Greens would stall any project there.

Superphenix still is a technological jewel, and France can certainly not afford to dismantle the highly skilled worker/engineer teams that have proven their excellence. Even if thermonuclear fusion and perhaps fission-fusion hybrid breeders ultimately will replace today's fast breeder, we cannot afford "burning our dry wood" carelessly, without regard for future generations.

Laurent Rosenfeld is editor-in-chief of the French-language Fusion *magazine.*

Killing the Comatose

Continued from page 9

state." Kopelman's ruling backs the unanimous decision of the staff and board of New England Sinai Hospital not to take the life of their patient, Paul Brophy, because they view their "primary function as prolonging the life of a patient."

Since March, 1983, Brophy, 48, from Dedham, Mass., has been in what is called a "locked in state." This means that he may have some sensory appreciation of what is happening around him, but is unable to communicate or give a response, because of paralysis in pathways controlling voluntary motor response.

Brophy turns away from noxious stimuli, recoils from tickling or pain, and, like the patients mentioned above, is considered quite healthy. He is neither "terminally ill" nor "brain dead" and depends only on a plastic tube for daily feedings.

His family, however, asked his physicians to starve and dehydrate Brophy last spring. The hospital refused and the family went to court.

Brophy's physician, Dr. Richard A. Field, told the court: "Bringing about death through starvation and dehydration is a barbaric and savage way to induce death. . . ." He compared what the Brophy family wanted to do with the horrors he saw when he helped liberate Nazi concentration camp survivors: "I saw literally thousands of people who had been subjected to dehydration and starvation, both dead and dying. I think Brophy is in good condition and it is going to take a lot of starving [for him] to die," Field said.

Judge Kopelman agreed. We reprint here segments of the "Procedural Background, Findings of Fact, Conclusions of Law" from Judge Kopelman's decision of Oct. 21, 1985.

Starvation: A Scientific Description

"107. If food and water are withheld from Brophy pursuant to the guardian's request, his prognosis will certainly be death from starvation, or more probably from dehydration, which would occur within a period of time ranging from a minimum of four days to a maximum of three weeks.

"108. During this time, Brophy's body would be likely to experience the following effects from a lack of hydration and nutrition:

"(a) His mouth would dry out and become caked or coated with thick material.

"(b) His lips would become parched and cracked or fissured.

"(c) His tongue would become swollen and might crack.

"(d) His eyes would sink back into their orbits.

"(e) His cheeks would become hollow.

"(f) The mucosa (lining) of his nose might crack and cause his nose to bleed.

"(g) His skin would hang loose from his body and become dry and scaly.

"(h) His urine would become highly concentrated, causing inflamation of the bladder.

"(i) The lining of his stomach would dry out causing dry heaves and vomiting.

"(j) He would develop hyperthermia, very high body temperature.

"(k) His brain cells would begin drying out, causing convulsions.

"(l) His respiratory tract would dry out, giving rise to very thick secretions, which could plug his lungs and cause death.

"(m) Eventually his major organs would fail, including his lungs, heart and brain.

"109. The above described process is extremely painful and uncomfortable for a human being. Brophy's attending physician was unable to [imagine] a more cruel and violent death than thirsting to death."

Finally Judge Kopelman found:

"27. A society which rejects euthanasia, the selective killing of the unfit, the insane, the retarded, and the comatose patient is morally obligated to sustain the life of an ill human being, even one in a persistent vegetative state. . . ."

The decision has saved Brophy only temporarily, for the pro-euthanasia "ethicists" and the Brophy family, determined for what they call a "dignified death," have appealed the decision.

According to varying estimates, there are anywhere from 5,000 to 100,000 people in the United States in the same highly disabled, comatose, or permanently uncommunicative states like the victims mentioned here. Judge Kopelman's ruling vividly describes the horrors these human beings face if we allow this Nazi policy to take hold.

Interview with Klitzing

Continued from page 31

analyzed it as a function of temperature, magnetic field, and so on, but at that time we we did not succeed in making the breakthrough, because we had a certain line of thought. We assumed, then, that for the Hall resistance it was necessary to know the magnetic field and other magnitudes. And therefore we measured the magnetic field and all the other magnitudes and calculated something.

We did not see then that this was the wrong way. This is why I can precisely determine the hour of birth of this new effect. It was not a new type of curve that I saw, but only the idea to interpret these curves in a new way, to go in a different direction, by introducing a measure relative to the fundamental constants. Therefore, I know precisely that it was Feb. 5, 1980 that I had the idea that we had to go into a different direction.

The curves and measurements taken afterwards only looked somewhat nicer; essentially they had been known for five years.

Question: Do you consider yourself more a theoretical physicist or an experimental physicist?

Today I would consider myself exclusively as an experimentalist. I have to conduct an experiment and in that way recognize problems. In fact, I am only successful when I am involved in an experiment myself. It is much more difficult to develop something at the desk.

In most cases, things go somewhat differently than planned. During an experiment you must have a feeling in your fingertips of what is important and what not: What do I have to understand? Is what I don't understand, important or unimportant?

I think, I have a little bit of this "feeling in my fingertips," which lets me see during the experiment what is important.

And then, there is the capability for enthusiasm—that you stick to an interesting statement of the problem. You cannot say, "Now my work day is over," for, possibly, by the next day the sample has changed or you may not find your thread again. Sometimes, you have to do 10 percent more, but this, then, yields 100 percent more.

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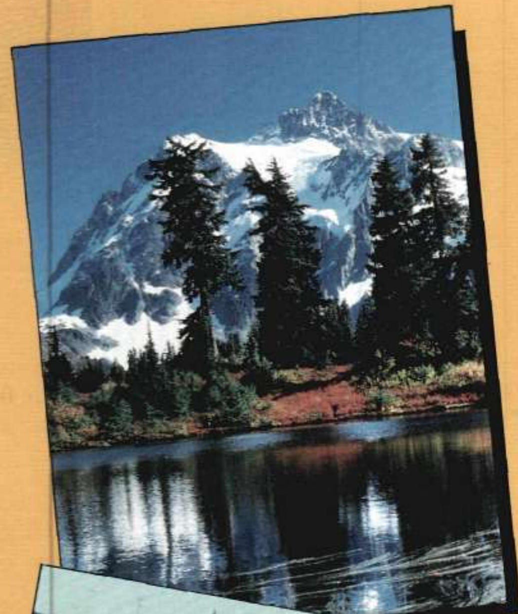

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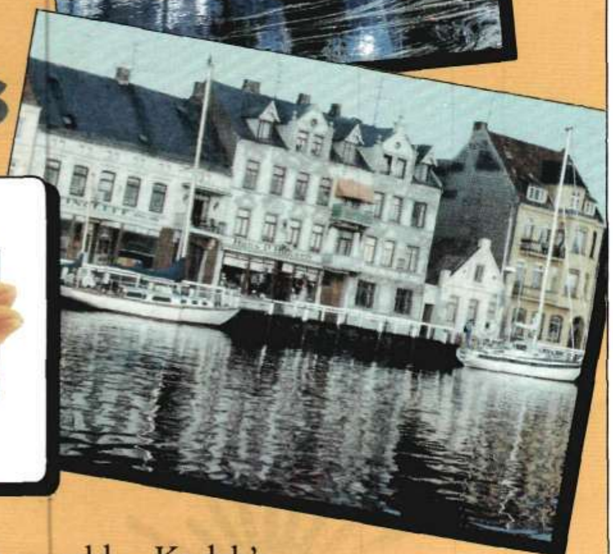

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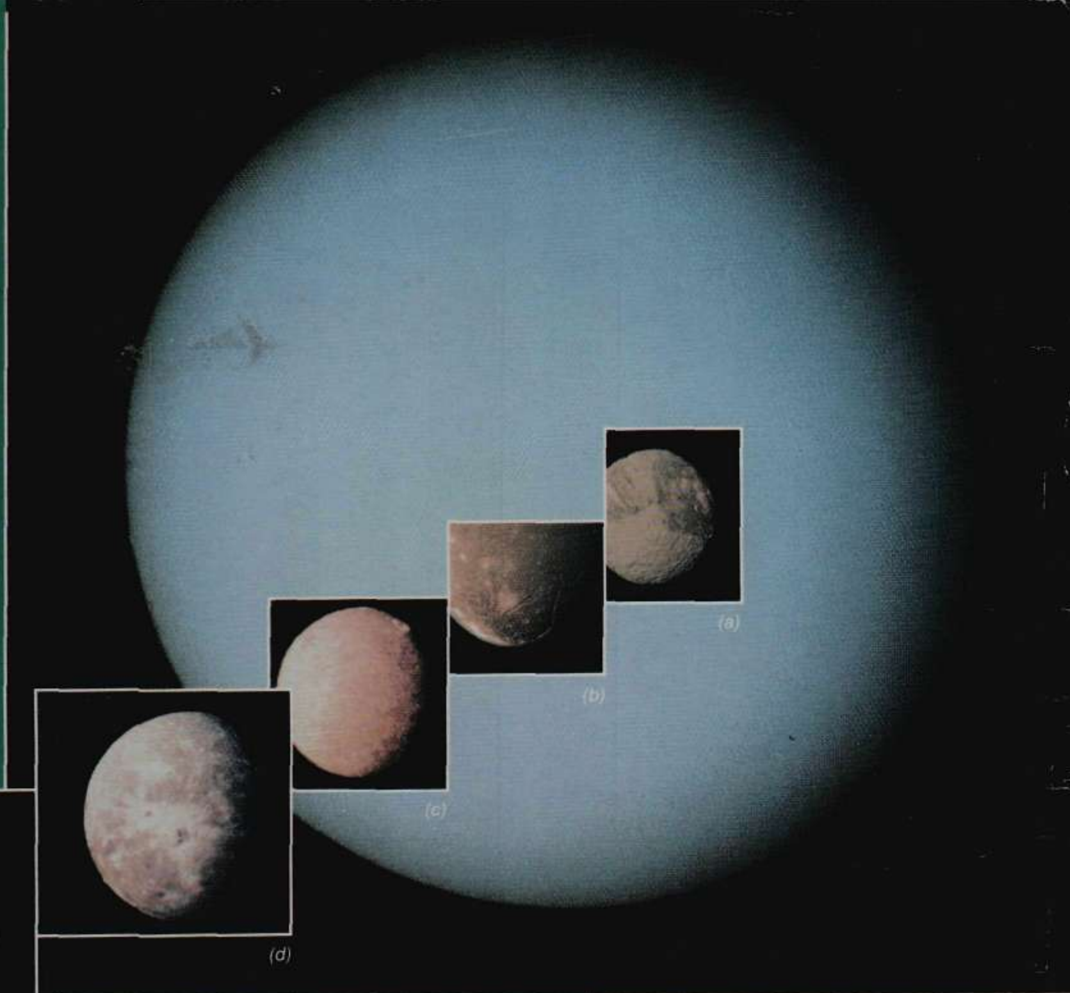
In This Issue

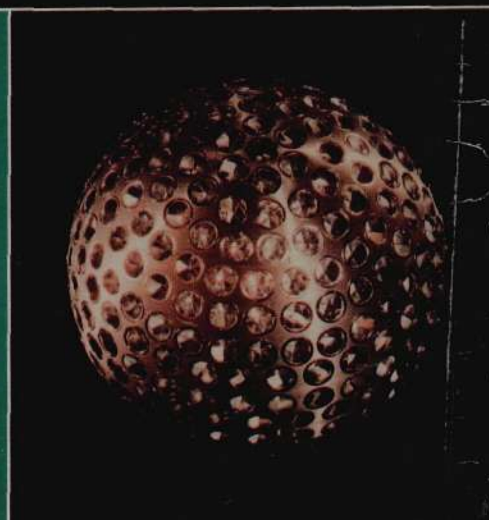
THE UNUSUAL NEW WORLD OF URANUS

In its brief flyby of Uranus, Voyager 2 gave us far more knowledge of this distant planet than astronomers have been able to accumulate over the past 200 years. Marsha Freeman and Jim Everett review the preliminary data and discuss the surprises—from Uranus's ring system to its magnetic field. They also take an in-depth look at how the spacecraft was ingeniously retooled by NASA in midflight by remote control to be able to send maximum information to Earth from a distance of 3 billion miles.



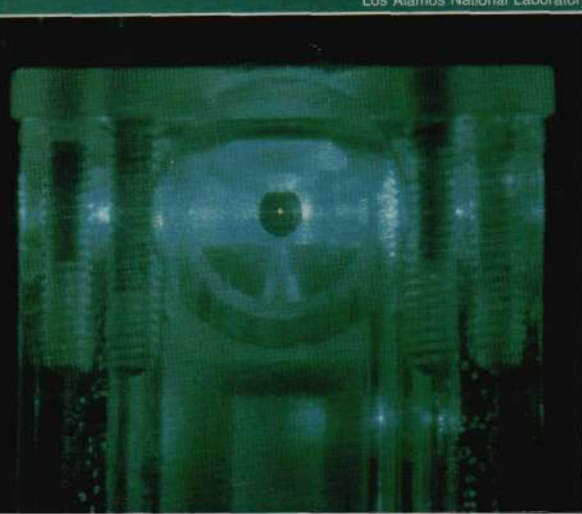
NASA

Uranus as it would appear to the human eye, in a photo taken by Voyager Jan. 17 from a distance of 6 million miles. Superimposed on the planet are its five major satellites, (a) the innermost moon Miranda, (b) Ariel's southern hemisphere, (c) Umbriel, (d) Oberon, and (e) Titania.



A half-scale model of the Lageos geodynamic satellite, launched in 1976, which tracks the Earth's crustal and rotational motion.

NASA



A close-up view of the flow chamber cell sorter of the flow cytometer. The yellow laser beam is shown intersecting the stream of cells.

Los Alamos National Laboratory

WHY IS THIS SATELLITE FALLING?

According to the accepted laws of physics, the Lageos satellite is in geodynamic orbit in a near-perfect vacuum and should not be falling. Yet scientists have measured a 1.1 millimeter drop per day in its orbit. The fascinating answer to this puzzle, provided by physicist Benny Soldano, challenges the fundamental "law" of physics that gravitational and inertial mass are equivalent. In our Research Report, Dr. Robert Moon and Carol White interview Soldano and comment on the significance of his work.

HOW LASERS CAN HELP DEFEAT AIDS

One of the spinoffs of the beam defense program, the flow cytometer/circular intensity differential scattering technique developed by Los Alamos National Laboratory, has the potential to detect—and possibly kill—retroviruses like AIDS that have become amalgamated to the cell structure. Wolfgang Lillge, M.D., discusses why we need a "biological SDI" to push this technology to commercialization.