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January-February 1989

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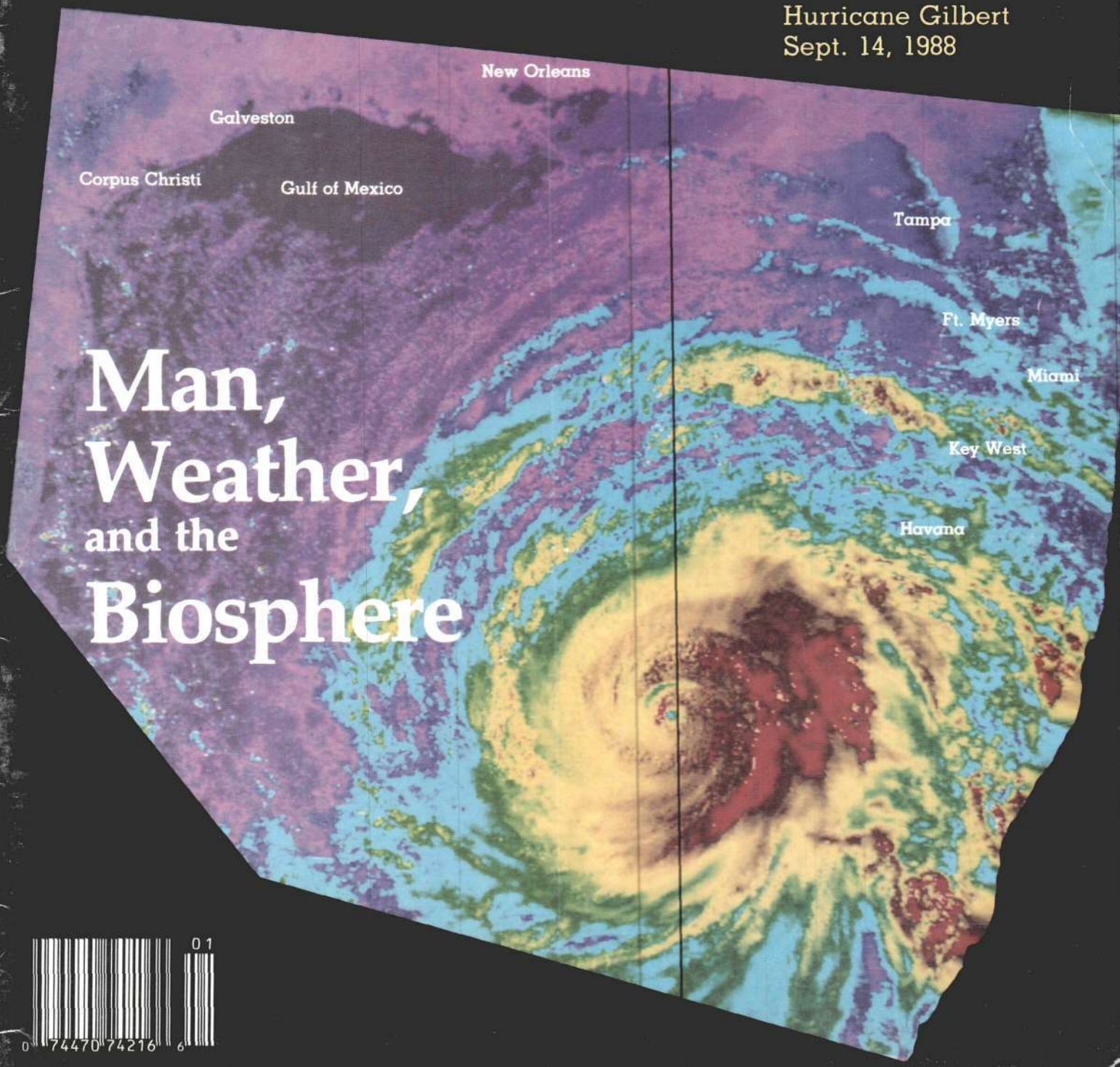

Hurricane Gilbert
Sept. 14, 1988

Man, Weather, and the Biosphere

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21st CENTURY SCIENCE & TECHNOLOGY

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Features

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On the cover: Visible image of Hurricane Gilbert approaching the Yucatan Peninsula, Sept. 14, 1988, taken from the NOAA-10 Polar Orbiter satellite using data from the Advanced Very High Resolution Radiometer. Winds were 175 mph, gusting to 205 mph and barometric pressure at the center of the storm was 891mb—a stage 5 hurricane. The color enhancement is used for dramatic effect; the highest clouds are lighter in color, the lower clouds are darker. Photo courtesy of NOAA, National Environmental Satellite Data and Information Service; cover design by Virginia Baier.

Let's Save the Biosphere

The call by Dr. Dixy Lee Ray for a new scientific organization that will battle on behalf of technology is a welcome intervention at a time when news headlines bombard us with antiscience propaganda. (See Viewpoint, page 6.) Fifty years after the discovery of nuclear fission, when we know more than ever about radiation and its effects, the media continues to run scare stories about radiation levels less than those received in a cross-country airplane trip or risks less than those involved in taking a bath. We urge readers to join in Ray's effort to make *scientific fact* the basis on which decisions are made, instead of the currently accepted *factoids*, as she terms them.

As this issue makes clear, there are real environmental problems. For example, the devastation of the rain forests in Brazil (and worldwide) must be stopped if we are to maintain the delicate world weather system. This is not a question simply of protecting trees, but of protecting the potential of the entire biosphere to develop. The solutions bandied about by the various Malthusian groups campaigning against modern technology would shut down industry and eliminate population allegedly to protect these trees.

Our solution is the opposite: We must gear up for a great *expansion* of both industry and population. In fact, the world needs more people—10 billion of them, in order to keep up with the coming fusion-powered economy. This fact alone sets the agenda for what we have to do to bring the far reaches of the globe up to and beyond the living standards of the industrialized sector.

The Development Agenda

The only way to ensure that the biosphere continues to develop is to make use of the most advanced technologies to produce enough safe and cheap energy to industrialize the world. This means an aggressive plan to mass produce modular nuclear plants, to bring on line the advanced nuclear technologies (like the high-temperature gas-cooled reactor and the advanced breeder reactor), and to push the nuclear fusion program into commercialization in a decade or so. It also means activating those great projects that have been in the blueprint stage for decades to build the electrical grids, bridges, railroads, dams, highways, water systems, and so on, that will bring the Third World out of miserable poverty and into 20th century living conditions. At the same time, of course, the advanced sector would have to gear up its industries and rejuvenate its infrastructure in order to be in a position to export the technologies and workers needed abroad.

The inspiration for such an ambitious program comes directly from Genesis: "Go forth and multiply. Dominate the earth and subdue it." Man's mission to turn this Earth into his garden could not be clearer.

This perspective puts us in direct opposition to the pseudoenvironmentalists, who self-righteously promote themselves as the "stewards" of nature. Such organizations, like the World Wildlife Fund, proclaim that they are hard at work saving various species, from trees to whales. Yet they know that their policies would condemn men to death, especially those of brown, black, or yellow skin. To these environmentalists, man is the enemy, a spoiler; the more population, the more nature is spoiled.

That such policies spell death is well documented: The antinuclear activities of these so-called environmentalists over the past two decades created a situation here where "public perception" became more important than scientific truth, thus ensuring that the United States did not build the number of nuclear plants it had planned in the late 1950s and early 1960s under the Atoms for Peace program. The results can be measured in the numbers of deaths that occurred because the economy lacked the advantage of more efficient nuclear power. In 15 years, according to our calculations, 115 million people needlessly died—people who would have lived had the world economy had the benefit of nuclear power.

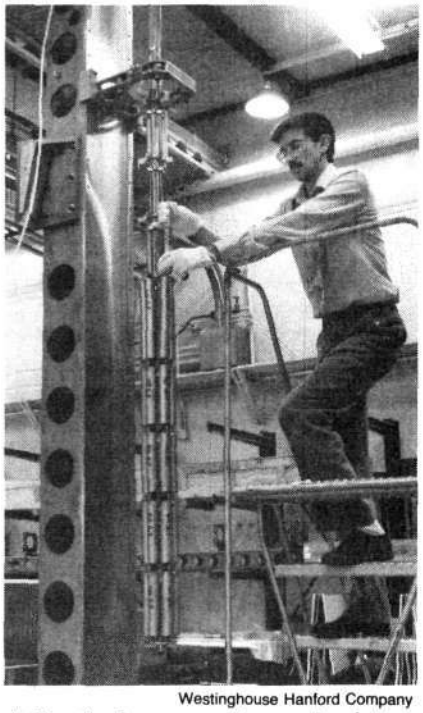
Similarly, the antipesticide activities here since the 1970s are responsible directly or indirectly for 100 million deaths *per year* in the developing sector—a chilling indictment of those groups who made their reputation and money singing paeans to lost whales, or disappearing snail darters.

As we start a new year and a new administration in January 1989, just a decade away from the 21st century, the promise of science and technology for uplifting the condition of mankind has never been greater. Yet, this promise, unlike some prophecies, is not self-fulfilling; those who understand the promise must stand up and wage a political fight to make it happen in our lifetimes. The penalty for inaction is not simply that we will have to wait longer for technologies to be developed, but that our civilization will be buried by the 20th century antiscience barbarians and their media allies who hold sway over popular culture and public education.

NEWS BRIEFS

FIRST FUSION MATERIALS TEST UNDER WAY AT HANFORD REACTOR

The Fast Flux Test Facility (FFTF) operated by the Westinghouse Hanford Company in Richland, Wash., in early 1989 will begin irradiating a test assembly of potential materials for use in fusion reactors. The Materials Open Test Assembly will be irradiated in the FFTF to determine the behavior of lithium oxide, beryllium, and other materials as they undergo intense heat and irradiation. These materials are being considered for use in future fusion reactor power plants. The FFTF is a multipurpose sodium-cooled reactor operated by Westinghouse for the Department of Energy. The test assembly features 30 test canisters that can house thousands of different materials specimens under precise operating conditions. U.S., Japanese, and Canadian laboratories are participating in the test.



Westinghouse Hanford Company

A Westinghouse engineer checks on the array of canisters in the new Materials Open Test Assembly. The 40-foot high assembly will be inserted in the FFTF and irradiated for more than a year to test the effects on fusion materials.

JOINT EUROPEAN TORUS ACHIEVES RECORD FUSION TEMPERATURE

The Joint European Torus or JET set record temperatures of about 200 million degrees in October 1988 and sustained them for more than 1 second. In addition, the fusion occurred at the desired density—100,000 times thinner than air. "We're very proud of our results, even though we're still a long way from the final product," said JET spokesman John Maple. JET, a cooperative project of the 12 European Community nations, is based in Culham, England, and is the world's largest tokamak.

STUDY SHOWS U.S. STUDENTS TO BE ILLITERATE IN SCIENCE

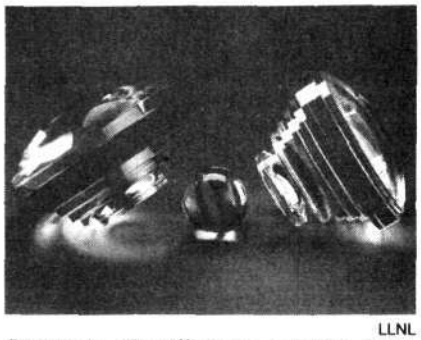
The National Assessment of Educational Progress, which has measured science achievement among 9-, 13-, and 17-year-olds since 1969, found that only 7 percent of the 17-year-olds tested in 1986 were prepared for college-level science courses and that their science achievement was well below that of students tested in 1969. "Our nation is producing a generation of students who lack the intellectual skills necessary to assess the validity of evidence or the logic of arguments, and who are misinformed about the nature of scientific endeavors," stated the panel of educators who interpreted the results of the study.

FOOD IRRADIATION PIONEER MARTIN WELT TO APPEAL SENTENCE

Food irradiation pioneer Dr. Martin Welt is appealing the two-year jail sentence and $50,050 fine imposed by Judge Maryanne Trump Barry in federal district court in Newark, N.J., Oct. 11. Welt's sentence, which is extraordinary in a case concerning technical violations of Nuclear Regulatory Commission regulations, climaxed a witch-hunt against him and nuclear technology in general by prosecutor Jacqueline Wolff, "environmental crime" coordinator in New Jersey.

NEW 'POPEYE' LENS CAN TRACK MISSILES, METEORS, AND STARS

Scientists at Lawrence Livermore National Laboratory and the Perkin-Elmer Corp. have developed a wide-field-of-view, high-resolution optical system with applications in systems that track incoming energy missiles or track stars as part of a satellite navigational system. The new system, called Popeye, has an image powerful enough so that a satellite-mounted camera could photograph the state of Virginia from a height of 600 miles and still see individual buildings. Popeye uses lens designs composed of spherically shaped elements whose radii of curvature are concentric about a common center point. The image surface is also spherical, sharing the same center point as the lens. Thus, the optical system generates an image surface with between 5 and 10 billion resolvable spots. The first generation of Popeye lenses have a 60° field of view, a 250-mm focal length, and an 89-mm diameter effective light-collecting aperture.



LLNL

Popeye's 89-millimeter camera lens, prior to final assembly.

Letters

Mistaken Paternity

To the Editor:

I am mistakenly credited with being the "father of the plasma focus" in the Sept.-Oct. issue of *21st Century* ("The Plasma Focus Fusion Device—Universal Machine of the Future," by Charles B. Stevens).

I would like your readers to know that this honor belongs to others: The actual parents of the plasma focus in Europe are N.V. Filippov and T.I. Filippova, and in the United States, Joseph Mather of Los Alamos National Laboratory.

Winston Bostick
Corrales, New Mex.

Engineers Sought on Aeromechanical Model

To the Editor:

I wish to correspond with interested and sophisticated aerodynamical and aeromechanical engineers on the general subject of my "Universal Aeromechanical Mathematical Model" and its applications.

I have developed this model for the most part from extensive reading and comparing in standard or classical (or fortuitous) mechanical or aeromechanical literature. My own primary training having been in mathematics, I have developed and added equations which evidently were both necessary and unavailable.

Using this universal model, I have performed extensive studies and comparisons of some 40 conventional, unconventional, military, civilian, experimental (and apochryphal) aircraft. My model enables one to calculate and insert most missing significant performance parameters, in tables and descriptions, which I have done for these aircraft.

Also, it enables one to derive performance parameters independently, which may then be compared to printed or published parameters. This also I have done, and found generally good agreement.

Further, using this same universal model, I have developed some 11 or 12 design versions of my own planned V/STOL/amphibious/sub-or-supersonic ("discraft") aircraft, and sought to extensively compare these calculated results, respectively with conventional or known experimental aircraft, of similar gross weight.

The result of one such vehicular performance comparison for my ultralight discraft design indicates a very significant performance margin in many parameters. Roughly proportional large performance margins have also been indicated by other analyses I have done, in which I pitted my own discraft design against conventional and known experimental vehicles, of similar, greater, or much greater gross weight.

The questions arise, (1) is my universal model both correct and complete, and (2) have I been applying it correctly? I hope that some aeromechanical/aerodynamical engineers will take an interest in helping me answer these questions.

John H. Bloomer
4851 SE 115th Avenue
Portland, Ore. 97266

Fluid-Dynamic Lift and Drag

To the Editor:

21st Century readers may be interested in obtaining two volumes by Dr. S.F. Hoerner, *Fluid-Dynamic Drag* and *Fluid-Dynamic Lift*. These works constitute the best set of published data on lift and drag in all sorts of media under varying conditions. They allow the beginner to see the depth of the subject area and the similarities in be-

Continued on page 64

Space Has a Structure

by Dr. H. Aspden

Dr. H. Aspden is in the Department of Electrical Engineering at the University of Southampton, England. He was formerly director of IBM's European Patent Operations. His article, "Project G: The Quest to Control Gravity," will appear in a future issue.

In the May-June 1988 issue of *21st Century*, Emeritus Professor Robert J. Moon gave sound reasons for a breakthrough in our attitudes to the understanding of the nature of space.[1] He pointed to the 1985 Nobel Prize winner Klaus von Klitzing who was recognized for his achievement in devising a way of measuring to great accuracy one of the most fundamental constants in physics. This is the fine-structure constant, a dimensionless number of approximately 1/137, but one which relates the basic electron charge, the Planck radiation constant, and the speed of light.

Vacuous space is a universal medium regulating the speed of light and the energy quanta that couple Planck's constant and the frequency of that light. Moon realized that the theoretical model of the semiconductor processes involved in von Klitzing's measurement of the fine-structure constant had replicated the form of the vacuum itself. The vacuum must have structure and it must incorporate characteristics defining that standard electrical charge we associate with the electron.

Moon has examined the way in which the structured vacuum interacts with protons and neutrons to locate them in that structure when they constitute atomic nuclei. This subject was discussed in detail by Laurence Hecht in a related article.[2]

The structured vacuum is an ether in modern form. It is not the old fashioned ether of the 19th century that raised the problem of understanding how its fluid form could sustain Maxwell's formulation of electromagnetic wave propagation. It is not the absolute ether that the famous Michelson-Morley experiment in 1887 sought to establish.

In those days, the liquid crystal technology of the late 20th century was not in sight. Now that it is, we have the benefit of hindsight and can ponder on the interesting possibility that the vacuum is like a fluid crystal. It has a structure that can conform in the presence of matter and dissolve into the background in response to optimum electrically based controls. It can comprise a virtual lepton field, leptons being particles known to be created and annihilated in pairs of opposite electric charge and featuring in vacuum-field interactions.

Such phenomena were not part of the physics known to Michelson and his world of the 19th century ether.

The Structured Vacuum

Unquestionably it is the structure of the vacuum that determines Planck's constant and causes it to be universally the same throughout the cosmos. Just as the properties of crystals are uniform in their effects upon light rays, wherever those rays impinge, so the structure property of the vacuum itself plays its role in ensuring uniformity of light speed and the Planck relationship between light frequency and energy quanta.

Moon is right in declaring that von Klitzing's discovery has implications for the structured vacuum property. No longer can those who advanced such ideas in the past be treated as dabbling with an old-fashioned ether and lacking the enlightenment of the relativistic doctrine.

There is enough evidence in Albert Einstein's own writings to show that he had always in mind the underlying existence of an ether.[3] Yet those who followed Einstein have sought to deny that

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VIEWPOINT

Who Speaks For Science?

Dixy Lee Ray, former head of the Atomic Energy Commission, has called for the formation of a new organization—the American Association for the Advancement of Technology—that would be a voice for technology and win America's support for a revival of faith in the applications of science. She told the winter meeting of the American Nuclear Society Nov. 1, that the U.S. nuclear industry had to stop being "doormats" for the antinuclear movement. "We need to have an information network to keep ahead of the antinuclear activists, she said, and she stressed that the controversies plaguing the nuclear industry are political, not technological problems.

Ray, now retired, was named in 1977 as one of the top 10 most influential women in the United States. A marine biologist who taught zoology for many years, she also served as governor of Washington State from 1977 to 1981.

This viewpoint was adapted from a longer article in the August 1988 issue of Imprimis, *published by Hillsdale College.*

Repeatedly, over the past few years, the American public has been subjected to a litany of catastrophe—to predictions of impending disaster that are claimed to be unique to modern civilization: The oceans are dying, the atmosphere is poisoned, the Earth itself is losing its capacity to support life.

The reported "hole" in the ozone layer is the most recent scare. Cancer, generally blamed on man-made chemicals, is rampant—so the doomsayers say. Warnings that in the past came from the pulpit and called for eternal punishment in the sulfurous fires of hell have been replaced by equally dire predictions that come from alarmist environmentalists who call for spending billions of dollars in order to avoid doom from the sulfurous effluents of industry. The anticipated catastrophes are our own fault, of course, blamed on the greedy and perfidious nature of modern man.

Well, it's all pretty heady stuff, but is it true? As with so many issues that involve technology, the answer is probably rather more "no" than "yes." In these areas of concern, there is clearly a dichotomy between what is known and understood by the predominant body of scientific experts—and what the public believes because of the information it gets. But what the public perceives to be true, even if it is wrong, has enormous consequences since it is public opinion that determines how public funds are spent.

Dr. Dixy Lee Ray

The answer to this vexing problem of what the public believes is always the same: Educate the public. To which I respond with a simple question: How? It seems so reasonable to conclude that once people understand how good and safe and environmentally benign a technology is, they will accept, if not welcome it. It seems reasonable to expect the public to be grateful for techniques that can mean responsible cures for environmental problems. But clearly it doesn't work that way because calm reason and alarmist environmentalism cannot coexist.

A Time of Optimism and Progress

There was a time, in my long-ago youth, when experts were believed. It was a time when most people and most institutions were presumed to be well-meaning and honest until and unless proved to be otherwise. It was also a time of unprecedented increase in our knowledge about the world, of belief in ourselves, and in our ability through understanding and logic to provide adequate solutions to technical problems.

It was a time of optimism and progress. It was a time of improvement in the conditions of living that made our society and our nation the envy of the world. It was a time when the use of knowledge was expected, when the myriad applications of science through technology made living on this Earth easier and better, and gave us more time to enjoy it by increasing our life span beyond three quarters of a century.

The funny thing is, it's still that kind of time . . . but it seems that hardly anyone enjoys it anymore. Too many people have exchanged confidence for despair, too many have come to fear technology and to hate and reject anything nuclear or chemical-related. Despite all the evidence of our physical well-being beyond the dreams of all previous generations, we seem to have become a nation of easily frightened people, the healthiest hypochondriacs in the world!

A Rotten Job of Teaching Science

What has brought this condition about? What has made us lament rather than rejoice, so quick to believe the worst about ourselves and so reluctant to recognize the good?

Well, among other possible explanations, we have simply done a rotten job of teaching science. Oh, not to those students who will become scientists—we're quite good at that—but at the equally important job of teaching science to all those others, the overwhelming percentage of the student population who will not enter science or engineering as a profession; there we fail miserably.

And so, we must ask further, if not from the schools and colleges, where

do most people get their information about science and about important applications of technology in modern society? The answer is easy: mainly from television, and, to a lesser extent, from the print media and radio. Who decides the content of this information? Not scientists, but reporters, news directors, and editors. It is said that Professor John Kemeny, chairman of the President's Enquiry into the accident at Three Mile Island, commented after dealing with the press about his report:

"I left Washington fully expecting to read the following story someday in one of our morning newspapers. 'Three scientists named Galileo, Newton, and Einstein have concluded that the Earth is round. However, the *New York Times* has learned authoritatively that Professor John Doe of Podunk College has conclusive evidence that the Earth is flat.' "

If we want people properly educated in science and therefore more competent to make rational decisions on technical matters that affect them, then we have to recognize that scientists, technologists, and engineers do not and cannot inform the public directly. The media inform the public. And in doing so, the media act as an information filter. The bottom line is that science and the media must learn to work together for a common purpose, because there is simply no other mechanism that can provide the necessary scientific information to society for social decision-making. So far, unfortunately, this rapport between science and the media shows no signs of developing.

There could hardly be two more diverse professions and it is no wonder that misunderstanding and misrepresentation arise. The good scientist strives to be precise by qualifying his statements and staying within the context of a scientific discipline. This is usually done in a deliberate manner. The good reporter strives for a fast response, for a compact statement that is reasonably accurate. Above all, a good reporter makes his statement in a manner designed to make the greatest impact on the audience. Therefore, information flowing from the scientific environment to the media environment inevitably suffers alteration and filtration, and this affects public perceptions. In this regard, there appear to be three main problems.

"The public will remain uninformed and uneducated in science until the media professionals decide otherwise, until they stop quoting charlatans and quacks, and until respected scientists speak up."

(1) An understandable, though unfortunate, emphasis on conflict between technology and social interest makes good press, but often unnecessarily heightens anxiety. The public will accept bad news, but it has been conditioned to reject good news as whitewash.

(2) False, exaggerated, or misleading information persists because it is made believable by constant repetition. This leads to dissemination of what we call *factoids*. Examples of factoids are: PCBs cause cancer; any level of radiation is harmful; acid rain is caused by sulfur dioxide from burning coal.

There are dozens of such factoids, that is, beliefs that have little evidence to support them. Some come about from the mistaken assumption that if two phenomena occur together or follow one another, they must represent cause and effect. Some come from an initial distorted opinion of a scientist desiring publicity for a cause or political position, or from a zealous reporter trying to make a name for himself.

(3) Since good scientists limit their remarks within disciplinary boundaries and good reporters extrapolate into a broad or common context, the result is often misinterpretation. "I was misquoted," says the scientist—and vows never to talk to a reporter again. Such a reaction is a mistake because it leaves the responsibility of communicating with the media to those scientists who avoid peer review for their work, have a mission or "cause," or are charlatans or quacks. Science has its quota of the latter just as does every profession.

Scientific Responsibility

It is up to good scientists to weed these phonies out, but we don't do it. Rather, we allow, by our silence, such renegade organizations as the Union of Concerned Scientists to present itself as the "voice of the scientific community." They back up the Helen Caldicotts, Barry Commoners, Paul Ehrlichs, Amory Lovinses, and other pretenders. While the respected scientific community judges very strictly those at the top of their profession, they simply ignore the incompetents and no-good at the bottom. It is left to others of courage like the Hon. Patrick F. Kelly of the U.S. District Court in Kansas to say in November 1984 what we should have been saying all along:

"This Court rejects the opinion testimony of Dr. Karl Morgan and Dr. John Gofman because they both evidence an intellectually dishonest invention of arguments to protect their opinion. . . . This is not a situation where the scientific community is equally divided between two respected schools of thought. It is a case where there is a small but very vocal group of scientists, including Dr. Morgan and Dr. Gofman, that holds views not considered credible by experts in the field."

We should be very jealous of who speaks for science, particularly in our age of rapidly expanding technology. A misinformed or uninformed public can stop anything even when it is clearly in society's benefit. How can the public be educated? I do not know the specifics, but of this I am certain: The public will remain uninformed and uneducated in science until the media professionals decide otherwise, until they stop quoting charlatans and quacks, and until respected scientists speak up.

The Lightning Rod

Dear Ben:

You are older and wiser than the rest of us, so perhaps you can help me with a problem I'm having.

Do you remember Smokey the Bear? When I was a little boy, Smokey was always around—gazing sternly at me from wall posters, trash barrels, even ads on buses and subway cars. With variations, Smokey always said the same thing. Don't toss that lighted match out your car window. Douse that campfire, and make sure it's out. "Only you can prevent forest fires."

This past summer, when I read about the fires in Yellowstone National Park, I realized I hadn't seen Smokey around for quite awhile. It turned out he'd been replaced on the subways by a "Crimestoppers" dog who instructs you to lock up your domicile and refrain from wearing your gold neck chains in public.

I always thought Smokey was pretty stiff and self-righteous, for a bear. But I've got to admit that after reading about the forest fires which burned up half of Yellowstone Park, I kind of miss Smokey and his lectures.

Since Smokey's day, the motto in our national parks has changed. "Only you can prevent forest fires" has been replaced by "No one should prevent forest fires."

Under a 1972 law passed when the "ecology" frenzy was in full swing, I learned forest fires were being treated as natural occurrences in the nation's parks. Government policy was "let them burn," in the belief that, in the words of the *New York Times*, "fire is a natural part of the forest cycle."

This policy was so firmly rooted, it turned out, that this past summer a lot of trees burned down because this old, rotten "stump" of a policy couldn't be pulled up. Even after July 21, when U.S. Secretary of Energy Donald Hodel ordered the National Park Service to fight all forest fires because of the severity of the drought, nothing was done until three weeks later.

Why? Let me quote from a *New York Times* article on the subject dated Sept. 22, 1988 by Timothy Egan:

"Park officials were not simply hoping that nature would snuff out the fires. As guardians of the park, they said they were trying to protect pristine areas from the destructive effects of bulldozers, fire engines, and irrigation pipes.

"In one case, park rangers chastised a firefighting crew for crossing a meadow with their truck to put out a spot fire; the crew was threatened with citations for destroying park vegetation. Several helicopter pilots say restrictions on where they could dip their large buckets for water made firefighting more difficult. And even at the height of the fire, bulldozers were only allowed into the park case by case."

Evoking the spectacle of the bulldozers filling out environmental protection forms in triplicate, while the woods blazed merrily away, the *Times* tells us, however, that none of this mattered, because "highly unusual weather conditions and extreme winds produced fires that no amount of heavy equipment could have stopped."

Still, some people clearly thought it was wrong even to try. "Fire is a benign, not a malignant force," the *Times* quoted Yellowstone's chief naturalist

George Robinson. When Secretary Hodel gave the order to fight the fires, they were burning in a few thousand acres. The order was not obeyed; instead, trucks and bulldozers were threatened with citations, and fires destroyed about 1 million acres.

"We're not villains," naturalist Robinson told the *Times*. " We wouldn't have devoted our lives to this park if we were." Mr. Robinson sounds a little bit like the fireman who hooked his pumper wagon up to the gas tank by mistake, trying to explain later how it wasn't his fault the house burned down. His intentions were good.

My father told me about firebreaks and counter-burning to contain fires back in my Cub Scout days—when Smokey was still around. Whatever happened to that cranky old bear?

Sincerely,
"Lonesome for Smokey"

My dear friend:

According to the environmentalists, "man is unnatural," and therefore whatever man does, somehow "interferes with nature."

Perhaps the environmentalists became uncomfortable with Smokey because they thought he was acting too much like a human being—taking responsibility for taking care of nature, not just leaving it alone.

One story I have heard is that the bear was banished for putting up signs that said, "Please do not feed the environmentalists."

I understand that there are some bears over in Moscow who agree with the Club of Rome that the only thing men and women can do really well is to mess things up.

But most of our American bears, like Smokey, take a more optimistic view of things—and I think we can persuade him to come back to give a good scolding to the foolish people who don't believe it is mankind's responsibility not just to maintain nature, but to improve it.

Your obt. svt.

Benj. Franklin

Time to Free Bangladesh From Nature's Fury

by Ramtanu Maitra

The 1988 flooding in Bangladesh, which has claimed more than 1,000 lives and destroyed crops and properties upward of $1 billion, is a clear warning that unless the annually predictable "accident" is stopped now through proper planning, this nation of more than 105 million people is doomed forever.

The enormity of flood devastation has caused a ripple within the usually unperturbable international agencies. Even the U.S. Agency for International Development has expressed its desire to join other donor nations in supporting the efforts of countries in the region to formulate a regional water management program for the Ganges-Brahmaputra basin that will prevent such crippling floods from occurring in the future.

More important, Bangladesh President H.M. Ershad came to New Delhi on short notice for personal discussions with Indian Prime Minister Rajiv Gandhi on an urgent approach to harness the mighty rivers. A day-long meeting between the two resulted in the establishment of a task force to take a fresh look at short-term as well as long-term measures to deal with the floods in the northeast and eastern part of the Indian subcontinent.

Located at the confluence of three major rivers—the Ganges, Brahmaputra, and Meghna—Bangladesh acts as a flood plain through which a massive volume of water passes down to the Bay of Bengal. Besides the "big three," there are 49 other rivers that flow through Bangladesh or merge into the major rivers. None of them originates in Bangladesh itself; many originate in the southern slopes of the Himalayas north of Bangladesh. These small rivers carry swift-flowing waters which, on impact with the wider rivers they feed, create a hydraulic ram effect and cause them to overflow.

The Multinational Brahmaputra

Of all the rivers, however, it is the Brahmaputra that causes the greatest amount of damage. Originating in southwest Tibet, the Brahmaputra (known as Tsang Po to the Tibetans) winds eastward for 1,625 kilometers along the northern foothills of the Himalayas before swinging sharply southwest into India. Out of its 2,906-kilometer journey, beginning at the Kanglung Kang glacier to its final destination merging with the Ganges about 200 kilometers upstream from the Bay of Bengal, the Brahmaputra traverses only the final 363 kilometers through Bangladesh. Since the Brahmaputra is an international river, multinational collaboration is required to tame it.

Located at the confluence of major rivers—the Ganges and Brahmaputra are shown here—Bangladesh acts as a flood plain through which a massive volume of water passes down to the Bay of Bengal.

In past decades, a number of proposals have been presented to deal with the river. By a 1980 Act of Parliament, the government of India set up the Brahmaputra Board, which prepared a detailed master plan of the Brahmaputra Basin. The plan called for establishing 15 large storage dams on the Brahmaputra's tributaries, including large dams on the Dihang and Subansiri rivers in Assam. However, the proposal lost its way in the maze of bureaucracy and petty quibblings.

In addition to the Brahmaputra Board's proposal, the Mitsubishi Research Institute in 1977 put forward the concept of damming the Tsang Po river in the upper reaches of the Brahmaputra in the frontier area between China and India and diverting some of the water into India through a tunnel across the Himalayas. The Mitsubishi group pointed out that such a plan would not only control floods, but also generate *30 gigawatts* of power.

The Rao Plan

In 1972, Dr. K.L. Rao, an eminent Indian engineer, envisaged a comprehensive plan that would revitalize the Ganges and at the same time control the waters of the Brahmaputra for effective use. Rao's plan included transfer of Brahmaputra water to the Ganges in the east to augment the flow of the latter during the dry season. A link canal, connecting the two rivers, was proposed to run through the northern tip of Bangladesh.

Rao's proposed canal is 200 miles long—of which one third falls in Bangladesh and two thirds in India. It is ½-mile wide, 30 feet deep, and diverts about 100,000 cubic feet per second of Brahmaputra water into the Ganges. Rao also proposed a series of storage

Continued on page 63

Thailand Builds Its Own Laser

by Sophie Tanapura

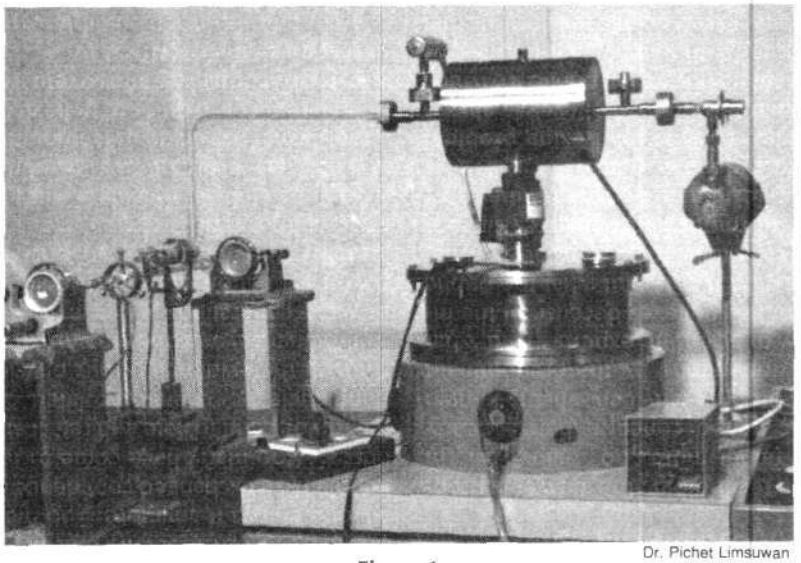
"Thailand is the first ASEAN nation to develop its own laser," Associate Professor Pichet Limsuwan of the Physics Department of King Mongkut's Institute of Technology, says proudly. The breakthrough occurred in 1987 when the indigenously developed helium-neon laser lased successfully for the first time, after eight years of perseverance in laser research and development.

Pichet is a graduate of Chulalongkorn University who earned his doctorate in optics at Pennsylvania State University in 1978. When he returned to Thailand, he was immediately given the task of repairing some 30 imported helium-neon lasers then in use in laboratories and classrooms. Two of these were at the Institute of Technology.

What began as an attempt to repair the broken imported lasers grew into a program to develop Thailand's own lasers. Pichet explained: "We only had one thing on our minds—how to save Thailand's hard-earned foreign currency by fixing the helium-neon lasers ourselves. The imported lasers were all broken in the same manner. Due to both high humidity and thermal variation, the metal electrode seal and the glass vacuum tube did not expand at the same rate. The tube broke, letting air into the vacuum. As a result of seeking to repair the electrodes, we can now build our own lasers and we have our own glassblower."

Looking back over the eight years, Pichet remarked, "We did not realize in the beginning that the helium-neon laser was a very difficult laser to start with, much more difficult than the medical carbon dioxide lasers, or we would have done it the other way around.

"The reason for the difference is that the helium-neon laser has low gain; that is, its efficiency is only 1 percent or less. Hence we must build it to specifications that will maximize its efficiency, using the formula $pd = 3.6$ to 4.0 torr-millimeter, where p is the pressure of the helium-neon mixture in the laser capillary tube and d is the inside-diameter of the tube. This leads to an inside-diameter of only about 2.5



Dr. Pichet Limsuwan

Figure 1
EXPERIMENTAL SETUP OF THE HELIUM-NEON LASER
Work on this helium-neon laser began in 1979, using only local materials (except for the mirrors). The laser tube is made of capillary pyrex tubing of inner diameter 2.5 mm and 450 mm length. Both ends are closed with optical glasses at Brewster's angle. The tube is placed between two dielectric coated mirors that serve as the external optical cavity. The laser tube was evacuated to 1.0 × 10^{-7} mbar before the helium-neon mixture was admitted. The laser output was measured at different gas pressures from 1 to 5 mbar.

mm. Now imagine the difficulty of getting the mirrors on the ends of the tube correctly aligned!

"In contrast, the efficiency of the CO_2 laser is in the range of 10 to 30 percent, so we can use a tube of almost any size, for example, in the range from 1 to 5 centimeters. It is correspondingly easier to get the mirrors aligned."

Industry Support

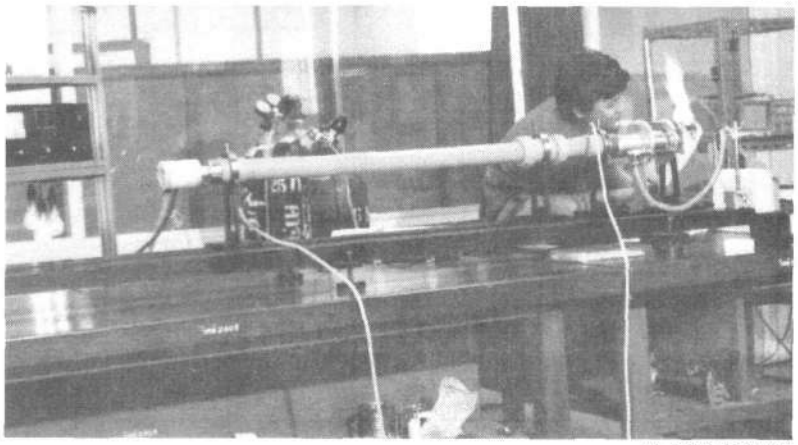
Excitement is building around the helium-neon laser, as many textile, metal, and automotive industries are beginning to subsidize the Institute's Physics Department in experiments with cutting and drilling various materials. Other sectors of the Thai economy that can use lasers are the paper, wood, and electronics industries.

Pichet, who heads the laser research and development program at the Institute, plans to put a new emphasis on medically useful lasers. Pichet foresees medical applications as one of the greatest benefits of laser technology in Thailand, and is gathering a group of physicians around the medical laser project. He makes the existing medical carbon dioxide laser at King Mongkut's Institute of Technology available free of charge to any interested doctor for laser surgery. Medical lasers are used, for example, in the surgery of bones, joints, and cancerous tumors, as well as eye surgery.

"Because we started with one of the most difficult lasers," Pichet said, "the others will seem very easy by comparison. While it took eight years to develop the helium-neon laser, I expect it will only take us about three months to develop each of the planned medical lasers. And believe it or not, once you have developed your own program and can show that it works, money is not a problem."

With government support, R&D programs are now underway for a 2-kilowatt CO_2 laser for materials processing and medical lasers of the CO_2, dye, and yttrium-aluminum-garnet (YAG) types.

The Physics Department of King Mongkut's Institute of Technology at Thonburi offers a bachelor of science degree and plans to add a master's degree program next year. There are about 120 students in the department, where the emphasis is on applied science and engineering.



Dr. Pichet Limsuwan

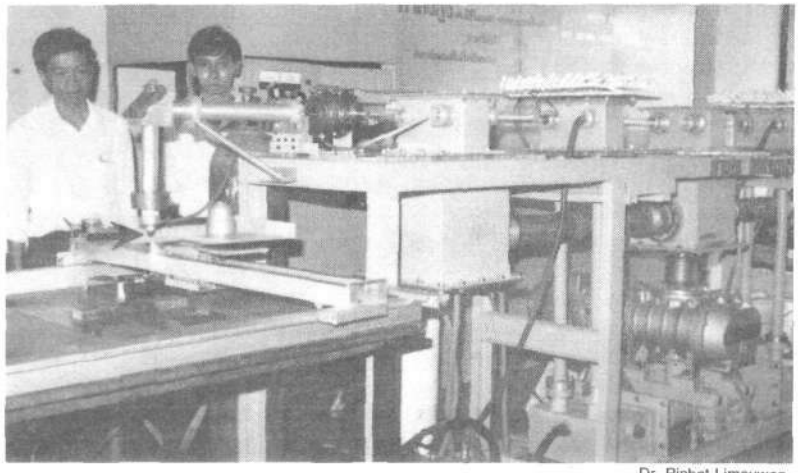
Figure 2

THE SLOW AXIAL FLOW CARBON-DIOXIDE LASER

In 1982, work began on a three-phase, slow axial flow carbon-dioxide laser, the first of its kind to be built in Thailand. A gas mixture of CO_2, He, and N_2 is injected into one end and is sucked out at the other.

The laser tube of pyrex glass has a diameter of 38 mm and an adjustable length of 1.20 to 2.40 m. It is encased in a PVC water pipe seen above, which cools it. One end of the laser tube is closed with a gold-coated mirror and the other with a zinc-selenium output window.

The alternating current of 380 volts—used by industries in Thailand—is transformed to direct current, variable from 0 to 12kV, for use in this laser. All materials are local except for the imported zinc-selenium output window through which the infrared radiation of the laser must pass. The laser functioned for the first time in 1985 at an output power of 40 to 80 watts.



Dr. Pichet Limsuwan

Figure 3

THE FAST AXIAL FLOW CARBON-DIOXIDE LASER

After completion of the slow axial flow laser, the Physics Department built a high-power CO_2 laser with an output of about 1kW, suitable for industrial use in the cutting, drilling, and welding of various materials. Although still under development, it is capable at present of cutting pieces of wood and plastic 4 mm thick and steel plates 2 mm thick. Above, students watch as a 1-kW CO_2 laser cuts a steel plate (the arrow points to the cone of sparks).

A medical CO_2 laser capable of both continuous (10W) and pulsed modes has also been developed and used successfully.

The Space Challenge For the Next President

by Marsha Freeman

Stuart Lewis

President Reagan greets the Shuttle crew at the White House. Will his successor ensure that the space program continues?

The September flight of the Space Shuttle, after its 32-month standown, renewed the interest and excitement of the American people that has characterized the the manned space program from the beginning.

The space agency is looking forward to flying 30 Shuttle missions over the next four years and taking delivery of a new orbiter in 1991 to replace the Challenger. However, there are major policy questions that must be decided in the first 100 days of the new administration in Washington.

There is no time to dilly-dally, creating committees and councils to study for the hundredth time what U.S. space policy should be. In the past four years, a number of high-powered groups have produced studies and presented their recommendations to the president and Congress.

Not surprisingly, these recommendations are basically all the same, because there is only one logical order in which man should explore and colonize the solar system. The primary difference among the various programs is timing.

The government must implement the completion and deployment of the space station; build new, more efficient launch vehicles of all kinds for cargo and human passengers; develop the technologies required to return to and live on the Moon early in the next century; and make the scientific breakthroughs to take man to Mars.

Without the plan of what to do in the future, there is hardly a justifiable reason to do what we are doing today. The Space Shuttle is primarily a transportation system, and the place to and from which it should be transporting people and things is an Earth-orbiting station.

Although the space station will accomplish many tasks on its own—in space science, technology development and testing, and medicine and biology research—like a train station, it is also a transportation, storage, and supply node, for travelers continuing on to other ports-of-call.

The easiest place to go from Earth orbit will be back to the Moon, where radio telescopes among other scientific experiments will be installed, and where the industrial possibilities will create a base of manufacturing to allow man to go yet farther out into the solar system.

The next goal is Mars, not because it is close or convenient (Venus is closer), or because the Soviets are going there, but because it is the most Earth-like planet and has the potential to be terra-formed. The water, atmosphere, and other raw materials on Mars will allow man to live there self-sufficiently, which is necessary, as he will be too far away from Earth to depend upon the home planet.

It would be sabotage to waste time now, going through yet more bureaucratic reviews, to decide the goals of the space program, just because there are new faces in Washington. The administration simply needs to *do* what has been already outlined by more than a half-dozen expert commissions for nearly 20 years.

The Immediate Agenda

The Space Station Freedom is currently funded only through March 1989. It is now up to the incoming president to request the full $900 million for Freedom for the rest of fiscal year 1989. This must be done immediately on assuming office.

In spring 1989, the new administration will have to decide what will be requested of the Congress for the space program for fiscal year 1990. In order for the station to be finished even by 1996—which is two years behind the original schedule—the funding for next year must be at least $1.5 billion. Industry contractors are ready to start building the modules for the station; they are just waiting for the funds.

Next-generation launch vehicles, needed for cargo and passengers, have also been studied to death. It is past time to start *building* an unmanned, heavy-lift launch vehicle; the second-generation Shuttle, which will make use of the many improved materials and technologies developed over the 15 years since today's Shuttles were designed; and the specialized nuclear and then fusion-propelled ships that will take man to the Moon and Mars.

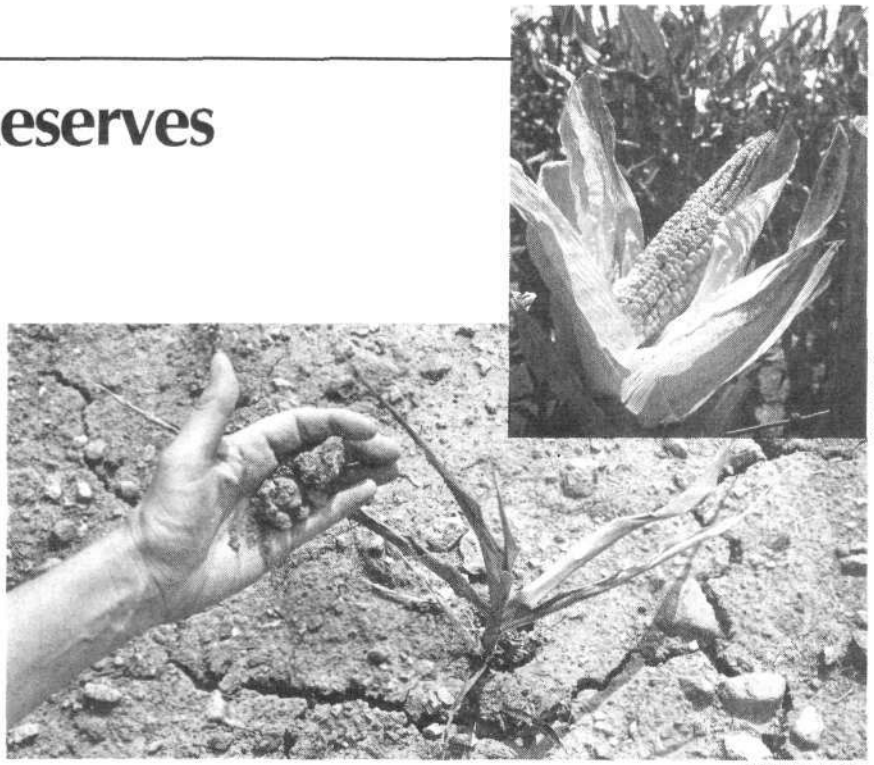
The small-scale Pathfinder technology program now under way must be extended in scope and funded more aggressively. That will ensure that the new systems and technologies are ready to match the goals that have been set.

Our international partners in Western Europe, Canada, and Japan have committed more than $6 billion to the construction and operation of space station Freedom. The same day Discovery lifted off from the launch pad, representatives from all the nations involved signed an agreement with the United States to complete the project.

Of these countries, only the United States has to now start living up to its commitment to get the space program back on track.

World Food Reserves Are Gone

by Marcia Merry



Scott Morrison

Philip Ulanowsky

Parched U.S. farmland, summer 1988, produced damaged corn.

As of year-end 1988, world reserve stocks of cereals, feedgrains, oilseed products, and such staples as dry milk powder have fallen to next to nothing, except for limited government stores and negligible private holdings.

The crop year of 1989 marks the third year in a row that worldwide grain output will be at a level below average annual consumption, unless emergency measures are taken. After two years of drawing down stocks, world food supplies are at crisis levels. The figure shows that in 1987, estimated world grain production was 1,600 million tons—50 million tons below consumption. In 1988, world grain output was forecast around 1,500 million tons, *160 million tons below recent annual consumption levels.*

At the beginning of October, the Global Information and Early Warning System of the Rome-based U.N. Food and Agriculture Organization described 1988 as "the largest drawdown of cereal stocks on record." The agency called for a dramatic increase in cereals harvests (wheat, rice, and all other grains for human consumption) during the upcoming growing seasons, projecting that "global cereals output will need to increase by at least 220 million tons, or 13 percent, just in order to maintain consumption and rebuild stocks to minimum levels for global food security."

The latest picture of plantings, crop conditions, and government responses to the crisis, shows that no such increase is in store. There were no coordinated efforts to maximize the southern hemisphere crops for the January-March 1989 harvest period, and there has been no mobilization to date, to maximize the northern hemisphere spring planting for the fall 1989 harvest.

Moreover, the southern hemisphere weather conditions are not favorable for the current crop. Winter wheat in Argentina, for example, has been hit by a prolonged drought, and the harvest will likely be down by at least 3 million tons. The stage is set for a world food crisis in 1989-1990 on an unprecedented scale.

The Drought of '88

The immediate cause of the situation is the record "Drought of '88" that hit the heart of the North American grainbelt during the entire growing season. In severity and extent, the drought is comparable in this century only to 1934 and 1936, and conditions cannot be expected to be ameliorated for at least two more years. In various parts of the corn and wheat belts of the continent, the harvest tonnages were down by 25 to 70 percent, depending on the type of crop.

The output of vegetables for the annual U.S. pea "pack" and other canning and freezing processes was also down by 25 to 70 percent, depending on the type of crop and location. The crop of edible beans in such states as Michigan and North Dakota was down by more than 50 percent—which automatically means that the supply for importers (for example, Great Britain, Northern Africa) is cut in half.

The drought has caused a liquidation of the beef breeding herd stocks in the United States, the direct result of the hot and dry conditions, and the indirect effect of high feed prices. Compared to a total cattle inventory in the United States of about 130 million head only a few years ago, the national cattle herd is likely to drop to under 97 million head.

Beef Decline

Internationally, a significant decline in beef output is taking place over 1988-1989, because of the shortages and high prices of corn and soybeans.

North America alone accounts for about 58 percent of the recent annual average world coarse grain and wheat exports (45 percent from the United States, and 13 percent from Canada). More than half of the world's annual carryover of grain is located in the United States, so when the U.S. stocks decline, this is automatically a world catastrophe.

Because of low stocks, the Canadian government announced in August 1988, that it would suspend all talks on new grain export contracts and meet existing export commitments on a de-

ferred timetable, as stocks permitted—which in some cases means grain will be delivered a year late.

The Myth of 'Surplus'

The ongoing cause of the world food crisis is the policy of the Western industrialized nations to deliberately "destock" food supplies, in the name of allowing the mythical laws of "supply and demand" to drive food commodity prices up. Since the mid-1980s, unprecedented food "surplus" reduction policies have been implemented in Western Europe, the United States, and Canada, with unprecedented cropland set-aside programs and milk reduction programs.

In the United States these programs include: the PIK, Payment-in-Kind, program to pay farmers to not produce milk; and the Dairy Herd Termination Program, which eliminated 1.5 million milk cows. In the European Community there is a milk output quota with penalties for "overproduction." Thousands of the world's most advanced farms have been ruined as a result of these programs.

Rationalizations for these policies have appeared in numerous documents and government and media sources over the past 15 years. The common excuse for making food scarce is that "surpluses" are costly to store and drive down the price to farmers. In fact, national food security and logistics experts recommend storing nine months to two years' worth of food as a desired level of food reserve in order to "bridge" growing seasons disrupted by war or natural disaster.

At present, worldwide food stocks are at best on a level of less than 50 days' worth of supply. Such key commodities as soybeans, the best cattle feed along with corn, are projected to be at a three weeks supply as of summer 1989. What this means in practice, is that there is not enough of the crop, anywhere, to even "keep the pipeline full."

By harvesttime 1988 (October), all grain prices, and milk powder had posted dramatic rises since the year began. Export prices for wheat rose by 38 percent, for corn by 66 percent, and for rice between 30 and 40 percent.

However, the rationalization that scarce stocks are good for the farmer does not hold, because the market prices are almost completely set by the few companies in the international food cartel—Bunge, Cargill, Continental, Garnac/Andre, Louis Dreyfus, ADM/Toepfer, Unilever, Nestle, and a few others.

Cartel Politics

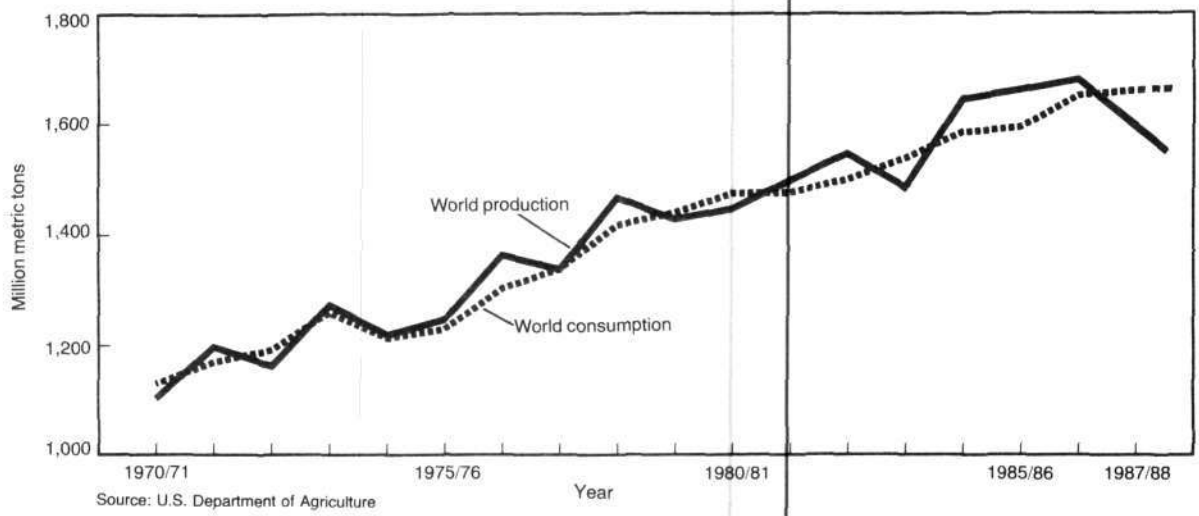
These traders orchestrated a temporary lull in food commodity price hikes in late summer and early fall 1988, while they brokered huge deals for Western grain exports to the Soviet Union, whom the cartel is attempting to placate in a perceived "New Detente." Though the official U.S. five-year "Long Term Agreement" to supply Russia with grain expired Sept. 30, 1988, the rate of grain shipments has been increasing, with or without a treaty.

The Soviet bloc may want to import in excess of 55 million tons of grains this trade year—a huge proportion of the total annual world grain trade of about 195 million tons—because of the desperate need for food.

At the same time, Third World nations are simply locked out of food supplies—at any price. After making modest food production gains in the 1960s and early 1970s, food output per capita in Africa, for example, has fallen in the last 10 years. The International Monetary Fund has given orders to debtor nations around the world to emphasize export crops, cease modernizing production for domestic food crops, and cease importing food. Therefore, food supplies for millions of people in the Third World have collapsed. Even the millions of flood victims in Sudan and Bangladesh have received only token food relief to date.

The food shortages and riots that characterized fall 1988 in Algeria, the East Bloc, and other points of need around the world will hasten in 1989.

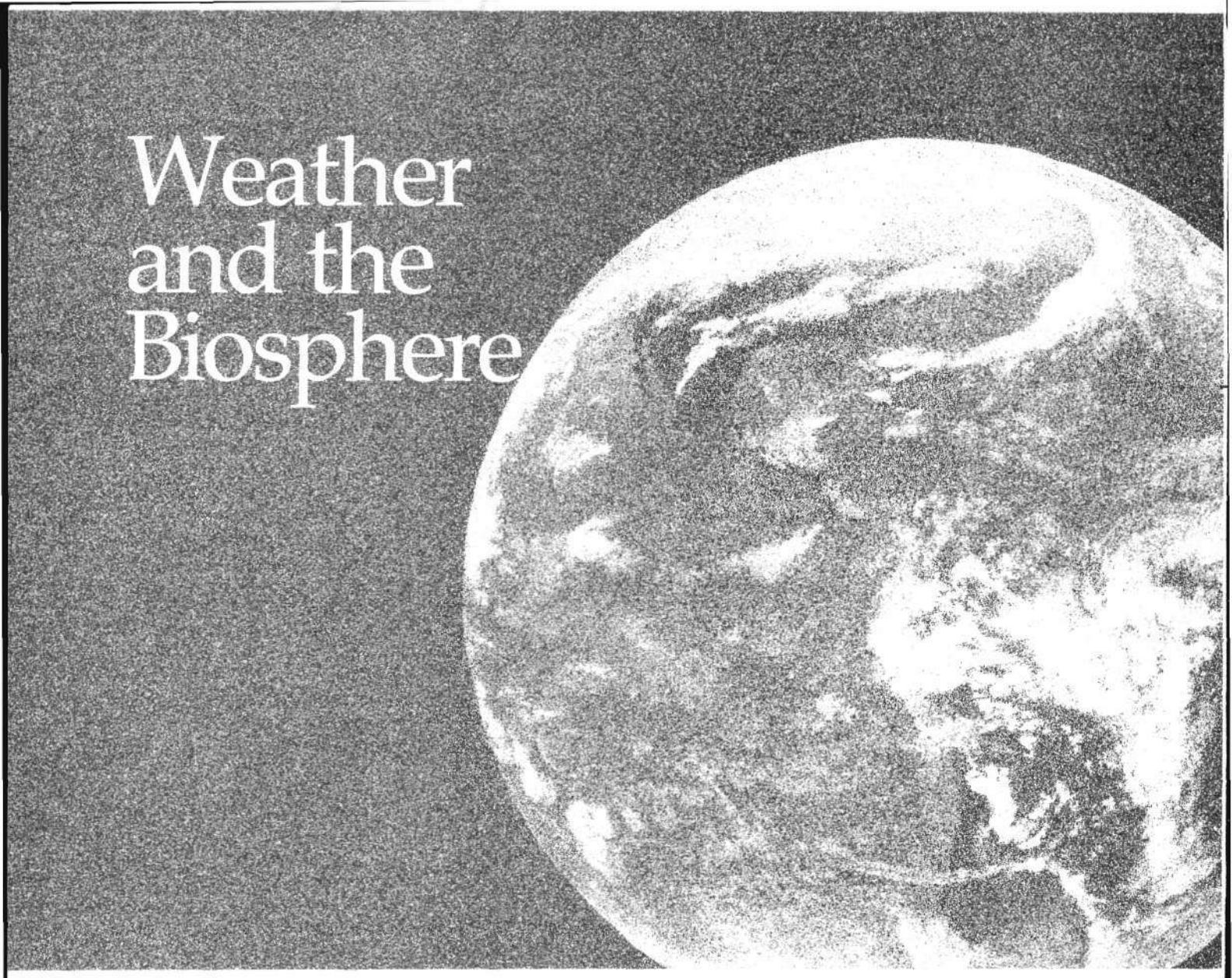
Marcia Merry is agriculture editor of the weekly Executive Intelligence Review.



WORLD GRAIN PRODUCTION AND CONSUMPTION

Grain production takes a sharp dip below consumption in 1987 and 1988.

Weather and the Biosphere



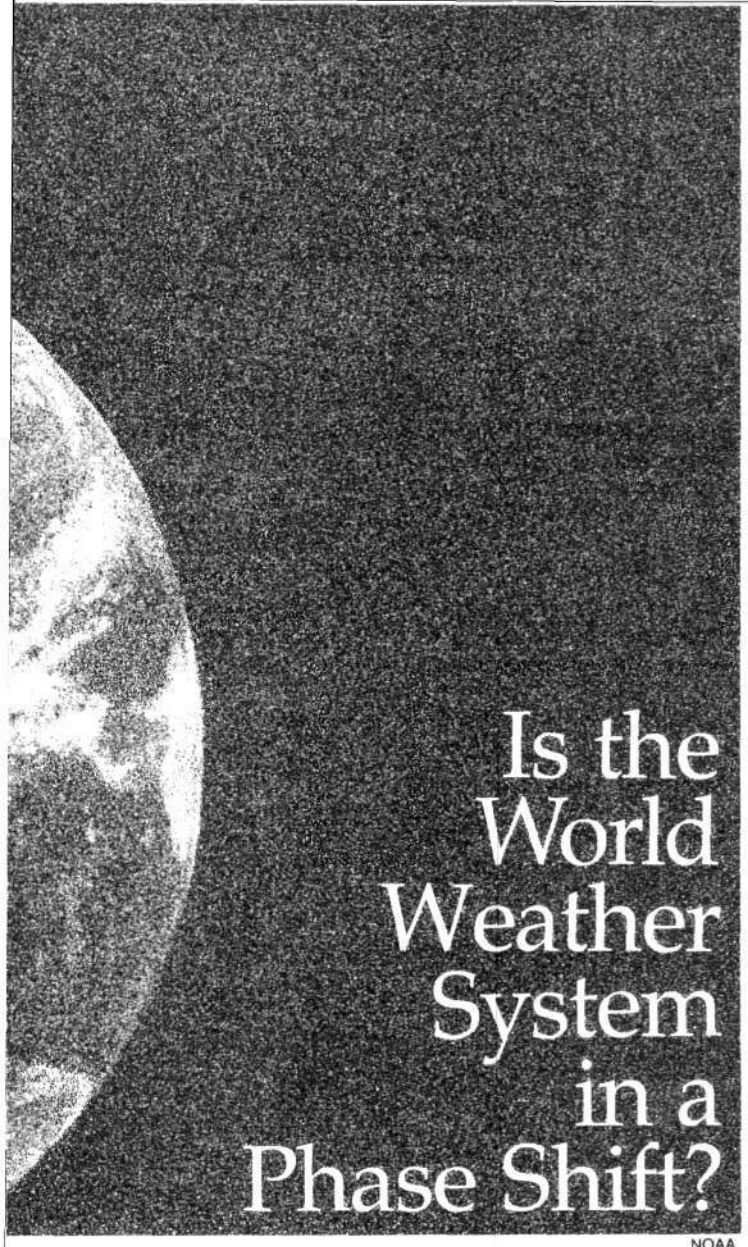
Failures to provide infrastructure projects to deal with normal oscillations in weather patterns turn every case of extreme weather into a natural disaster.

by Carol White

A year in which there are no extremes of weather, no anomalies somewhere on the globe, would be an aberrant year indeed. Notwithstanding, we appear to be living through a period of increasingly more dangerous natural disasters. Last summer's large-scale crop destruction caused by severe drought on the North American continent, floods and hurricanes more severe than any before in the century—all portend that we may be facing more extremes of weather on a global scale. The question raised is whether the global climate system is going through a phase change and, if so, how this will affect us. As yet, we have no final answer, but there are serious indications that the present rate of deforestation in the tropical rain forests may be doing irreparable damage to the ecosystem of the biosphere as well as destabilizing global weather patterns.

In particular, many are now sounding the alarm about the deforestation of Brazil, where forest fires have been deliberately used to strip the land. In addition to massive pollution, the burning is widely acknowledged to be creating the conditions for alternating drought and flooding: drought because the rain forests, as their name suggests, act as virtual pumps to move water vapor through the atmosphere; and flooding, because once the forest is burned down, the land no longer absorbs rainfall, thus creating greater runoff.

The removal of the rain forests also has a more profound effect upon the biosphere. The rain forest areas are unique, biologically determined singularities that generate the hydrodynamic flow patterns of the atmosphere. More precisely, these rain forest low-pressure zones—in the Amazon, the Indonesian archipelago, and equatorial Africa—are closely coupled with oceanic high-pressure areas to



Is the World Weather System in a Phase Shift?

NOAA

Image of North and South America and adjacent oceans, taken by NOAA's Earth-synchronous satellite using the Visible and Infrared Spin Scan Radiometer on board the spacecraft.

create tropical vortical weather flows, which in turn interact with the polar vortices. Any destabilization of these vortices will affect the entire world weather system.

Climate as a whole is subject to various oscillating patterns; however, in normal times, these oscillations are bounded. The task is to discover the harmonics that govern these boundaries. At present, there is a strong basis for supposing that a phase change—both in frequency and in amplitude—is occurring in those oscillations, which produces extremes of temperature and rainfall. Whether or not this hypothesis is true, we cannot afford to continue the deforestation experiment in order to scientifically determine that we have destroyed the habitability of our planet! There is more than sufficient reason to act now to prevent further destruction from occurring. At the same time, it must be assumed that there will be a period of instability ahead, even if a program of reforestation begins immediately.

Such instabilities are no surprise to those of us who have followed the escalation of environmentalist attacks on advanced technologies, particularly energy technologies, in the past decade or so. We predicted that without the aggressive development of nuclear energy, there would be an increasing inability to provide for a growing world population. Similarly, we predicted that if large-scale water projects were not instituted here and in the developing sector, there would be problems with both food production and water supply.

In 1974, I was involved in a project initiated by economist Lyndon H. LaRouche to correlate the evolution of the biosphere with the capture of greater and greater amounts of radiant energy. Indeed, the ability of a population to grow scales exactly with the more efficient use of energy. The biosphere project took on a more immediate focus in 1978, when the environmentalists proposed biomass and solar energy as alternative energy sources. This was coupled with a vehement attack against nuclear energy and a policy of "benign neglect" for the development of fusion power. At that time, we warned that the consequences of such a policy would be a sharp increase in apparent "natural" disasters, not the least an increase in disease, and a precipitous fall in the living standards of the world's population. Unfortunately, these predictions have been borne out by today's unhappy reality.

We live within a *biosphere*. The Earth's atmosphere and also its climate have been created by life. When the amount of solar radiation captured by the biosphere over time is systematically modeled, it plainly shows a correlation to the evolution of life forms, emphatically including man. Over the most recent several centuries, there is a further interplay between the capture and deployment of energy through man's technology and the rest of the biosphere. Any reversal of this trend line, moving toward devolution—a vector away from supporting human evolution toward encouraging lower forms of life, or away from life itself, as in the present large-scale deforestation—can be expected to create serious instabilities with devastating implications for the future of mankind on this planet.

Reducing the world's population by half, as demanded by the environmentalist groups as well as the international monetary agencies, will not allow us to return to the conditions of the 19th century; instead there will be a forward march into misery that may even threaten the continued existence of our species. Technology is not the enemy; the enemy is the failure to develop new technologies when they are needed.

How Weather Is Organized

Some of the best recent work in meteorology has established a rotational shift in the global weather system as a whole that can explain aberrations as apparently unconnected as the Indian monsoon rains, the El Niño current off the coast of Peru, and the Saharan drought. These models have shown an interaction between the atmosphere and oceanic currents. They do not operate on a level of detail sufficient to model the effects of deforestation, but mete-

Continued on page 20

A Historical Look at Meteorology

The first weather satellite, Tiros I, was launched April 1, 1960, to a height of 725 kilometers. Today, with the successor satellites maintained by NOAA (the National Oceanographic and Atmospheric Agency), the entire world weather system can be viewed. Variations in the intensity of the radiation provide a "three-dimensional" picture as seen from the satellite, which can be speeded up, using methods similar to lapsed-time photography, to create two-day weather loops that show the pattern of weather flow.

This capability is coupled to more traditional information sources like radar—a horizontal probe of the weather system—and radiosonde balloons. These balloons have been sent aloft since the late 1930s in order to get readings of temperature, pressure, and humidity, which are then relayed back to ground weather stations by radio. (See Figure 1 for a map of meteorology aids.)

A major development in improved weather forecasting was, of course, the development of high-speed computers in the 1950s, which allowed forecasters to rapidly integrate information taken from many different sources. Yet, even today, these computer simulations must be updated and corrected on a daily basis. The judgment of the meteorologist is still a crucial element in the process, and even now in the United States, a five-day forecast is considered long-range forecasting. Researchers studying actual long-range climate trends also work with computer modeling, but their best models are strictly local; for example, a good model of the Sahara will not fit the Brazilian climate patterns. As a

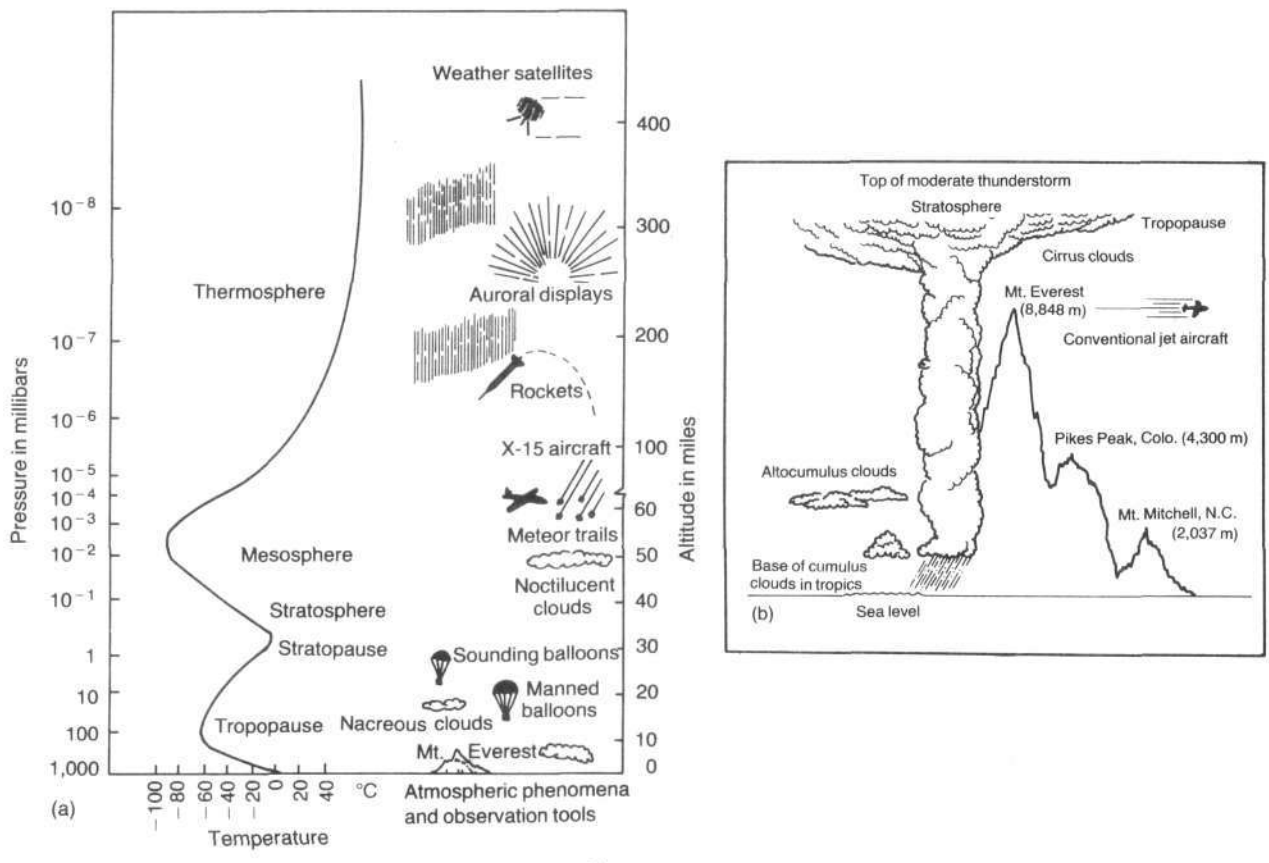


Figure 1
A VERTICAL SCHEMATIC OF THE ATMOSPHERE

Atmospheric phenomena and observation aids are shown in (a) according to altitude (right vertical axis), pressure (left vertical axis), and temperature (horizontal axis). The thermosphere and the mesosphere are also known as the ionosphere, because of the ionization that occurs at these elevations. The rise in temperature at the stratosphere corresponds to the increase in the absorption of short wavelength radiation by ozone and oxygen molecules.

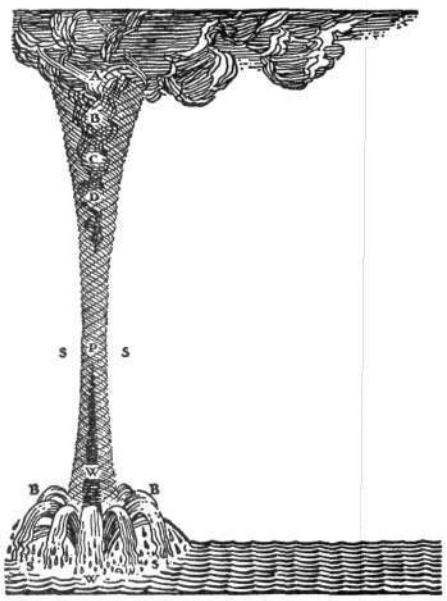
The vertical distance from sea level to the stratosphere is shown enlarged in (b). Jet streams travel at the upper border of the troposphere and just above it in the lower stratosphere.

result, global integration of weather flows cannot be modeled with any great accuracy.

This is not necessarily such a bad thing, since computers of necessity linearize inherently nonlinear processes. What is needed is the development of analog computers that will enable the direct modeling of nonlinearity. In any case, the major advances in science historically have occurred without the aid of computers. Benjamin Franklin, for example, developed a sophisticated notion of how the weather works. He described anticyclonic weather systems (he called them spouts), which develop as vortical whirlwinds from low-pressure centers (Figure 2). Today we know that tropical rain forests operate on a similar principle to power the global weather system as a whole.

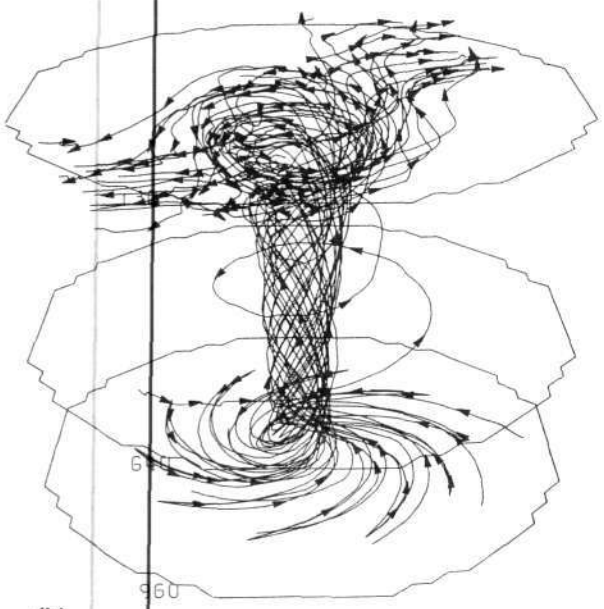
Christopher Columbus, a few centuries earlier, noted the role of vegetation in rainfall. In a biography of his father, Columbus's son Ferdinand wrote of his father's trip to Jamaica in 1494:

> The sky, air, and climate were just the same as in other places; every afternoon there was a rain squall that lasted for about an hour. The admiral writes that he attributes this to the great forests of that land; he knew from experience that formerly this occurred in the Canary, Madeira, and Azore Islands, but since the removal of forests that once covered those islands they do not have so much mist and rain as before.



(a)

Source: *A Benjamin Franklin Reader*, ed. Nathan G. Goodman (New York: Thomas Y. Crowell Company, 1971), p. 435.



(b)

Source: Richard A. Anthes et al., *The Atmosphere* (Columbus, Ohio: Charles E. Merrill Publishing Company, 1978), p. 208.

Figure 2

A HURRICANE MODELED TODAY— AND BY BENJAMIN FRANKLIN

Benjamin Franklin's 1753 drawing of what he called a whirlpool or water spout (a) is very similar to a contemporary model of a hurricane (b). Both describe the convective flow of air upward. The contemporary model describes a vortex with low-level inflow, upward motion near the center, outflow of air in the upper atmosphere, and intense rainfall near the center.

Franklin described his model as follows:" . . . I imagine, that the heated lighter air, being pressed on all sides, must ascend, and the heavier descend; and as this rising cannot be in all parts or the whole area of the tract at once, for that would leave too extensive a vacuum, the rising will begin precisely in that column that happens to be the lightest, or most rarified; and the warm air will flow horizontally from all points to this column, where the several currents meeting, and joining to rise, a whirl is naturally formed, in the same manner as a whirl is formed in the tub of water, by the descending fluid flowing from all sides of the tub to the hole in the center. . . .

"Lastly, as the lower air, and nearest the surface, is most rarified by the heat of the sun, that air is most acted on by the pressure of the surrounding cold and heavy air, which is to take its place; consequently its motion toward the whirl is swiftest, and so the force of the lower part of the whirl, or trump, strongest and the centrifugal force of its particles greatest; and hence the vacuum around the axis of the whirl should be greatest near the earth or sea, and be gradually diminished as it approaches the region of the clouds, till it ends in a point, as at A, forming a long and sharp cone."

Continued from page 17

orologists working in the field agree that the present rate of deforestation is very likely distorting oscillations in the rotational patterns that normally occur over a two to seven year cycle. These dynamic models are a useful point of departure for future work.

As a background to understand these models it is necessary to look at the major weather flows. The key determinant of the world's weather is the amount of incident radiation. Thus, there is a temperature gradient between the equator and the poles. Warm air rising over the equator will be attracted toward the poles, although it will actually tend to collect and settle at about 30° north and 30° south latitudes. This is the zone of the trade winds. The temperature gradient, of course, shifts according to the seasonal variation between winter and summer, with the greatest variation occurring in winter.

Another important determinant of the weather is the variation of moisture in the atmosphere, which will depend in part on the availability of water at a particular location. Warm, moist air is less dense than cool, dry air, so that it is borne upward by convection, where it is then cooled in the less-dense upper atmosphere. The troposphere, however, is warmed by the release of latent heat when moisture is released from the atmosphere as rainfall.

Areas of warm, moist air create low-pressure zones, in contrast to cool, dry air, which forms a high-pressure zone when it settles. A circulation pattern is established between the high- and low-pressure zones, so that the warmer air flows above the colder air in the direction of the poles, and the cooler air returns to the equator, moving in underneath, where it is compressed to form a denser high-pressure region. This air will be warmed by compression and will pick up evaporated moisture as it travels over the ocean surface. It is this moisture, combined with the recirculated moisture from vegetative matter, that creates the high rainfall of the tropical rain forest.

If the Earth did not rotate, and we discounted variations

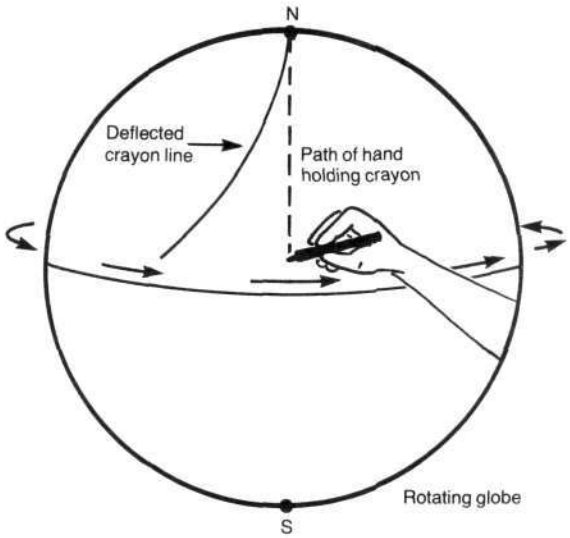
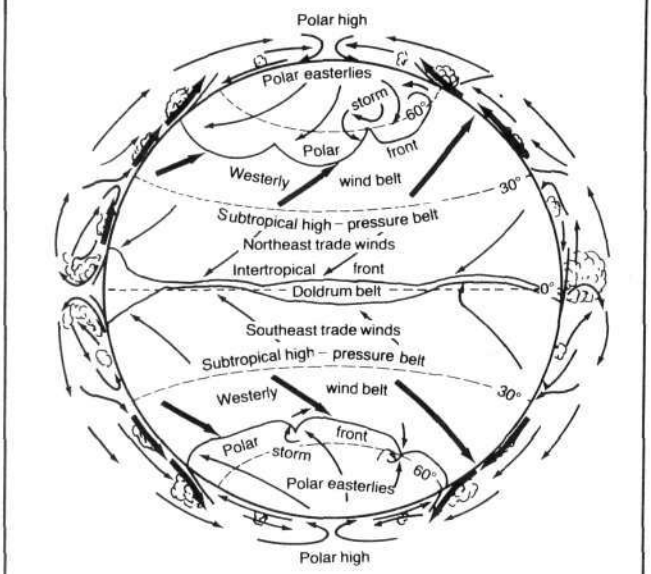


Figure 3
THE CORIOLIS FORCE

If the Earth did not rotate, air would flow from areas of high pressure to areas of low pressure. However, the Earth's rotation has a deflective effect, which causes the moving air to be deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. The Coriolis force, as it is known, was named for the French mathematician who first explained it.

Most simply, the Coriolis effect can be demonstrated by rotating a globe in a counterclockwise direction while drawing a vertical line with a crayon over the Northern Hemisphere. The line will be curved, running from northeast to southwest. Although the hand and the crayon did not change direction, the rotation of the globe caused an apparent change in the recording of the movement. The strength of the Coriolis force increases as one moves toward the pole.



Source: Adapted from Clarence E. Koeppe and George C. De Long, *Weather and Climate* (Huntington, N.Y.: Robert E. Krieger Publishing Company, 1979), p. 92.

Figure 4
MAJOR PLANETARY CIRCULATION PATTERNS

If only the rotation of the Earth were considered, the wind belts would look like this. The low-pressure belt of calm at the Equator is called the doldrums. The northeast and southeast trade winds begin around 25° north and south latitude. High-pressure belts between 20° and 30° north and south are called the horse latitudes and are characterized by calms or variable winds and clear skies. The northesterly and southeasterly winds proceed from the polar highs to the subpolar lows. The air attracted from the subtropical highs to the subpolar lows creates the westerly winds that prevail in temperate regions.

in the Earth's surface like mountains and flat areas as well as the alternation of land and sea breezes, then air near the equator would simply expand and then overflow, so that cooler air from higher latitudes would crowd under it, forcing it aloft. At or near the Earth's surface there would be north winds in the northern hemisphere and southerly winds in the southern hemisphere. At higher altitudes above the Earth's surface the flow would be reversed from the equator to the poles. (The direction attributed to a wind is determined by its point of origin, so that a north wind flows from north to south.)

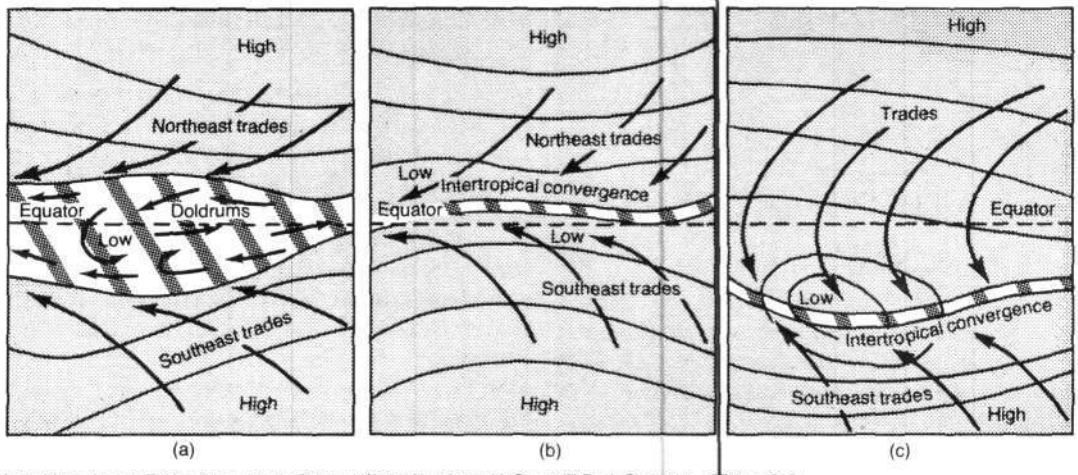
Obviously the variability of seasons, land and water, and mountains and plains creates a shifting weather pattern; however, it is the Earth's daily rotation that creates the vortical flow that characterizes the global weather system as a whole. The fact that the Earth rotates from west to east means that from the point of view of an earthbound observer in the northern hemisphere, winds will always be diverted to the right from their point of origin. In the southern hemisphere the reverse will be the case, and the winds will be diverted to the left.

If air north of the equator moves in a southerly direction, it will become a southeast wind. This deflective effect is known as the Coriolis force (Figure 3). It is least at the poles but it increases as one moves poleward, because the Earth's rate of rotation increases as the circumference of a given latitude is reduced. The Earth's weather patterns are therefore determined by alternate bands of wind, as shown in Figures 4 and 5.

At the equator are the *doldrums*, a region of calm that was the bane of existence for early sailors. Above the doldrums are the northeast and southeast trade winds, which proceed from a north or south latitude of about 25°, toward the equator. High-pressure belts between 20° and 30° north and south are known as the *horse latitudes*—a region of descending air again characterized by calms or variable winds and clear skies.

Air at the poles shrinks as it is cooled. This favors the inflow of air aloft from warmer latitudes, creating subpolar low-pressure belts at approximately 60°, north and south. Low-pressure centers are not always related to temperature conditions. For example, one of the lowest pressure centers on Earth is located in winter over the Aleutian Islands in the North Pacific. And in July, two large cells of high pressure, which are slightly elliptical in shape and have a major axis in the east-west direction, are located in the northern hemisphere in the eastern third of both the Atlantic and Pacific, somewhere between the latitudes of 30° and 40°. Northeasterly and southeasterly winds proceed from the polar highs to the subpolar lows. Finally, air is attracted from the subtropical highs to the subpolar lows, creating the westerly winds that prevail in temperate regions like the United States.

At higher altitudes in the troposphere, there are high-speed wind belts. Although these were noted as early as 1933, they were encountered only during World War II, when they startled American bomber pilots flying to Japan. Known as jet streams, these air currents are erratic in speed (they vary from 150 miles per hour to as high as 400 mph), direction, extent, and altitude (on average they are at 30,000 feet). They can be thought of as boundaries between shifting high and low pressure regions (see Figure 5).



Source: Adapted from Joseph E. Van Riper, *Man's Physical World* (New York: McGraw-Hill Book Company, 1971), p. 212.

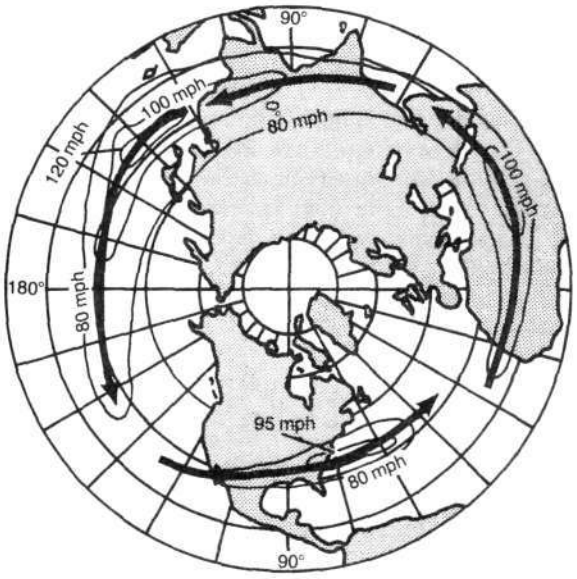
Figure 5
DIFFERENT TYPES OF CONVERGENCES

Here are three types of convergences that occur in the general convergence zone between the two hemispheres. In (a), the doldrum area, the trade winds weaken and lose momentum as they approach the equator, where they develop a westerly drift. Air motion is is fitful and variable. In (b), near the equator, there is a narrow zone of convergence that enhances the conditions for instability and precipitation. The convergences in (c), away from the equator, occur most frequently at the time of the solstices. Heat lows developing over a continent in the subtropics tend to result in a steep pressure gradient, which produces an airflow from the equator like that over the rain forests in summer. High and low pressure areas are noted.

The Rotational Flow of Weather

The world weather system is actually organized according to vortical circulation patterns both horizontally and vertically. (See Figure 4 for major planetary circulation patterns.) The average global tropical circulation is characterized by three major convective areas of rising motions, clouds, and rain. The first is in Southeast Asia and the western Pacific. This is the area of warmest ocean waters and includes what is described as a stratospheric fountain over the Indonesian archipelago where all of the world weather systems can be said to converge. The other two major circulation patterns occur over the Amazon rain forest and in the African Congo region.

On average at these points, moisture-laden air will be pumped up to a height of 12 kilometers, to the upper troposphere, from which it will descend to high-pressure zones over the ocean that are also known descriptively as *dry ocean deserts*. The large-scale convection from these circulation zones acts as a major force for the circulation of the atmosphere as a whole. Their unique feature is the important role of plant respiration, creating evapotranspiration of moisture in the atmosphere. The transportation of latent heat to the midtroposphere, where it is released, is central to the energetics of global weather. Hurricanes (or cyclones or typhoons as they are also known) transport the energy globally, through smaller vortical circulation cells.



Source: Adapted from Joseph E. Van Riper, *Man's Physical World* (New York: McGraw-Hill Book Company, 1971), p. 209.

Figure 6
THE JET STREAM IN JANUARY (NORTHERN HEMISPHERE)

Jet streams are bands of high-velocity winds that make their way around the continents like rivers. The most consistent westerly jet streams, which travel at 30,000 to 45,000 feet and between the latitudes of 30° to 40° in normal years, are called the midlatitude jets. It was this jet stream that was "stuck" in Canada, causing the U.S. drought in 1988.

The entire region of the equator is a zone of convergence—the intertropical convergence zone or ITCZ (Figure 7). Water-laden air from the more northerly and southerly ocean high-pressure zones is sucked toward the warmer equatorial region, where it converges and is drawn up. The evaporated moisture is then condensed in the upper atmosphere, where it falls as rain. The atmospheric flow diverges and circulates outward from the equator to the trade zones, where it is again compressed over the oceans into high-pressure zones. The ITCZ moves to the north in July and August, and to the south in December and January, following the summer months of the northern and southern hemispheres.

The role of vegetation in the cycle of precipitation has been extensively studied. J. Shukla and Y. Mintz, for example, found that over the globe at large, the measured water drainage in a year is only one third as large as the measured precipitation, so that water cycled by vegetation—by what is called evapotranspiration—is about two thirds as large as precipitation.[1] In some regions, evapotranspiration exceeds rainfall in some months, because stored water is drawn from the ground by plant roots.

In the early 1920s, a relationship between ocean water pressure, temperature, and rainfall was observed by G.T. Walker. The simplest example of this is the attraction of rainfall to those locations at which the ocean temperature is highest. He was able to correlate transformations in the Indian and Pacific Oceans with variations in the amounts of Indian monsoon rainfall, a phenomenon called the *Southern Oscillation*.

El Niño-Southern Oscillation

Thirty years after Walker's work, a further connection was made—between the Southern Oscillation and the periodic incursion of warm water from the western Pacific into its eastern shores off the coast of Peru. The latter is known as an *El Niño event*, giving the name El Niño-Southern Oscillation or ENSO to the total configuration. (El Niño was named by Peruvian fishermen in the 19th century who called the late December flow of warm water to the coastal waters "the child," meaning Christ Child.) In normal periods the easterly trade winds in the equatorial Pacific sweep the thicker and warmer mixed upper layer of the ocean to the west. There will be as much as a 40-centimeter difference in the height of the western Pacific Ocean to the eastern Pacific coastline. When the trade winds slacken, the ocean tends to level off, bringing the warmer water back east.

An El Niño event differs from the normal winter influx of warmer water by being more severe and of longer duration. When this occurs the normal upwelling of nutrient-rich, deeper, and colder coastal waters is disrupted, and this, in turn, ruins anchovy fishing, one of the main exports in Peru. In 1972-1973 and then again in 1982-1983, severe El Niño effects were widely publicized because of their economic side effects. These events occur irregularly, with lapses of anywhere from two to seven years.

The dynamics of normal winter circulation were developed in 1957, during the International Geophysical Year, by the Norwegian meteorologist J. Bjerknes. He described what he called the *Walker circulation*, a west/east rotation of the three major convective areas that is associated with shifts in the easterly trade winds and Pacific Ocean depths, pressures, and temperatures. This combined atmospheric/oceanic model correlates a buildup of a thicker, warmer top layer of the ocean in the western and central Pacific with the occurrence of easterly trade winds at that latitude. It is the easterly trade winds in the equatorial Pacific that drive ocean circulation.

During an ENSO event, a reversal of this process occurs so that the westerly ocean water flows eastward, and the easterly winds are abated or, on some occasions, even become westerlies. Coupled to this reversal are abnormally light Indian monsoon rains. In fact, the 1987 Indian monsoon rains were totally suppressed in the relatively less severe (considering only its El Niño component) prolonged ENSO event—which began in 1985, aborted, and then recurred in the years 1986 and 1987.

The ENSO event of 1982-1983 was unusually severe, generating renewed interest in the phenomenon. It was accompanied by floods, gales, a reversal of the trade winds, a below-average Indian monsoon, and severe drought in the African Sahel, equatorial East Africa, and Australia. On the other hand, there were torrential rains in Ecuador and northwestern Peru and heavy rainfall in Colombia, Paraguay, and the border area between Argentina and Brazil.

One question that continues to puzzle meteorologists is what causes an El Niño event to occur. Although there are as yet no adequate causal hypotheses for this aperiodic event, a recent study by a group from the Scripps Institution of Oceanography in La Jolla, California, shows that a contributing factor in causing an El Niño reversal in the water flow of the Pacific may come about because of the reflection of slow-moving water waves in more northerly or, respectively, southerly latitudes of the Pacific as the waves reach the ocean's western border.[2] These waves, known as Rossby waves, are actually large-scale vortical cells traveling across the ocean, and their reversal normally occurs over a nine-month period. The waves reverse direction so that instead of moving from east to west, they flow back toward the east. This reversed circulation is what would contribute to the creation of El Niño events.

These reversed wave patterns in periods of El Niño events may be fueled by unusual hurricane activity, particularly in the area of the Indonesian low-pressure zone. How perturbations caused by deforestation of tropical rainfall zones affect local cyclonic activity is yet to be determined, but an east/west shift in the weather system as a whole is a feature of the El Niño oscillation. This east-west oscillation is accompanied by a north-south oscillation as well, so that there is actually a *rotation* of the weather system. In ENSO years there will be a southerly as well as easterly drift of the weather system.

Normally an El Niño event occurs over a one- to two-year period and then "normal" weather patterns are reestablished. Sometimes, either following an El Niño event or following a normal part of the cycle, an abnormal reversal occurs. Now there is an extreme buildup of warm water in the western Pacific and unusually cold ocean temperatures off the coast of Peru. Other transformations of weather patterns follow.

These *anti*-El Niño events are far more rare (the last one occurred in 1974) and much less well understood. Indeed, it may not be appropriate to think of them as simply opposite to the El Niño. The problem of course, is that a sufficient causal explanation for the existence of either the El Niño or the *anti*-El Niño is lacking. The *anti*-El Niño is of interest now because there appears to be at present such a cycle reversal.

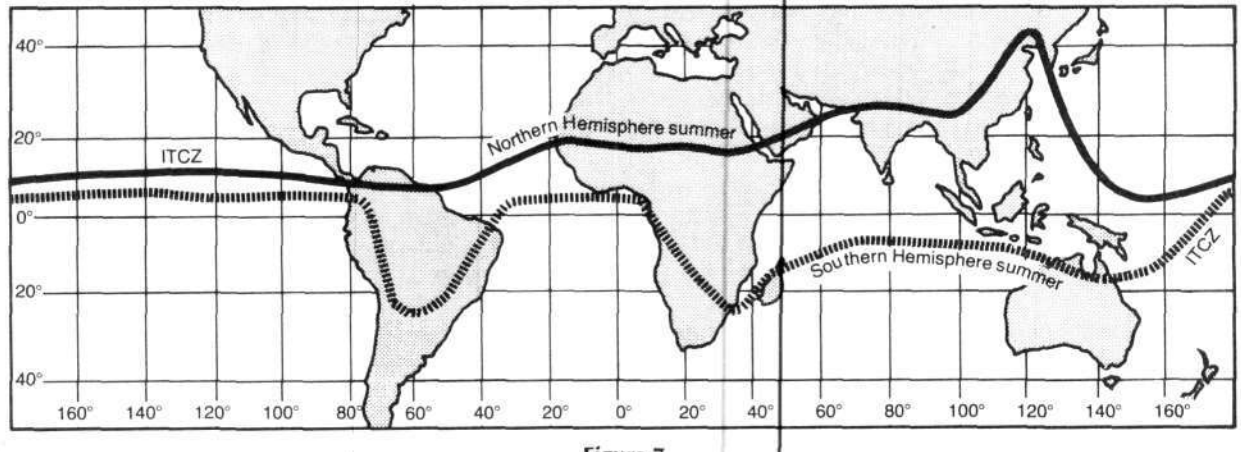


Figure 7
THE INTERTROPICAL CONVERGENCE ZONE (ICTZ)

The convergence between the trade winds, known as the Intertropical Convergence Zone, migrates seasonally, as shown here, to the areas of the tropical rainforest in the summer of each hemisphere. Water-laden air from the ocean high-pressure zones is sucked toward this warmer equatorial region where it converges and is drawn up into the upper atmosphere, where it falls as rain.

In the *anti*-El Niño (sometimes also referred to as a La Niña) the world weather system has an opposite rotational shift, so that in the northern hemisphere highs and lows are shifted southward and westward. Such a shift has been noted this past year. The ITCZ has moved northward and there are unusually cool temperatures in the central and eastern Pacific. The present worldwide concatenation of drought, severe hurricanes, and extremely severe rainfall cohere with the occurrence of an *anti*-El Niño event.

The northerly shift of the major circulation cells would account for the northerly jet stream over India resulting in unusually high monsoon rains, and it might also account for the U.S. drought, although normally temperate zone climate is not closely correlated with tropical weather shifts. The northerly shift would also affect the strength of hurricanes once they developed and their path of destruction. It is of interest that the 1988 Hurricane Gilbert was the strongest hurricane of the century.

An anti-El Niño westerly and northerly oscillation of the world weather system may also account for the unusual U.S. drought. This hypothesis, raised by William Grey at Colorado State University, correlates the drought with the existence of unusual high temperatures at a northern latitude of 15° and a longitude of 150° in the northern Pacific Ocean, caused by the northerly shift of the ITCZ.

The immediate cause of the U.S. drought, which began in the winter of 1987-1988, was a high-pressure zone that sat over the northwestern states—including Montana and North Dakota—pushing the jet stream to the north. Thus, normal shifts of the westerly subtropic jet stream, which allow the mixing of warmer and colder fronts and bring precipitation, were suppressed. A similar though reverse trapping of the jet stream occurred to suppress the Indian monsoons. Here an ENSO shift to the south trapped the Indian easterly jet to the south, behind mountains.

Studies of the Sahel drought by a group led by C.L. Folland at the Meteorological Office at Bracknell, England, have found a 10-year cycle that correlates with the Sahel drought and also in part with the Indian monsoon cycle. What they measured is the difference in sea surface temperature between the northern and southern oceanic systems globally, with the Indian Ocean considered as part of the southerly system. In dry years there is a significant temperature gradient between the southern and northern oceans. Wet years in the Sahel were those with a smaller temperature gradient between the two systems. In the dry year of 1984, the ITCZ was pulled markedly to the south over the Atlantic, where southern ocean temperature is markedly higher than in the northern ocean. They found that similar distortions of the ITCZ in other years correlated to rainfall patterns. This cycle shows similarities to shifts otherwise identified as *anti*-El Niño events, and there has been an increase in rainfall in the Sahel this past year.

Benchmark years for the Sahel were 1958, a wet year, and 1983 and 1984, which were very dry. The year 1983 was still an El Niño year, with strong warming in the tropical East Pacific. This was absent in 1984; however, the tropical south Atlantic was substantially warmer in 1984 than in 1983. The primary source of moisture for the western and central Sahel region is low-level, southwesterly flow from the tropical Atlantic Ocean. Dry years had a southerly shift in the ITCZ, which affected the upper-level easterly jet. In 1983, the ITCZ tended to be drawn southward over the Pacific, while in 1984, the distortion occurred over the southern Atlantic.

These shifts point directly to the critical role of the tropical rain forests, the key convective areas in the ITCZ.

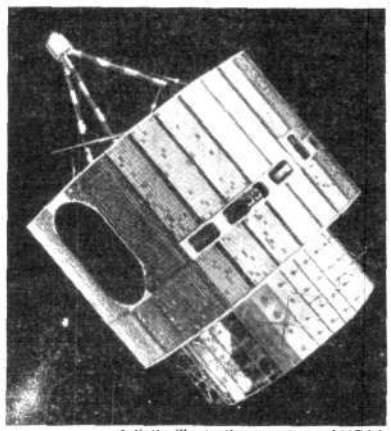
Long and Short Cycles

Climate varies in both long and short cycles. For example, ice ages occur on average every 100,000 years. On a shorter time scale, the general warming trend of about ½°C over the past century was interrupted by a sharp 20-year cooling trend in the northern hemisphere during the 1940s and 1950s.

Over long-range time scales of hundreds of thousands, tens of thousands, and thousands of years, it is changes in the Earth's orbit that account for major changes in climate. For example, the Earth's orbit varies in eccentricity over a range in the order of magnitude of 100,000 years. Eccentricity measures the variation from a circular to a more or less elliptical orbit. The axis of the Earth also rotates. This precession (change in orientation of the Earth with relation to the plane of the ecliptic) results in a one-month seasonal shift every 2,000 years. There have also been changes in the magnetic core of the Earth leading to reversals in the magnetic north and south pole.

The 11-year sunspot cycle correlates to shifts in the magnetic axis of the Sun, with one complete rotation taking place every 22 years. Failure of such a cycle to occur resulted in a reduction in solar flux and a 1°C drop in temperature during the 18th century, creating a mini-ice age. We are now in a period of increasing sunspot activity, which correlates with an increase of solar flux, and it looks like there will be a higher-than-normal solar maximum. Sunspot activity correlates in particular with lightning, rainfall, and temperature statistics. Furthermore, geomagnetic storms dramatically increase the vorticity of the Earth's atmosphere as a whole in the two- to four-day period following such a storm.

Over the last 200 years there has been a strong correlation between the 22-year magnetic cycle and U.S. droughts in the northern plain states. Major U.S. high-plains droughts have been recorded for the years 1815 to 1818, 1842 to 1847, 1866 to 1869, 1892, 1912, 1934, 1953, and 1974 to 1976. As these dates show, the present U.S. drought does not fall into this approximately 22-year pattern. This strongly implies that the world weather system as a whole is in the process of an unusual transformation, and leads us back to the strong hypothesis that the deforestation of the rain forests is destabilizing world weather patterns. (There are also periodic 18-year lunar cycles that have recently been coincident with the sunspot cycle, which some investigators think are influential in causing U.S. drought cycles. Alignment of the Earth, Sun, and Moon creates maximum and minimum cyclical tidal pull; however such a repeating cycle would not account for the severity of present weather shifts.)



The GOES Earth-synchronous satellite. GOES provides a full-disk image of nearly one-third of the Earth's surface, from about 50°N to 50°S every 23 minutes, with a spatial resolution of 2 miles.

Artist's illustration courtesy of NOAA

NOAA: From Satellite to Weather Report

Four complete satellite views of the Earth daily provide the raw data for weather forecasting, climatic studies, oceanic assessments, and crop assessments—all of which take place at the World Weather Building of the National Oceanic and Atmospheric Administration (NOAA) in Maryland. The data are processed by NOAA's Environmental Satellite, Data, and Information Service.

One satellite system, the Geostationary Operation Environmental Satellites or GOES, is in equatorial orbit, where satellites are kept at predetermined spots near the East and West coasts of the United States. The satellites of the other system, NOAA-9 and NOAA-10, are in orbits that pass over the Earth's poles and provide complete views of the Earth's surface twice daily.

The NOAA-9 and -10 satellites carry the Advanced Very High Resolution Radiometer or AVHRR, which senses radiation in five different bands (or channels) of the electromagnetic spectrum—one each in visible light and near infrared, and three in the thermal infrared range. One of these thermal channels senses radiation of about 3.8 micrometers, a wavelength at which hot objects radiate more strongly than at others. Thus, the AVHRR will see a "bright spot" over hot targets, like fires, on the ground. The image of Brazil's Amazon fires on the back cover was produced from AVHRR data, as were the U.S. vegetation index images, and the front cover's Hurricane Gilbert.

The GOES satellites are the main ones used for weather analysis. The computer center at the World Weather Building processes and displays the data in real time, in a program designed in collaboration with the University of Wisconsin Space Sciences and Engineering Center. Customized applications can be keyed in by computer—such as winds, moisture, cloud-top temperatures, and geographic features on land.

Advanced Technology Vs. Devastation

If the coming year's weather is a repeat of last summer's droughts and floods, the consequences will be nothing short of devastating: Hunger will once again stalk the globe. There is no sense in which this will be a "natural" disaster. Civilization has progressed because it made provision for the future; civilizations that failed to do so have suffered the consequences. It may be that the present weather swings are not yet the result of the stupid policies that have been systematically stripping the biosphere of vegetation and emiserating its population, but the same mentality that forced deforestation has prevented nations like Brazil and Bangladesh—and the United States—from repairing and improving water management, from building new dams and hydroelectric plants, from dredging rivers, and so on.

We have been placed here on Earth with a mission: to turn this Earth into a garden *for Man*, and then reach out to the rest of the universe. The same ecologists who forced the developing-sector nations to burn wood for fuel are now complaining that the forests are being destroyed. Their solution is to save the forests and destroy men, a solution that is both foolish and evil.

We need to restore the *equipotential* of nature. To the stone-age savage, iron ore was merely another rock; to the man of the future, burning carbon as fuel will seem idiotic. Each civilization, depending upon its level of culture and technology, redefines the resources upon which it depends. What must be replaced—or preserved—is not some predefined and limited resource, but the existence of an equivalent or better resource base upon which man can depend.

No doubt in the future man will be able to directly control the world's weather by deploying electron beams and lasers to redirect weather flows, or perhaps by placing mirrors in space that precisely focus solar radiation. When that time comes, we can reconsider the hypothesis that the existence of the rain forests is essential to the continued health of the biosphere. For now, the continued course of deforestation is criminally foolish. What we must do is move rapidly forward to a fusion-based technology.

Carol White, a mathematician, is editor-in-chief of 21st Century.

Notes

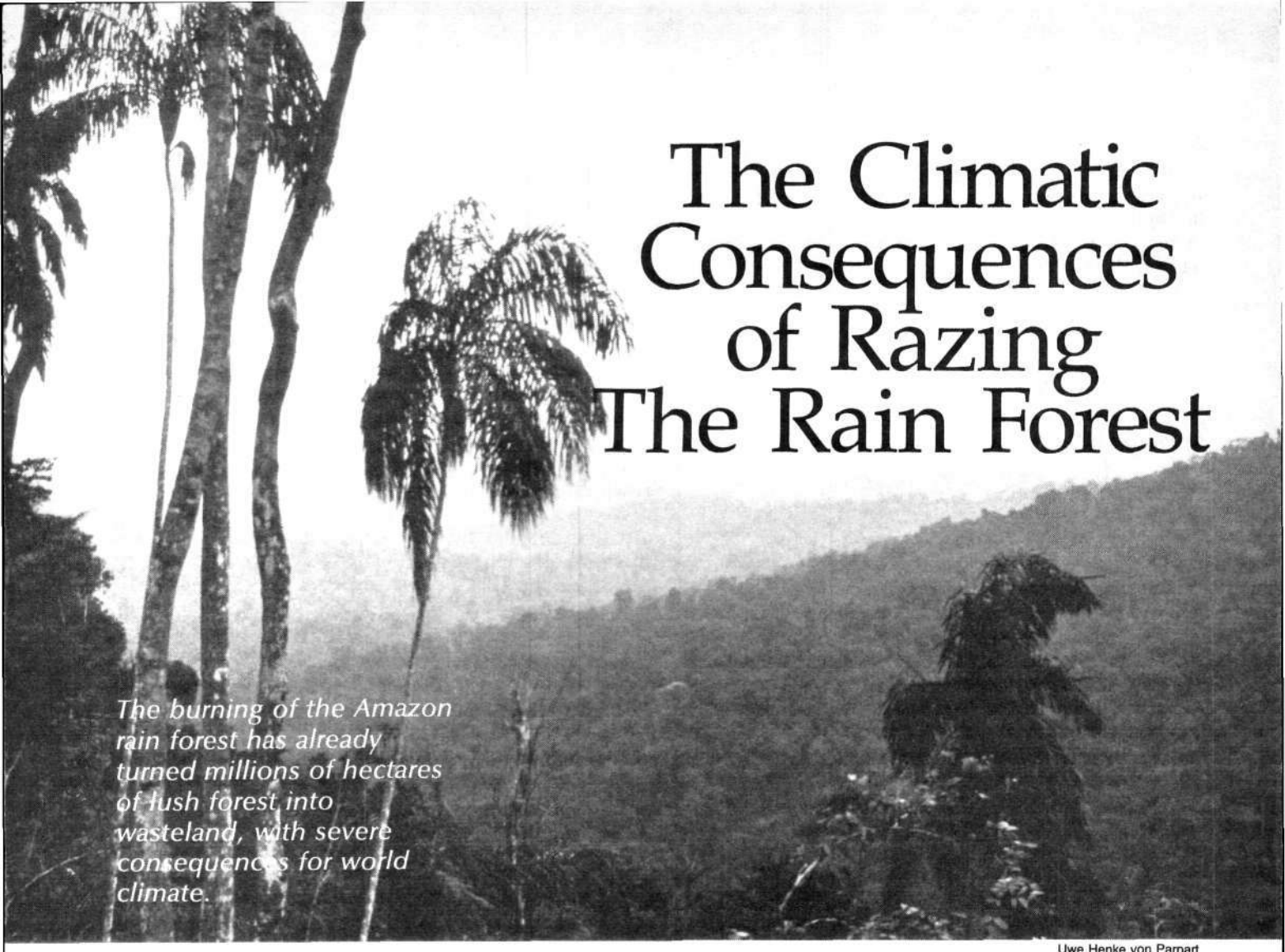
1. J. Shukla and Y. Mintz, "Influence of Land-Surface Evapotranspiration on the Earth's Climate," *Science*, March 19, 1982.
2. Scripps Institution, "The El Niño Cycle: A Natural Oscillator of the Pacific Ocean Atmosphere System," *Science*, June 3, 1988.

Suggested Reading

Two publications of the World Meteorological Organization in Geneva are well worth careful study. They are *The Global Climate System—A Critical Review of the Climate System During 1982-1984* (1984), and the *The Global Climate System—Autumn 1984-Spring 1986* (1987). These books summarize the most advanced work now being done on climate modeling and definitely benefit by treating climate in terms of overall patterns of hydrodynamic circulation, rather than in the more standard textbook manner. Each has an extensive and useful bibliography.

A useful textbook on meteorology that incorporates satellite studies is *The Atmosphere* by Richard A. Anthes, et al., published in 1978 by the Charles E. Merrill Publishing Company, Columbus, Ohio.

The Climatic Consequences of Razing The Rain Forest



The burning of the Amazon rain forest has already turned millions of hectares of lush forest into wasteland, with severe consequences for world climate.

Uwe Henke von Parpart

by Rogelio A. Maduro

When the NOAA-9 meteorological satellite began monitoring the Brazilian Amazon to detect burning of biomass in July 1987, a frightening picture emerged: 8,000 square kilometers of land were on fire with 6,800 fires counted in just one day, none less than a square kilometer and several over 10 square kilometers. The satellite study, led by Brazilian scientist Alberto W. Setzer of the Institute for Space Studies in São Paulo,[1] conservatively estimated that more than 20 million hectares (200,000 square kilometers) were burned down in the Amazon Basin during 1987 (Table 1). Of this, at least 40 percent had been virgin forest.

The rate of burning of the Amazon rain forest has increased dramatically since 1985, following the opening of penetration roads into previously virgin territory, especially in the Brazilian states of Rondonia and Mato Grosso (Figures 1 and 2). Between 1966 and 1975, 11.5 million hectares of forest were cleared; in 1987, the total amount cleared was 8 million hectares.

Data from the Landsat satellite show that the world's forests were being deforested at a rate of 11.3 million hectares a year in 1980 (Table 2). That rate has increased exponentially, as the Brazil statistics show.

The study of burnings for 1988 is still continuing, but the preliminary results, based on real time data from the NOAA-9 satellite, show that there has been a 30 percent increase in the amount of burning this year. By the end of the dry season, scientists at the Brazilian Space Studies Institute expect that an area larger than West Germany, and almost as large as the nations of Guyana or Surinam, just north of Brazil, will be razed.

The burnings in the Amazon Basin produced dense smoke clouds over areas of 1.5 million square kilometers. "The smoke from the fires is thick enough to close down large and small airports for weeks, and it certainly increases the number of cases of respiratory illness in the area, but there are no official statistics," Setzer stated.

The damage can be compared to that done by nuclear explosives. Between 760 and 815 one-megaton hydrogen bombs would have been required to wreak similar devastation over the Amazon jungle area. The main difference between burning large areas of rain forest at once and a thermonuclear strike is that an H-bomb would lift a somewhat larger amount of debris higher up into the atmosphere, and of course, leave behind a large amount of radioactivity.

Who Is Doing the Burning?

Why is this devastation occurring? The World Bank and International Monetary Fund policies have forced nations like Brazil to use what they call "appropriate technologies" rather than the advanced technologies used by industrial nations. One of these appropriate technologies is the use of biomass for fuel, instead of coal, petroleum, major hydroelectric projects, and nuclear energy. And so, valuable forest is being wasted as "biomass" to substitute for the nondevelopment of more advanced energy sources. In addition, the international monetary agencies backed primitive agricultural projects in the rain forest region on a large scale. The unavoidable result of the overall policy is that the lush rain forest is being transformed into desolate laterite.

There is a common misconception that most of the Amazon burning is done by peasants and Indians, but the facts are otherwise. During the decade of 1965-1975, 60 percent of the forest clearance was done by highway developers (3,075,000 hectares) and cattle ranchers (3,685,271 hectares), and only 17.6 percent by peasants. Today, these ratios have shifted: *Transnational corporations account for almost the entire devastation.*

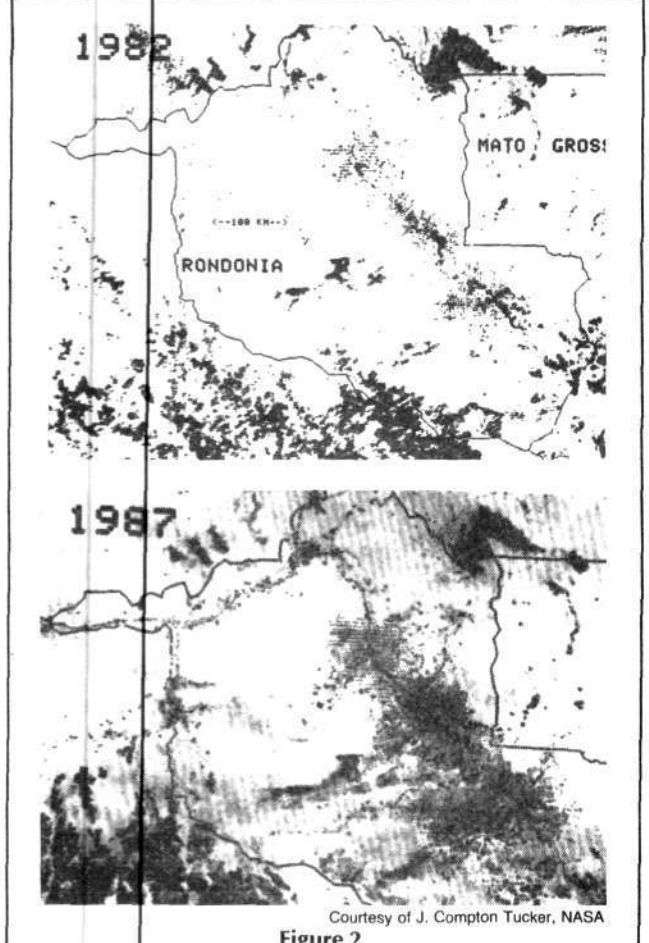
Transnational corporations and European noble families—like the Thurn und Taxis and Matarazzo families—bought most of the Amazon rain forest wholesale in the 1970s and early 1980s, when the Brazilian government sold plots larger than 2,000 hectares for $5 per hectare. The price per hectare rose to $35 in the 1980s, as the Brazilian government started running out of land to sell, and the price continues to rise in the highly speculative real estate market.

The standard operating procedure in these vast tracts of land is for corporations—for example, Volkswagen, Goodyear, Nestle, Borden, Kennecot Copper, and Liquigas—to clear-fell the forest, sell the few trees worth the trouble of extracting, and burn the rest. Then they sow grass and bring in cattle, despite the fact that the land has proven able to sustain only about one head per 10 hectares on average, and that the average life of each ranch is a mere two to seven years before it has to be abandoned because of the invasion of toxic weeds, erosion, and loss of nutrients.

Raising cattle in the Amazon is a money-losing proposition. The corporations do not intend to produce beef; their enormous profits are made in land speculation and huge government subsidies, tax write-offs and import duty exemptions. *The story is as follows:* To pay the foreign debt and fulfill the International Monetary Fund's conditionalities, Brazil has agreed to take a huge internal loss. The country thereby can maximize the export of cattle and cash

Figure 1
AMAZON BASIN AREA COVERED BY SATELLITE STUDY

The shaded area on the map is the Amazon Basin that was under real-time observation by the NOAA-9 meteorological satellite. The percentage of total ground cover observed to be on fire in individual states in 1987 is shown in parentheses. The total area burned in the Amazon Basin is larger than the total area of either Surinam or Guyana, to the north of Brazil.



Courtesy of J. Compton Tucker, NASA

Figure 2
RAIN FOREST DESTRUCTION, 1982-1987

These satellite images show the increase in rain forest destruction in the Brazilian states of Rondonia and Mato Grosso between 1982 and 1987. The dark areas are burned forest.

crops that bring in foreign exchange needed to pay the interest on the debt.

In the 1970s, the Brazilian government, with financial backing from the World Bank, started an ambitious program to settle the Amazon, both to quiet the clamor for land reform and to populate the areas that the transnationals wished to exploit. Land was given free to settlers, and wave after wave of immigrants arrived, enticed by hopes of a new life on their own property. The government, however, did not provide any agricultural machinery, technologies, or infrastructure—not even hospitals, schools, or the most basic services. The settlers were thus forced to use the most primitive slash-and-burn techniques to try to eke out a bare subsistence. Most failed because of the poor soil, and many ended up as laborers on the big ranches. Several hundred thousand of these colonists are now

Table 1
AREAS BURNED IN BRAZIL'S AMAZON BASIN IN 1987 (ESTIMATED)

State	Area burned (in square kilometers)	% of total state area
Rondonia	45,452	18.7
Mato Grosso	78,718	8.9
Goias	38,910	6.1
Acre	7,274	4.8
Maranhao	13,766	4.2
Para	19,365	1.6
Amazonas	1,093	0.1
Total	**204,608**	**4.4**

Source: Alberto Setzer, Relatorio de Atividades do Projecto IBDF-INPE "SEQE"-1987.

These figures were compiled by the Brazilian Institute for Space Studies using data from the NOAA-9 meteorological satellite.

Table 2
ANNUAL RATE OF DEFORESTATION IN 1980 (in thousands of hectares)

Region	Type of tree formation: Closed	Open	All
Tropical America (23 countries)	4,339	1,272	5,611
Tropical Africa (37 countries)	1,331	2,345	3,676
Tropical Asia (16 countries)	1,826	190	2,016
Total	**7,496**	**3,807**	**11,303**

Source: Jean Paul Lanley, "Tropical Forest Resources," FAO Forestry Paper 30 (Rome: U.N. Food and Agriculture Organization, 1982).

In 1980, 11.3 million hectares of world forest were lost. Today, that annual rate of loss has doubled.

AN INTERVIEW WITH DR. ALBERTO W.

The Rainforest Will Be Gone in

Dr. Alberto W. Setzer of Brazil's Institute for Space Studies in São Paulo was interviewed by Rogelio A. Maduro on Aug. 24, 1988. Setzer, an environmental engineer, is in charge of the institute's forest-fire monitoring team.

Question: Your report published by the Space Research Institute this year states that there was a massive amount of burning of the Amazon rainforest in 1987, which you detected through satellite observations. What did the satellite show?

We saw that the burnings occurred at an increasing rate starting early in June, reaching a peak about mid-September, and then declining until the end of October or early November. During the peak of this season we could detect over 5,000 large fires burning on a single day in one state, such as Mato Grosso.

Question: What is the total amount of burning that occurred last year?

Based on the satellite work, we estimated about 200,000 square kilometers were burned in 1987. That amount includes recent deforestation and also second-generation forest, pastures, and different vegetation covers. About 8 million hectares (80,000 square kilometers) approximately corresponds to forest cut last year.

You must keep in mind that the burning occurs only *after* you cut the forest and wait until it is dry. The forest is usually very wet and will not burn.

Question: Who is burning the rainforest?

You have farmers who get small properties and clear the forest to use the land, you have mining activities, you have farmers with huge pieces of land. . . . All sorts of people doing all sorts of things.

Question: Are you conducting satellite studies this year too?

Yes, we are repeating exactly the same work we did last year.

Question: What have you detected so far?

We still don't have the figures. From what we see on the screens when we process the satellite images, the picture looks a bit the same as last year, and probably even more intense—more fires than last year.

Question: What was the standard area of the fires that you detected? Were there any especially large fires?

We found some fires with a 1,000 hectares and typical small fires of about 10 hectares or less. It varies a lot.

Question: What about the effects on the population. Is it true that airports have to shut down and drivers must use their headlights during daylight hours in the Amazon?

Yes, and that is happening again this year. Today the airport in Portugada, the capital of Rondonia, is closed be-

10 to 15 Years

cause of the smoke. Even navigation on the rivers has been restricted or stopped because of the smoke problems. Meanwhile, respiratory diseases are increasing.

Question: Do you have an estimate for the total amount of rainforest that has been destroyed in Brazil in the past 20 years?

There is no official data and there is no good estimate. There is an accepted number of about 700,000 square kilometers deforested in the last 10 years, but these are just estimates or calculations based on partial data.

One important point is that we should be aware of increasing *rate* of deforestation in the Amazon forest. The estimates are for something between 20 and 30 percent of increase per year in deforested area. That corresponds to a doubling time of close to three years. In other words, every three years the deforested area doubles. So if the current trend continues, there won't be more than 10 or a maximum of 15 years for the forest.

Question: Is there any attempt in Brazil to get the government to do something about this?

We are doing our best. The first step was to call attention to the problem. Nobody knew it was this big. Now we have the data. We are working on publicizing it with television programs. We are trying to reach government officials.

Question: How much deforestation going on in the rest of Brazil?

There is very little forest left outside of the Amazon. We had much forest in the state of Espiritu Santo and in the south of Bahia, but the forest has been cleared in about the last 10 years. In the south of Brazil, maybe less than 2 percent is covered by forest.

Question: How much of that used to be covered by forests?

Almost all of it.

Question: How did you come to study the burning of the Amazon rain forest?

In 1985, NASA conducted a major study of the troposphere, the Global Tropospheric Experiment, which included almost 100 American and Brazilian scientists.

As a part of that work, we sought to study the interaction of the forest environment and the atmosphere. The Amazon forest was chosen because at the time everybody thought that was a place without pollution, where the study could best be performed. In July and early August 1985, we recorded satellite images, just to be sure that we wouldn't have any effect of strong sources of pollution in the area.

It turned out that we *did* have strong effects of biomass burnings which occurred thousands of miles away from the site of the experiment. The experiment was very interesting because it documented the transport of all of the pollutants and how the atmosphere changes because of the burnings. That was in 1985, and our results have just been published in the *Journal of Geophysical Research* for February 1988 in a paper by M.O. Andreae and others, of which I am one.

We got very interested in this because we came to the conclusion that we could monitor the large forest fires or burnings using the satellite. So we designed a project for operational monitoring of burnings in the Amazon forest. We submitted it to the Brazilian Forestry Institute (INPE) and they got very excited about this too, since it could help them locate and monitor the big fires, and they gave us some money to partially finance the project.

In 1987 we started the operational monitoring of biomass burning in the Amazon forest. The result of that work is in the report that you mentioned. We were surprised. We found something we didn't expect. It's like having a volcano in South America—because of the amount of emission—that no one knew about before.

Question: What effect do these massive burnings have on Brazil's climate?

Large areas are saturated by smoke, not only in the Amazon basin but all over Brazil. Some stations that monitor air pollution far away from the burning sites have registered a very significant increase in the level of all pollution. On a global scale it is hard to say. Our estimates indicate that the burning season emits about 10 percent of the fuel pollution emitted by industrial sources worldwide—and this of course will contribute to the question of the greenhouse effect.

We have good hypotheses and theories about how the temperature can increase, and what's going to happen to the icecaps, but so far we haven't seen any real changes in world climate. Most hypotheses hold that we're going to see things change within the next few years.

Question: In terms of the deforestation itself, have you seen any changes in the amount of precipitation or the local temperatures?

Of course, in terms of local temperatures, once you remove the forest, you get a strong heating of the soil, of the surface, and of the local temperature. But on a regional or synoptic scale we haven't noticed anything.

Question: Has any change occurred in the amount of precipitation?

Not that I know of.

Question: After you burn down a rainforest, how long can the land be cultivated?

That depends. Where the soil is good, they can do it for—I don't know—a very large number of years. But where soils are poor, which happens in most of the cases, they can use it for a few years—maybe four years—not more than that. Then they have to abandon the land, because it's not productive.

Question: What happens to the land once it is abandoned?

There is a degraded vegetation that starts growing—degraded forest. It is always very poor.

Loren McIntyre

Many of the Brazilian rain forest settlers are of European descent, like this family, second- and third-generation immigrants to Brazil. Their living conditions are primitive and mortality rates are high.

trapped in the Amazon, working on the ranches as virtual slaves and suffering some of the highest mortality rates in the world from disease and malnutrition.

Turning Forests into Gasohol and Charcoal

At the same time that the rain forest is being decimated, a large amount of Brazil's rich and productive farmland, located largely in the south, is used to grow sugar cane for the production of ethanol. The ethanol is mixed with gasoline, making gasohol, the fuel used by all cars in Brazil.

Tropical forests are also being destroyed by the systematic harvesting of logs to make charcoal. Even in the case where trees are replanted to replace those cut down, the same problem exists as with slash-and-burn agriculture. The original nutrients are taken away with the trees, and thus the seedlings seldom survive. Vast areas of tropical rain forest have been cut down to make charcoal, especially in Africa where firewood and charcoal represent between 60 percent and 90 percent of all the energy used in most African countries.

In Brazil 5.34 million metric tons of charcoal were produced in 1986, more than one quarter of the total production of charcoal in the world. Under orders from the world monetary organizations, Brazil is limited in its importation of coal for steelmaking so that it can preserve foreign reserves to pay its foreign debt. Not possessing significant coal reserves, Brazil utilizes the charcoal to turn iron ore into pig iron, despite the fact that the development of advanced steelmaking technologies or importing much higher quality anthracite coal from the United States would be cheaper—and would not require destroying any forest.

The cost in human lives is staggering. In the state of Rondonia, in the western part of Brazil, bordering Bolivia, an explosion of epidemic diseases is occurring. More than 228,000 cases of virulent strains of malaria have been officially registered—more than one quarter of the population of the state. The settlers are part of the World Bank's Polonoroeste project. Nearly all the money—half a billion dollars—was spent on a superhighway leading 900 miles into the Amazon rain forest, and then the World Bank ran out of money to build sanitary facilities. In the 1960s only 11,000 people inhabited Rondonia, eking out a miserable living; since 1980, the World Bank's resettlement program brought more than a million people to settle the rain forest.

Disease is rampant throughout Brazil directly as a result of such resettlement programs and the accompanying cutbacks in health and sanitation imposed upon Brazil by World Bank and IMF conditionalities. An outbreak of dengue fever that infected more than a million people in Brazil in 1985 was traced to settlers returning from the failed projects in the Amazon.

From Rain Forest to Desert

Full-blown deserts, with moving sand dunes and sandstorms, have emerged in many areas of Brazil and other tropical countries where just 10 to 20 years ago there were lush tropical rain forests. Every year, about 6 million hectares of land are irretrievably lost to desertification and a further 21 million hectares are so degraded that crop production becomes uneconomical. About 3,500 million hectares of land worldwide—an area the size of North and South America combined—are affected by desertification, while the rural population dislocated by serious desertification rose from 57 million people in 1977 to 135 million people in 1984.

The shift from forest to desert is visibly dramatic, but what about the effect on global climate? What happens when the rain forests no longer contribute to the global circulation of water vapor?

The tropical rain forest functions as a solar engine, absorbing more sunshine than any other living land cover, moderating surface temperatures, and reducing heat re-

flection into the atmosphere. It uses this absorbed energy to combine atmospheric carbon dioxide gas to form all kinds of substances. It is the largest terrestrial net producer of oxygen. It is also the greatest source of terrestrial water vapor into the atmosphere, which provides rain in other areas, sometimes thousands of miles away.

As demonstrated in the now nearly extinct rain forest of Africa, deforestation creates a cycle of desertification, including a rise in temperatures as the albedo effect starts to take place, a result of cutting the green cover—and drought: Rain becomes scarcer when water vapor is no longer being returned into the atmosphere.

A mere 10 countries on the planet possess 75.62 percent of the world's rain forest (Table 3). The three most important tropical ecosystems in the world, which provide the vast majority of water vapor transpired from land masses into the atmosphere, are located in the Amazon, the delta of the Zaire (Congo) River, and Indonesia. From here, masses of water vapor are circulated throughout the rest of the globe by jet streams, hurricanes, and other high-energy processes. The greatest amount of global precipitation falls on these tropical rain forests (Figure 3). Disastrously, these areas, especially the Amazon and Indonesia, are where the greatest amount of deforestation is now occurring.

New Data on Rain Forest Dynamics

The complex workings of this biosphere and its relation to the atmosphere are largely unknown, but a recent joint study conducted by scientists from the United States and Brazil has provided a wealth of discoveries that are still being evaluated. The expedition, the Global Tropospheric Experiment/Amazon Boundary Layer Experiment (known as GTE/ABLE), was conducted above the Brazilian Amazon rain forest in July and August 1985 and in April and May 1987. It combined, for the first time, local measurements at ground stations, regional measurements aboard aircraft, and global measurements from the Space Shuttle and satellites to study the influence on the troposphere of the world's largest rain forest and its influence on chemistry and meteorology of the Earth's atmosphere.

In a paper summarizing the results, mission scientist Robert C. Harris of the National Aeronautics and Space Administration's Langley Research Center asserted that the data obtained supported hypotheses that:

(1) Tropical rain forest environments are characterized by relatively intense sources of biogenically produced gases and aerosols.

(2) The world's largest rain forest, in the Amazon basin, is a region of frequent atmospheric instability with intense thunderstorm activity, resulting in a potential for rapid mixing of biogenic gases and aerosols at high altitudes, where they affect global tropospheric chemistry.

(3) The tropical troposphere is a region of intense photochemical activity where sinks for certain biogenic trace gases (like isoprene, C_5H_8) produce sources of gaseous products (like carbon monoxide, CO) that may be significant to the global budget.

One of the most important discoveries was the role of Amazonian forest soils and vegetation as sources of nitrous oxide NO and C_5H_8 to the atmospheric mixed layer, and consequently, the potential for photochemical production of ozone, O_3, during the oxidation of C_5H_8.

Table 3
PRINCIPAL TROPICAL FOREST COUNTRIES OF THE WORLD BY AREA
(in square kilometers)

Country	Total area	Undisturbed forest	Unproductive forest	Legal/ managed forest	Total forest area	% world total
Brazil	8,511,965	2,886,300	120,000	556,500	3,562,800	30.68
Indonesia	1,903,650	389,150	346,600	400,000	1,135,750	9.78
Zaire	2,345,409	797,400	3,800	255,300	1,056,500	9.09
Peru	1,285,215	373,200	60,000	259,900	693,100	5.97
Colombia	1,138,914	386,000	9,000	69,000	464,000	3.99
India	3,166,828	48,850	334,730	76,860	460,440	3.96
Bolivia	1,098,580	177,600	120,900	141,600		3.79
Papua New Guinea	475,300	138,150	2,200	196,750	337,100	2.90
Venezuela	912,050	76,000	116,100	126,600	318,700	2.74
Burma	678,030	141,070	90,090	80,770	311,930	2.68
Cumulative total		**5,413,720**	**1,203,420**	**2,163,280**	**8,780,420**	**75.62**
And 63 other countries		1,270,430	720,350	838,550	2,829,930	24.39
World total		**6,684,150**	**1,923,770**	**3,001,830**	**11,610,350**	**100.00**

Sources: Forest types and area from *Tropical Resources Assessment Project* (Rome: FAO, 1981). Country areas from John Paxton, ed., *The Statesman's Yearbook, 1983-84* (London: Macmillan, 1985).

Brazil possesses 30.68 percent of the world's tropical forest; Peru, Colombia, Bolivia, and Venezuela, 16.5 percent; Indonesia alone, 9.78 percent; and the "deforestation belt" of Asia—Burma, Indonesia, and Papua New Guinea—accounts for 15.36 percent of the world's tropical rain forest.

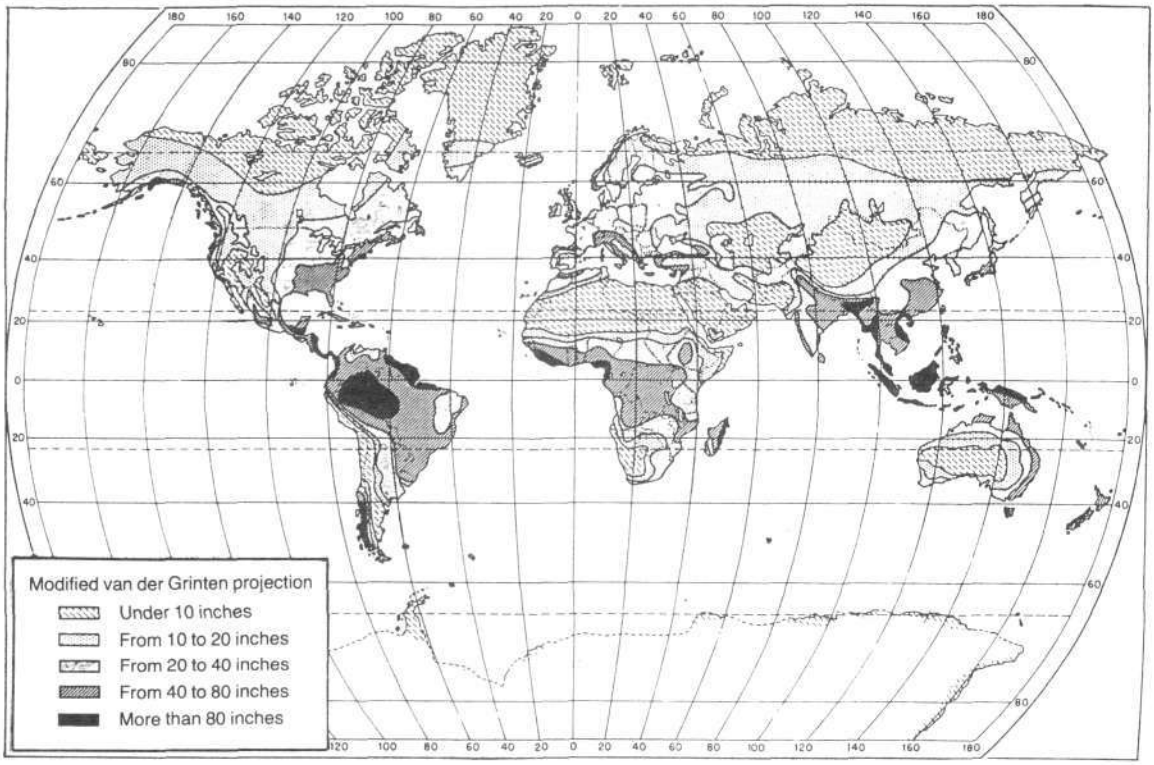


Figure 3
ANNUAL PRECIPITATION WORLDWIDE

The greatest amount of rain globally falls on the three major tropical ecosystems—the Amazon, the delta of the Zaire River, and Indonesia. These are the same areas—especially the Amazon and Indonesia, where there is the most deforestation. As temperatures increase because of the deforestation, precipitation in these areas and neighboring areas will decrease.

Source: Clarence E. Koeppe and George C. De Long, *Weather and Climate* (Huntington, N.Y.: Robert E. Krieger Publishing Company, 1979), p. 184.

It is also important to consider the effect of the variation in the quantity of vapor condensing in the higher parts of the atmosphere. During evaporation, solar energy is transformed into latent heat, which is released in the highest layers of the atmosphere where the water vapor condenses to form clouds. This energy is partially responsible for the circulation of the upper atmosphere. Part of this vapor is transferred to the polar regions, and upon condensation, releases energy; this is one form of energy transfer from equatorial to polar regions.

A Case Study: The Amazon Rain Forest

The Amazon ecosystem removes ozone from the air in the forest and the air immediately overlying the forest. Concentrations of ozone are typically 40 parts per billion (ppb) in the upper atmosphere over the Amazon, decreasing to 20 ppb in the boundary layer; they go to undetectable levels at night in the forest. Thus, tropical forest ecosystems act as a filter, removing ozone from the air through reactions of hydrocarbon gases emitted by vegetation and by ozone uptake on soil and plant surfaces.

Large convective thunderstorms were observed to transport ozone from above 5 kilometers to the lower atmosphere where ozone removal occurs. Thus, the rain forest ecosystem removes ozone, a chemical poisonous to human and animal life in the forest, while it pumps ozone and chemicals basic to the formation of ozone up into the ozone layer. The destruction of the rain forest may therefore be one of the principal causes of the thinning of the ozone layer.

The GTE/ABLE-2 expedition also revealed that as air coming from the Atlantic Ocean flows over the Amazon to the Andes Mountains and exchanges of gases and aerosols (particles) occur, a series of chemical reactions is set off that eventually affects global air quality and the Earth's radiation budget.

Natural organic carbon makes up more than 80 percent of the aerosol mass. The chemical composition of aerosols changes as inflowing ocean air transects the Amazon Basin, and frequent rainstorms remove sea salt and mix forest aerosols up into the tropical atmosphere. Large convective thunderstorms typical of tropical regions can transport rain forest gases and aerosols to altitudes of greater than 6 kilometers, where they become integrated into the atmospheric circulation. These aerosols play important roles as cloud condensation nuclei, creating the conditions for rain to occur as water vapor is transported to other areas of the world.

Deforestation plays a critical role in destroying the climate of a region, by reducing humidity and rates of plant

evaporation and changing the energy balance. In the Amazon forest, it has been calculated that 25.6 percent of precipitation is intercepted by the vegetation and returns to the atmosphere by direct evaporation, 45.5 percent is transpired by plants, and 25.9 percent is drained through the surface runoff. Therefore, about 75 percent of the precipitation returns to the atmosphere in the form of water vapor through the action of plants, indicating the importance of this type of vegetation cover for the components of the Earth's water budget.[2]

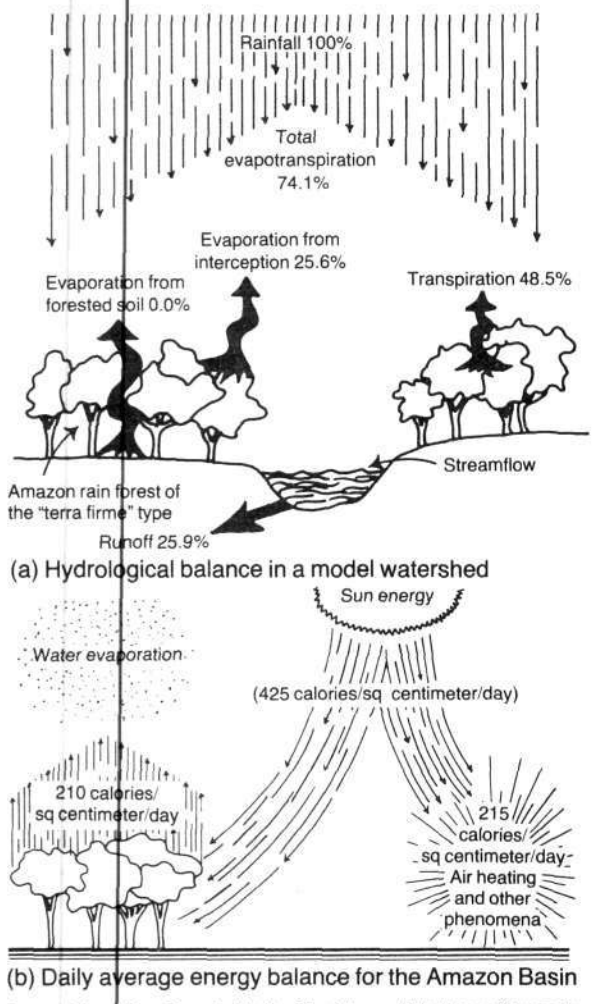
Approximately 6,430 billion tons of water vapor are generated within the Amazon water basin as a whole through the direct action of plants in interception, evaporation, and transpiration (Figure 4). This is the same magnitude of water vapor as that coming from the ocean. There are several hypotheses as to what happens to this water vapor, but no empirical studies of this have been done in the atmosphere. The best working hypothesis, supported by qualitative data from weather satellites, is that the water vapor generated by the Amazon moves toward the west and is replaced by primary vapor generated in the Atlantic Ocean. The Andean Mountains form a natural barrier 4,000 meters high and effectively prevent the exit of water vapor to the Pacific Ocean. This is the reason that the western side of the Andes on the Pacific Coast is so dry, while the eastern slope of the Andes has enormous precipitation rates.

The Andes Mountains funnel the water vapor both to the north and to the south, depending on the latitude. Above the Intertropical Convergence Zone, which moves north or south of the equator depending on the season, the rotation of the Earth moves the vapor northward over the Guyana Plateau and the Colombian and Venezuelan plains, the Amazon water vapor ending up in the Caribbean Sea, where most of the storms and hurricanes that hit the East and Gulf coasts of the United States are generated. As could be seen from the satellite images of Hurricane Gilbert, vast amounts of water vapor that fed the hurricane came from convective storms in the Amazon.

Below the Equator, the water vapor is driven south over the central plateau of Brazil and the lowlands of Bolivia, Paraguay, Argentina, Uruguay, and Brazil. The final destination of the Amazon water vapor is Antarctica, where it may also play a critical role in global climate.

Deforestation drastically changes this water and energy cycle. If there is less water available for evapotranspiration, there will be a decrease in relative air humidity, which will alter the energy balance. The incident solar energy, instead of being used for water evaporation, will be used for heating the air.

Modifications of small areas surrounded by forest should not influence the energy and water balance or regional climate as a whole, but when thousands of hectares are involved, drastic local climatic changes occur, as can be witnessed in India and Africa. Several studies have documented the role of deforestation in increasing the temperatures and sharply reducing precipitation in local areas of Africa, Asia, and the Amazon, but no large-scale studies have been done. In India, Indra Kumar Sharma wrote that the unreliability of the rains in the Rajasthan region has increased as a direct result of deforestation: The dry air



Source: Adapted from Eneas Salati, *The Climatology and Hydrology of Amazonia* (Oxford: Pergamon, 1985).

Figure 4
THE WATER AND ENERGY CYCLE OF THE RAIN FOREST

Approximately 6,430 billion tons of water vapor are normally generated within the Amazon water basin as a whole, through the interception, evaporation, and transpiration of plants. The percentages for each process are shown in (a).

What happens to this water vapor? The most recent hypothesis is that it moves west, but is stopped by the natural barrier of the Andes Mountains from reaching the Pacific Ocean. The Andes range funnels the water vapor both north and south, depending on the season. Much of the Amazon water vapor then ends up in the Caribbean, where it feeds the hurricane and storm systems that hit the East Coast of the United States.

The Amazon Basin energy balance in this process is shown in (b). Increased deforestation will drastically change this balance, as air humidity is decreased and the incident solar energy is used for heating the air, instead of generating the normal evaporation.

currents rising off the hot ground dispel weak monsoonal fronts, whereas in contrast, the warm, moist air rising from vegetated areas promotes the buildup of local thunderstorms so that areas of dense vegetation receive 40 percent more rain than neighboring deforested areas.

The Three-Dimensional Rain Forest

It would seem, as it did to all early explorers of the Amazon, that the soil must be very rich to grow such a lush forest. Yet, the truth is that tropical rain forests are thriving on the poorest soils on Earth. In tropical moist forests, most of the available nutrients are already bound into plant tissues. While binding the shallow topsoil, the tree root systems and symbiotic fungi (together called mycorrhizae) are efficient recyclers of any organic matter falling to Earth. The tropical rain forests have developed an extremely complex ecosystem that essentially captures all the nutrients necessary without recourse to the soil. The crowns shade the soil from damaging sunlight and protect the soil from compacting and leaching by rain. The many trees and other plant species are the source of food for a large number of animals, including especially fish and invertebrates.

A forest in temperate climates, like that of the United States or Europe, is differentiated "horizontally." First there are shrubs, then small trees, then tall trees; pine trees will dominate certain areas, while maple and oak trees will dominate other areas.

A rain forest is completely different; the differentiation is "vertical." There are five canopies of trees, each with its own specializations. In the constant warm and humid con-

The Hoax Behind the 'Greenhouse Effect'

The leading advocates of the so-called greenhouse effect claim that industrial emissions are responsible for the greatest amount of carbon dioxide being released into the atmosphere every year and that this CO_2 is contributing to the warming of the atmosphere—with disastrous results. Their solution is to curtail industry.

What these greenhouse proponents carefully avoid, however, is disclosing the fact that the largest amounts of carbon dioxide are released by burning biomass here and in the developing sector. To take the egregious example discussed in the accompanying article: The emission of pollution annually from the burning of Brazil's rain forest is nearly equal to the total air pollutant emissions in the United States in one year.

According to calculations made by Alberto W. Setzer at Brazil's Institute for Space Studies, 6.22 million metric tons of particulate matter were dumped into the atmosphere by the burning of the Amazon rain forest last year (Table 4). In comparison, the total particulate matter released by all industrial, human, and nonhuman activity in the United States in 1986 was 6.71 million metric tons, according to the U.S. Environmental Protection Agency.

As for carbon monoxide (CO) emissions, the total amount of CO released into the atmosphere in the United States in 1986 was 60.96 million metric tons, while that released by the burning of the Amazon was 44.03 million metric tons. Setzer's calculations for the Amazon, however, took only the molecular weight of carbon molecules into account. If the molecular weight of oxygen is added to Setzer's figures, the burning of Brazil's tropical rain forest in 1987 dumped more than 102 million metric tons of CO into the atmosphere, nearly twice the entire amount of the CO produced by all sources of pollution in the United States in 1986.

In terms of CO_2, comparisons with U.S. figures are difficult, because the Environmental Protection Agency (EPA) does not keep figures on CO_2 pollution. Nevertheless, several environmentalist groups have calculated the total amount of CO_2 pollution from all sources in the world to be slightly more than 5 billion metric tons (including the molecular weight of the oxygen as well as the carbon involved). Setzer's figures indicate that 540 million metric tons were released by the burning of the Amazon rain forest, just over 10 percent of the world total. If the molecular weight of the oxygen is added to Setzer's figure—to make it comparable—the total amount of CO_2 emissions from the Amazon burning, 1,897.32 million metric tons, is nearly half the total estimated CO_2 pollution worldwide.

This year, the burning of the U.S. national forests on a vast scale will be an added factor to pollution here. It should be emphasized that the extent of the burning was the result of a deliberate environmentalist policy to let nature take its course and not to fight the fires on the scale required.

'Appropriate Technologies' Pollute

While greenhouse advocates promote a return to the simple life without big power plants, the little published fact is that one of the environmentalists' favorite alternatives—wood burning—dumps seven times more carbon monoxide into the atmosphere than all other emissions from fuel combustion sources combined in the United States. Thanks to President Carter, who dumped nuclear energy and promoted solar and biomass, the greatest increase in CO emissions between 1975 and 1982 came from residential wood burning, which went from 3,170 gigagrams/year to 7,060 gigagrams. In 1986, the soot produced by burning firewood in residences accounted for more particulate emissions into the atmosphere throughout the United States than all electric utilities, railroads, aircraft, and vessels put together.

And what of the developing sector, where for lack of infrastructure people are stuck with the so-called appropriate technology of burning biomass as cooking and heating fuel? The same environmentalists who fear the CO_2 increase propose more of the same—biomass as fuel instead of fossil fuels or nuclear energy.

ditions of the forest floor, fallen leaves and twigs and other organic matter rapidly disappear, in contrast to the thick mat of organic materials found in temperate climate forests. Every nutrient—for example, nitrogen, phosphorus, potassium, and calcium—is immediately recycled before it is washed away by the rain. If a leaf falls, the insects, bacteria, and fungi that live in symbiotic relationship with the roots of the trees will digest it immediately, returning the minerals and nutrients necessary for growth back to the canopy. In the canopy itself, there are epiphytes, plants that capture all necessary nutrients and minerals from the surrounding air.

Nitrogen is captured from the atmosphere by bacteria and converted into ammonium, which other microbes convert to nitrates that can then be absorbed by plant roots. Nitrogen is thus recycled by the ecosystem, but the rapid decay of organic matter means that nitrogen is quickly depleted when the forest is cut and burned down.

Much of the phosphorus in tropical soils is chemically bound to the clay. Once in the clay it is very difficult for roots to absorb the phosphates, so roots seek it in the surface, one of the reasons the floors of some tropical forests are carpeted by a thick mat of fine roots at the soil surface. Phosphorus uptake is also facilitated by mycorrhizae, which grow closely associated with root cells. The fine network of the fungus more quickly and thoroughly penetrates the soil and freshly fallen litter than do plant roots. Through these mycorrhizae, plants are able to obtain sufficient phosphate for growth in otherwise nutrient-poor soils.

Table 4
EMISSIONS OF BRAZILIAN RAIN FOREST BURNED IN 1987, COMPARED TO U.S. POLLUTANTS
(estimated in millions of metric tons)

Substance	Burning rainforest* (a)	(b)	Total U.S. pollutants 1986**
CO_2	518.00	1,897.32	—
CO	44.03	102.65	60.96
POC (particulate organic C)	4.09		—
EC (elemental C)	1.14		—
NO_x	1.09		19.23
NH_3	0.48		—
SO	0.17		21.23
K	0.17		—
TPM (total particulate matter)	6.22		6.71
O_3	2.49		—
CH_4	4.66		—
CH_3Cl	0.012		—

*Source: Alberto Setzer, Relatorio de Atividades do Projecto IBDF-INPE "SEQE"-1987.
**U.S. Environmental Protection Agency, *National Air Pollutant Estimates, 1940-1986.*

The emission of carbon dioxide from the burning of the Amazon rain forest in one year is nearly half the total estimated carbon dioxide pollution worldwide. The figures in column (a) include only the molecular weight of the carbon, while the figures in (b) include also the molecular weight of the oxygen. The U.S. figures all include both carbon and oxygen.

Senator J. Bennett Johnston, a Louisiana Democrat, opened Senate hearings on the greenhouse effect Sept. 20 by advocating the appropriate technology route. He asked how "to convince newly developing countries to forego economic and industrial expansion that developed nations already enjoy in the interests of a future global environmental threat? . . . We must seek to ensure that Third World development funded by industrialized nations is not wreaking havoc on the world's environment."

The Rapidity of Desertification

There are two major reasons why the areas where rain forests have been either cut or burned down become desertified so rapidly. The first is the very poor quality of the soils under the forest canopy. The second is the volume of rain that falls—several feet a year. Once the forest cover is removed, severe erosion occurs and whatever nutrients were above ground—like the remains of burned plants—or in the soil itself are leached and washed out in a short period of time. With the root and fungus network no longer in place to capture nutrients released from decaying vegetation, nutrients cannot be regenerated.

Because the soils are unconsolidated—the only thing holding them together, the rain forest, is gone—enormous amounts of erosion take place. The forest mat no longer captures and stores the water, and landslides become very common in the hillsides. It has been calculated that an average hectare of rain forest loses approximately .5 kilograms (1 pound) of soil due to erosion per year. If that forest is cut down, the same hectare may lose up to *14 metric tons* of soil per year.

Extensive flooding, such as the severe and recurrent flooding in Bangladesh, is caused by the deforestation of Nepal. The same phenomenon is happening to the Amazon River, which is cresting several inches higher every year and now flooding areas that had been dry for centuries. The amount of silt discharged by the Amazon has increased enormously, covering the formerly white beaches of Surinam and French Guyana, several hundred miles to the north, with a thick cap of mud. The change in the discharge of the Amazon has also had unpredictable effects on the marine life of the Atlantic Ocean.

The rain forest can reclaim a small plot of land rather quickly. When the area becomes larger, however, the rain forest cannot recover. Thus, tens of millions of hectares of Brazilian rain forest have now become desertified.

Rogelio A. Maduro, a geologist by training, has participated in several studies on development in Ibero-America.

Notes

1. An interview with Alberto W. Setzer appears on page 28.
2. The best overview of this subject is found in *The Climatology and Hydrology of Amazonia* (Oxford: Pergamon, 1985), by Brazilian scientist Eneas Salati, from which these figures have been taken.

Biotechnologies exist to increase productivity, from growing food crops resistant to frost to those that grow in salt water. Now is the time to push ahead on these frontiers, to make sure we are ready to meet the food needs of the 21st century.

Walt Disney World ©1988

New Technologies To Feed a Growing World

by Marsha Freeman

Every year, millions of people see the frontiers of research in agriculture in action at a seemingly unlikely place: The Land exhibit at the Epcot Center in Florida's Walt Disney World. Dedicated in 1982 by Kraft Foods, Inc. and the Walt Disney Company, the six-acre pavillion is the world's only major display of food and fiber crops from all climate zones under one roof. In addition to exhibiting the crops grown in different climates around the world, The Land scientists are collaborating with scientists from the nearby NASA Kennedy Space Center to solve a variety of problems in agriculture.

Man is currently using about 350 plants in agriculture, which is less than one tenth of 1 percent of the more than 350,000 plants on Earth, according to The Land's agricultural systems manager, Dr. Henry Robitaille. One of the reasons Kraft is sponsoring The Land exhibits is to "help to dispel doomsday prophecies about the future availability of food," Robitaille said.

The frontier technologies demonstrated to the public at Disney World could indeed beat back the Malthusian predictions of doomsday—if they are widely applied to agriculture as quickly as possible. The frontier research areas on exhibit that are important for their ability to increase agricultural productivity here and in the developing sector include:

Drought-tolerant crops. The Land's Desert House has crops under cultivation that are drought tolerant, but not now widely used in all arid parts of the world. One such plant is the rapid-growing Leucanena tree, which is grown to demonstrate its use in reclaiming eroding desert areas. This tree, a member of the legume family, develops a symbiotic relationship with bacteria that fix nitrogen from the air and make it available to plants. This allows the crop to thrive in nitrogen-deficient soils, which is an important factor for a desert environment.

Salt-tolerant crops. Halophytes, or salt-tolerant plants, are also under cultivation at the Desert House; their development could make available crops that can be irrigated with salt water in areas of the world where fresh water is scarce.

Non-soil-based agriculture. The Kraft exhibit shows extensive cultivation using non-soil-based agriculture in greenhouses or closed environments. These include hydroponic systems, where the plants are grown in a liquid nutrient medium, and aeroponics, where the plant roots are in the open and periodically sprayed with a nutrient solution.

Astroponics. The application of these non-soil-based technologies to space is called astroponics and the closed-environment agriculture is being done in conjunction with scientists working on the problem of growing food in space, where the entire biosphere for the plants will have to be created and controlled by man.

Disease elimination. Integrated pest management, the elimination of plant disease, and optimized productivity are all under examination in the Production House exhibits at The Land.

Tropical food crops. In the Tropics House, there is a display of little known crops that have a high food value and could be adapted to tropical climates to increase food production in developing nations. This includes the winged bean, with its seed containing up to 37 percent protein, that has the potential to become the "soybean of the tropics."

Biotechnology. Kraft announced the opening of a new exhibit to the public Oct. 7, 1988—a biotechnology laboratory for basic scientific research that will be field tested in the exhibit's growing areas. The laboratory, developed by Kraft, Disney, and the Agricultural Research Service of the U.S. Department of Agriculture, houses thousands of plantlets that have been created through cloning, genetic engineering, and other biotechnology techniques.

New kinds of plants as well as new methods of hydroponics, aeroponics, pest management, and biotechnology are on display at The Land exhibit sponsored by Kraft Foods at Walt Disney's Epcot Center in Florida.

Salt-Water Plants to Make the Deserts Bloom

Imagine the possibilities if we could turn salt-damaged land to fertile growing areas. Worldwide an estimated *2 billion* acres have already been lost to salinity. This loss of cultivated land adds to the spread of marginal and desert regions and adds to the unstable weather effects resulting from the lowering of high-quality water and energy throughput in the biosphere from man-tended agriculture. In the United States alone, nearly 300,000 acres of cultivated land are lost every year because of salt accumulation. Most of this occurs in fertile California, where intensive irrigation with poor drainage has left mineral deposits in the soil.

In addition, there are about 30,000 miles of desert coastline in the world that could be productively developed for agriculture, were salt water used for irrigation. According to researchers in the field, the two resources most necessary for high productivity in terrestrial plants, sunlight and water, are the two most abundant resources available in a large portion of the unused land area on this planet. These regions include the entire Mediterranean coast of Africa and part of the coastline of South America, both of which could be developed to increase food production where it is desperately needed. Where desalination of salty or brackish water is currently uneconomical and the infrastructure is unavailable, large acreages of unused land could support the growth of halophytes (salt plants) with just the use of pumps and pipelines.

Agricultural scientists are researching the problem of increasing the salt-tolerance of domesticated crops to reclaim salinized land. However, increasing the salt tolerance raises the energy consumed by the plant, which decreases the productivity in terms of yield.

The halophytes concentrate salt in the leafy part of the plant and produce seeds that are not salty. These plants could be hybridized to produce domesticated species that would optimize the most desired characteristics of a number of different naturally occurring species. The leaves could be used for animal feed and forage, and the seeds could be used for flour meal, vegetable oils, and industrial products.

At the Arizona Environmental Research Laboratory, Ben Gurion University of the Negev in Israel, and the University of Delaware, scientists are looking at the potential of using plants that have a naturally high salt tolerance. Some plants,

such as *chenopdium quinoa,* which was cultivated in the Andes for hundreds of years, have a protein content higher than our major cereals and an amino acid composition that is better balanced.

Several candidate crops have been irrigated with seawater in these experiments. The most productive produced between 8 and 17 tons of produce per hectare, comparing favorably with the common feed crop of alfalfa irrigated with fresh water, which produced between 5 and 20 tons. However, the halophytes have a high ash content, which reduced the actual dry weight to about 12 tons per hectare—still a respectable level of productivity.

The crude protein levels of the halophytes have been found to be between 10 and 24 percent, again comparable to alfalfa which is in the 12 to 22 percent range. The high salt content of the halophyte vegetative tissue, which would make animals thirsty, can be successfully fed to animals in a mixture that contains only a 25 percent halophyte component.

The University of Arizona research team has grown experimental potential forage or fodder crops with hypersaline water in Mexico's Sonora desert. The hypersaline water was taken from a shrimp aquaculture facility that had increased the salinity to 40 parts per thousand, which is higher than seawater. This water was then used to irrigate crops on beach sand with high-volume, high-frequency irrigation. Productivity varied widely among the various species, with the best results coming from native species. In fact, some native crops had productivity and protein content in the alfalfa range.

It has also been found that halophytes grown in less salty water—brackish water rather than seawater—expend less energy storing the salt, which doubles their growth rate. Dr. James O'Leary in Arizona and other researchers are currently collecting and studying many species of halophytes so that they can start selecting some for breeding and genetic improvement.

Halophytes like salt brush have the potential to stop the spread of the world's deserts by creating a green barrier to the cycle of desertification. Other species can be used to reclaim formerly cultivated land, and still others will allow some of the richest but water-poor soil on the globe to be cultivated for the first time.

Zeoagriculture for Earth and Space

Farmers in the United States and the rest of the advanced sector spend a large amount of time, money, and resources increasing crop productivity through the addition of fertilizers, pesticides, and herbicides to the soil. Scientists are now developing a group of naturally occurring mineral crystals to do this job. Known as zeolites, these crystals can act as a time-released source of fertilizer and can also be "doped" with various chemicals to easily deliver nutrients and other treatments to crops (Figure 1).

Increasing Agricultural Productivity to Feed 6 Billion People

U.S. farmers do *not* grow too much food, as the drought of 1988 should have made clear. The fact that more than 90 million acres of farmland were taken out of production in 1988, combined with the heat and drought, has left the United States and other food-surplus nations without the buffer stocks to meet world food requirements this year.

According to agricultural policy specialist Dr. Don Holt, director of the University of Illinois Agricultural Experiment Station, 40 percent of U.S. seed, fertilizer, farm machinery, and other supporting infrastructure has been shut down, and the public "intervenors" have been allowed to delay and even halt the application of new technologies (as well as old ones) to production. About 35 percent of our most productive land has been "set aside." As a result, 40 percent of U.S. farmers' income on average comes *not* from growing food, but from the subsidies that are supposed to *substitute* for growing food.

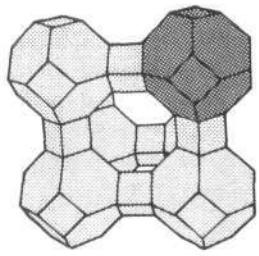
The last few years of relatively good growing conditions have allowed so-called policy experts to promulgate the idea that advancements in productivity were *the problem* with American agriculture. In the words of Dr. Holt, "It was a black day in the history of this country when productivity became a bad word in agriculture."

The Reagan administration policy, through the U.S. Department of Agriculture, has been that "all the important productivity problems have been solved for the next 50 years," and that the mythical "private sector" should take care of applying research breakthroughs to farming. Now we are faced with a global crisis, where increasing numbers of people in developing nations will starve and food for the rest of us will be priced beyond our pocketbooks.

To feed the more than six billion people the world will have by the turn of the century requires an increase in the global productivity of agriculture. This means bringing the developing sector up to the level of the more technology-intensive advanced sector, as well as applying the latest scientific developments to aid productivity. We now have the technology to reclaim destroyed and currently marginal land and to improve the energy and water throughput of the biosphere.

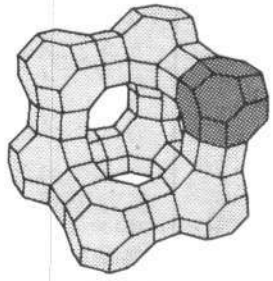
We also have the technology to make plant species themselves more productive; to increase the variety of plant species; to more efficiently apply fertilizers, pesticides, and water to crops; and to increase stress-tolerance in plants while lessening that stress by improving the weather and undoing the damage of destructive land-use policies.

All that is missing is the political will to get the job under way.



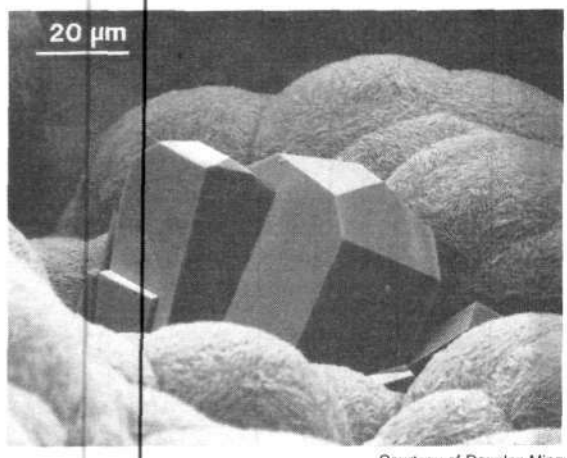
Zeolite A

(a)



Faujasite

(b)



Courtesy of Douglas Ming

Globular clinoptilolite

Figure 1
THE GEOMETRIC STRUCTURE OF ZEOLITES

The naturally occurring mineral crystals (a) have large central cavities that allow the passage of small molecules into the crystal through a network of pores. Useful minerals can thus be taken inside the crystals without chemical combination and then released into the soil. Schematics of two varieties of zeolites are shown.

A spectrographic picture of the zeolite globular clinoptilolite is shown in (b), on a scale of 20 micrometers. Part of the tetrahedral stucture of the crystal is visible. This sample was mined in San Miguel, Tex.

Zeolites are found in deposits all over the world and have been used for centuries as a constituent for cement construction, although not much was known about them. Zeolites are currently being used in greenhouse agriculture in Bulgaria, in open fields in Cuba, and as an animal dietary supplement in Japan. However, their potential use in agriculture has barely been explored.

The zeolite minerals lie close to the surface and can be easily mined. More than 50 species of natural zeolites have been located in 2,000 separate deposits in 40 countries, occurring largely in soils that have been influenced by or developed from volcanic materials. In addition, about 150 zeolite species have been created synthetically for use in industry. Because they can change composition without altering their basic structure, zeolites are used as catalysts. And because they can capture selected molecules through the channels in the crystal that lead to void spaces, zeolites were developed for use by the U.S. Atomic Energy Commission in the 1960s to remove radioactive cesium and strontium from nuclear waste, in a process called molecular sieving.

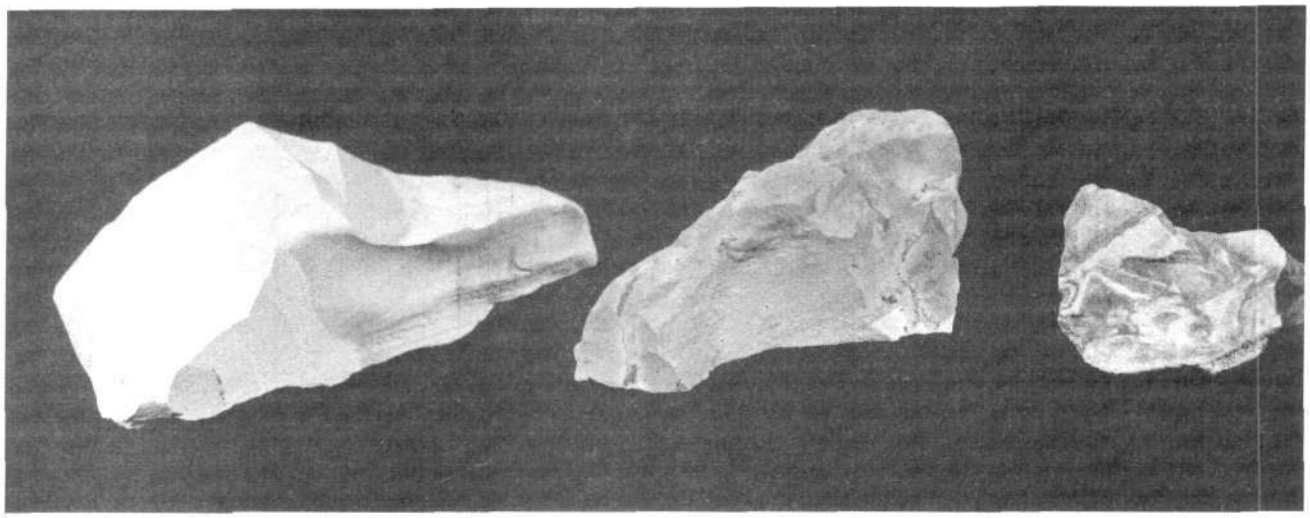
Zeolites were discovered in 1756 by Swedish mineralogist Baron Axel Fredrick Cronstedt, who named them from the Greek words meaning "boiling stones." The reason was the observed frothing effect when zeolites were heated. Zeolites are crystalline, hydrated aluminosilicates. They lose and gain water reversibly when heated, and exchange constituent cations (positively charged ions or molecules) without major changes in structure.

The framework of the crystal is made of silicon oxide and aluminum oxide molecules, arranged in a tetrahedral geometry that is described as an infinite three-dimensional structure. Because of an imbalance between the silicon and aluminum, the crystal is negatively charged. This geometry creates open space inside the crystal, with a void volume between 20 and 50 percent of the crystal. A network of channels or pores leads into the void space.

Loosely bound molecular water is present in all zeolitic structures and is between 10 to 20 percent of the weight of the crystal. When heated to about 400 degrees Celsius, the crystal dehydrates, allowing small molecules to be adsorbed (taken in but not chemically combined) in the open cavity. However, even when the cavities are hydrated, cations of sodium, potassium, calcium, and other minerals, are inside the zeolite to balance its natural negative charge.

The zeolites can be coaxed to give up these useful minerals or exhange cations when they are washed with a strong solution of another cation. This allows the crystals to be loaded, or "doped," with a variety of molecules that are important in agriculture. The desired molecules are then released into the soil over a period of time. All of these unique qualities make zeolites attractive for a number of applications in agriculture.

The Japanese have been using zeolites in agriculture since the mid-1960s. The crystals are important in both releasing to the soil useful elements they may naturally contain and as a carrier for inserted soil supplements, such as fertilizer. The Japanese not only mine zeolites for themselves, but



Samples showing the diversity of natural zeolite. (From left) clinoptilolite from Tilden, Tex.; clinoptilolite from Green River, Wy.; and chabazite, from Bowie, Ariz. Samples courtesy of Douglas Ming.

also export a small amount annually to Taiwan. In 1968, the Japanese reported increased yields with the use of the zeolite clinoptilolite, which has potassium and sodium cations. The addition of 40 tons per acre of clinoptilolite with standard fertilizer, for example, increased the nitrogen available to plants in rice paddies by 63 percent. The zeolite acts as a time-release agent in the soil.

In the 1970s, the Japanese further reported that they were able to increase wheat yields by 13 to 15 percent, eggplant by 19 to 55 percent, apples by 13 to 38 percent, and carrots by 63 percent—simply by adding between 4 and 8 tons of zeolite per acre. In U.S. greenhouse experiments, there were similar results: The weight of radishes was increased 59 percent as more nitrogen was available to the plants.

In Bulgaria, an extensive project managed by the State Trust Mineralagro uses clinoptilolite as a soil substrate for greenhouse peppers and strawberries, although few data are available to the West. The Cubans, however, appear to have done the most intensive experimental and operational research with zeolites. As reported by M. Castro in a 1988 presentation on soilless culture, the Cubans are using zeolites in open-air hydroponic production fields, which their tropical climate makes possible. They grew tomatoes, cucumbers, lettuce, parsley, celery, radishes, leeks, and onions using zeolites as the substrate, and compared the results for the same crops grown in the substrates usually used for Cuban hydroponics.

On the average, germination of the plants was 83 percent, compared to 64 percent for the control group, mainly because the water reserves from the zeolite particles were available to the plants. They found that the tomatoes had twice the vitamin C content as the control plants, and yield was 30 percent higher than the control. The Cubans report they are introducing zeoponics in child-care centers and schools for educational purposes, and at workplaces for consumption.

Pesticides and herbicides are also being delivered to plants via zeolites. In 1974, the Japanese reported that about 100 tons of zeolite were being used as "loaded" carriers of pesticides. The mineral was dehydrated and doped with insecticide that was released to the soil on contact with atmospheric moisture. The optimum level of application, frequency of application, size of the zeolite particles, and specific chemical pretreatments still need to be determined.

Since 1965, the Japanese have used zeolites in another agricultural application—as a dietary supplement for pigs, cattle, and chickens. They report that the zeolite increased the efficiency of the animals' feed, because it slowed down the passage of nutrients in the digestive tract, allowing them to be used more completely. Chickens required less food and water, and efficiencies increased 20 percent. In swine, there was a 25 to 29 percent weight gain, compared to the control, and food efficiency increased 35 percent. When zeolites were fed to pregnant sows, at the end of weaning the weight of the young was 65 to 85 percent higher than the control.

It has also been found that the mortality of animals is significantly reduced with zeolite supplements, even when compared to the addition of antibiotics to the animals' diet. In tests in Japan on 4,000 swine, the mortality rate went from 4 percent to 2.6 percent. According to agriculture researcher Fred Mumpton, this may be because the zeolite binds ammonia, preventing a toxic buildup in the animal, and the zeolite crystals select certain toxic heavy metals, like copper, cadmium, and lead. The removal of ammonia is also used in the treatment of animal manure, to make life more pleasant both for the animals and the farmer. Zeolites have also been tested in aquaculture, to remove excess nitrogen from closed systems.

Lunar Zeoagriculture

Although in general zeoagriculture has just recently started to receive attention in the United States, zeoponics is under serious consideration for Moon agriculture. At the second conference on Lunar Bases and Space Activites of the 21st Century, held in April 1988 at the NASA Johnson Space Center in Houston, Douglas Ming reported he had

successfully synthesized zeolites from simulated lunar soil. The lunar regolith lacks ion-exchange minerals like clay, however, and will have to be altered to support the growth of plants.

For use in space, zeolites have the advantage of being sterile; they will not introduce pathogenic organisms in space. In addition to agricultural use, they can also be used to remove materials from waste water (molecular sieving), to remove buildups of carbon dioxide and other gases from the atmosphere, and to catalyze chemicals.

As Ming noted, the Moon is one of the most barren environments for human existence compared to Earth's near neighbors in the solar system. If we develop the technologies to survive on the Moon, therefore, we will surely find we are improving our possibility of surviving on planets like Mars. The development of zeoagriculture for space applications will push forward the research in this technology, and this will help advance it on Earth, where the need to increase agricultural productivity is urgent, especially in the developing sector.

Harnessing Biotechnologies

For hundreds of years, agriculturalists have worked to domesticate varieties of plants, to maximize their positive characteristics, and to turn them into cultivated crops. This has been time-consuming work because processes like hybridization have had to wait through the natural life cycle of the plant. With the development of biotechnologies like genetic engineering, and recent dramatic advances in all of the life sciences, a multitude of procedures and tools have become available to alter plants and the microorganisms they depend upon and to change plants themselves or their environment.

For agricultural applications, plants have been cloned from tissue culture to produce thousands identical to one original; cell fusion and other methods have been used to create new hybrids; and genes have been transferred from one plant and inserted into another to alter specific characteristics, among other techniques.

Microorganisms perform extremely important functions in a plant's life, and some have recently been genetically engineered to peform those functions better. Recombinant DNA research has now produced new and altered organisms that are ready for testing on a large scale. Opposition from environmentalists like Jeremy Rifkin has delayed and interfered with testing, but hopefully reason and truth will prevail and technologies like the ice-minus bacteria described here will be commercialized.

Ice-minus bacteria. On the average, between $1 and $3 billion worth of produce per year is lost in the United States as a result of frost. This loss is mainly in fruits and vegetables, and about half of this loss is from drops in temperature to not lower than 23 degrees F.

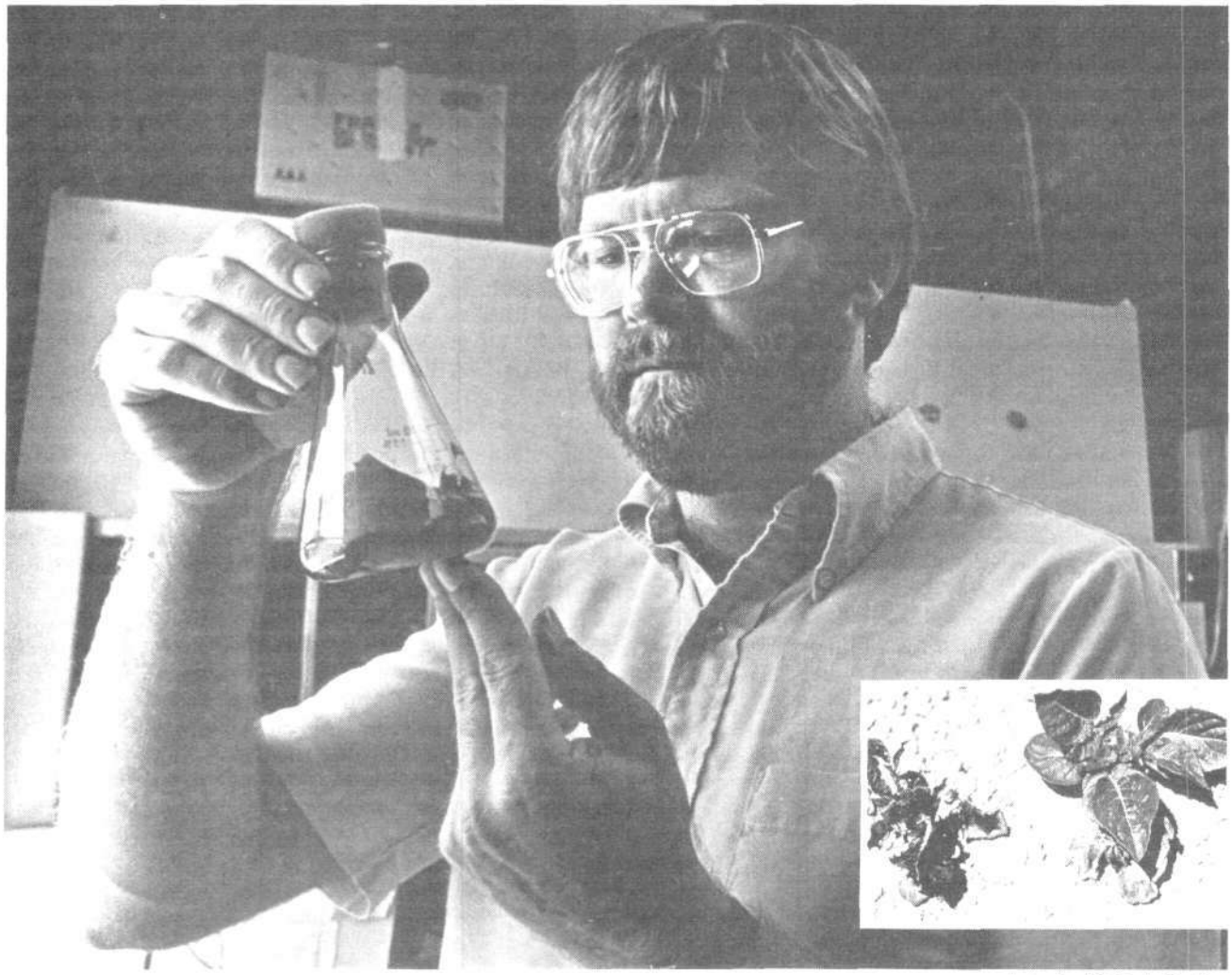
The pioneer in this research, Dr. Steven Lindow at the Plant Pathology Department of the University of California at Berkeley, estimates conservatively that about half of the loss to frost could be saved with an ice-minus bacteria he has developed and is now testing. Frost damage is triggered by a common and naturally occurring bacterium—*pseudomonas syringae*. This organism produces both a protein that serves as a nucleus for the formation of ice crystals on the plant and a naturally occurring non-ice-forming counterpart. The non-ice-forming variety of the bacteria is not abundant enough in nature, however, to displace the destructive variety.

Drs. Lindow and Nickolas Panopoulos used recombinant DNA techniques to delete the one gene that codes for the protein production in the bacteria and thereby to produce a non-ice-forming organism, INA^-, that could be applied to plants. After extensive laboratory testing of the genetically engineered INA^-, Lindow and Panopoulos obtained approval in 1982 from the National Institutes of Health to do open field testing of the bacteria on potatoes.

The method of the experiment was to "preemptively" colonize the plants with the INA^-, giving it a head start as the dominant bacteria. Laboratory testing had already established that this altered bacteria has no harmful effects on animals (including man), that it thrives only on the leaves of plants and does not live long in the soil, and that it has no observable pathogenic effects of any kind. Nonetheless, the testing of the bacteria became a cause celèbre of the antiscience faction. Conjuring up images from science fiction to terrorize people about uncontrolled "mutant" bacteria, Jeremy Rifkin and friends succeeded in delaying the tests for more than *four years*. Rifkin, president of the Washington-based Foundation for Economic Trends, is a true believer in a "steady-state society." In his book *Entropy*, Rifkin says that God created a "fixed universe" and that the law of entropy means we should not develop the technology to feed a growing world population, but try instead

Walt Disney World ©1988

Dr. Henry Robitaille, agriculture manager at The Land (right), and plant pathologist Andrew Schuerger give Mickey a lesson in astroponics—hydroponics adapted to space. NASA scientists from the Kennedy Space Center are working with The Land scientists on new agricultural technologies for both Earth and space.



University of California, Berkeley

University of California Professor Steven Lindow has developed a genetically engineered bacteria that prevents frost damage in crops down to a temperature of 23 degrees F. The ice-minus bacteria is being field-tested at the university's Tule Lake agricultural field station in California. Inset are two potato plants grown side by side; the plant at left was frost protected by the ice-minus bacteria.

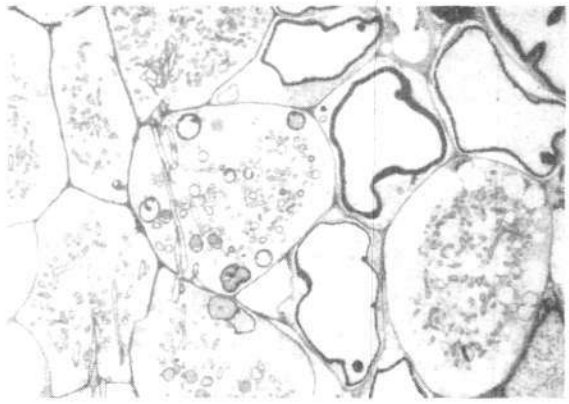
to *reduce* the world's population.

However, even with the media on his side, Rifkin did not win this fight. The Environmental Protection Agency became involved in the approval process through a series of lawsuits filed by Rifkin et al. The university spent about $.5 million on legal fees, announcements for public meetings to allay the manufactured fears of the public, educational material to distribute in the area surrounding the test plot, security guards on site during the experiment, and a multi-hundred-page Environmental Impact Report, among other things.

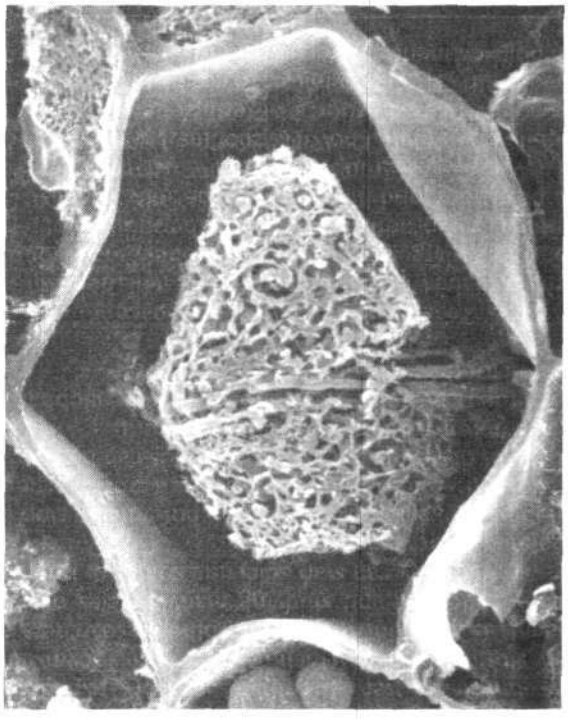
Testing finally began in spring 1987. Lindow reports that in this first year of tests, bacteria behavior was similar to the laboratory experiments and some frost protection was observed. When I asked Lindow if there were plans for testing other crops besides potatoes or testing other varieties of bacteria, he said that he had no plans at this time for further testing because it is "too expensive" as a result of the personnel to monitor the experiments, the security guards, and other regulatory requirements. During the current testing, he said, vandals uprooted 100 potato plants and the scientists had to replant them and increase security.

Nitrogen-enhancing bacteria. Other important microorganisms are being genetically engineered to increase productivity. At the University of Florida, scientists are examining the use of a blue-green algae, *cyanobacteria,* to enhance the delivery of nitrogen to plants (Figure 2). The nitrogen required for plant growth is usually supplied either by the farmer as ammonia fertilizer, or by the biological nitrogen fixation of atmospheric nitrogen by bacteria supplied to legume plants like soybeans and peas.

In the natural process, the nitrogen-fixation is catalyzed by enzymes called nitrogenase that are present in the bacteria. These bacteria produce ammonia and rather than using it for their own growth, they pump it out and make it available to surrounding plant roots. However, in naturally occurring bacteria, nitrogen-fixation is very energy intensive and the energy is taken from the plant.



(a)



(b)

Figure 2
NITROGEN-FIXING BACTERIA IN PLANT CELLS

Electron micrographs of the nitrogen-fixing Australian pine tree Casuarina. *A thin slice of root nodule tissue is magnified 1,000 times in (a), showing the filaments of the nitrogen-fixing bacteria* Frankia *that have invaded the cells. The bacteria increase the nitrogen content of the soil surrounding the tree. A cross section of a root nodule (b) at a magnification of 2,000 shows a single cell with both filaments and cytoplasm visible at the top of the cell.*

Source: Electron micrographs by R. Howard Berg, courtesy of University of Florida, Institute of Food and Agricultural Sciences, Microbiology and Cell Science Department

Dr. K.T. Shanmugum and colleagues at the University of Florida have been studying nitrogen availability in rice. In rice paddies, the free-living nitrogen-fixing bacteria do not release the fixed nitrogen, but use the ammonia for their own growth. To increase productivity, researchers have been experimenting with a mutant strain of *cyanobacteria* where the fixed nitrogen is not assimilated by the bacteria, but made available to the plant.

In these experiments, rice plants grown with the altered bacteria, SA-1, had an eightfold increase in dry weight compared to the control group, which had no nitrogen supplements. The rate of growth was 18 times higher, and not significantly different from that of plants that had been fertilized. The total nitrogen content of the plants demonstrated that the SA-1 did supply them with nitrogen for growth, because their nitrogen content was 5.8 times larger than the control group, though it was lower than the fertilized plants. In these experiments, the amount of SA-1 added was low, and it has been reported that the effect is enhanced with more concentrated treatment.

The frontiers of research in agriculture are being pushed forward in laboratories, at universities, and in industry all the time, and the research areas described here are only a small sample of what science has developed. For years, the antigrowth faction has propagandized that we have too much food, making it politically impossible to translate these scientific developments into commercial technologies for farmers here and in the rest of the world. Now as the specter of hunger is before us, we need to rapidly develop technologies to enhance agricultural productivity and thereby avoid a regression in the biosphere as a whole and the human species in particular.

Marsha Freeman is an associate editor of 21st Century magazine.

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Acknowledgements

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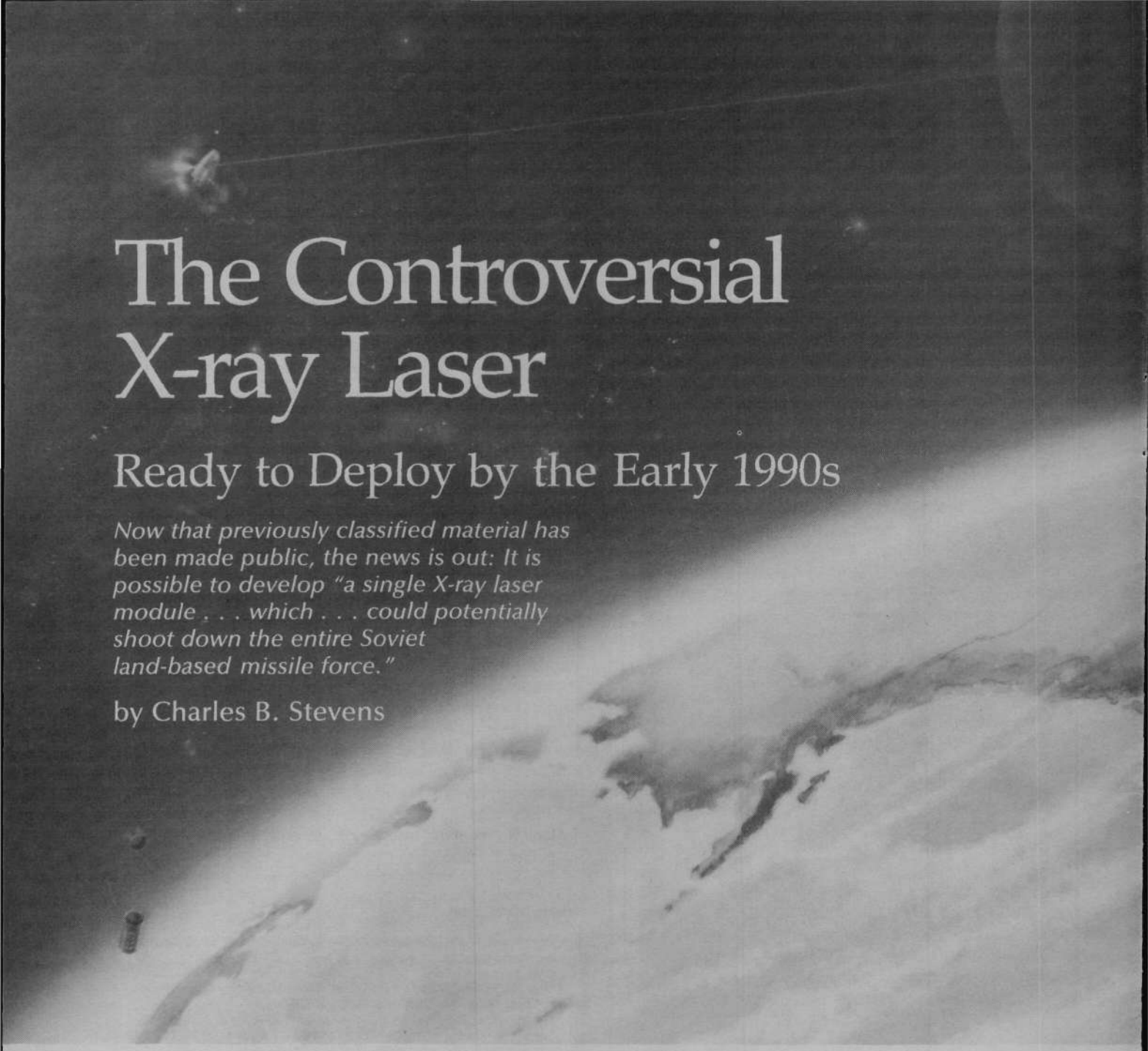


The Controversial X-ray Laser

Ready to Deploy by the Early 1990s

Now that previously classified material has been made public, the news is out: It is possible to develop "a single X-ray laser module . . . which . . . could potentially shoot down the entire Soviet land-based missile force."

by Charles B. Stevens

From the time that it was first reported as being achieved by Soviet researchers in 1977, the X-ray laser has been among the most controversial developments in the history of science and technology. At first, Western scientists failed to reproduce the reported Soviet results. The Soviet effort in this area was at least an order of magnitude greater than that of the United States. Not only had the Soviets published limited data concerning their X-ray laser experiments, but also all X-ray laser information in the open literature ceased after these initial reports of success. In fact, the Soviet X-ray laser specialists ceased publishing papers on *any* subject in the open literature after 1977.

In early 1981, reports appeared in *Aviation Week* magazine that U.S. weapons scientists from the Lawrence Livermore National Laboratory had succeeded in demonstrating in secret experiments an X-ray laser powered by a hydrogen bomb. It was suggested in these reports that this device would have major applications for defense against nuclear-armed ballistic missiles.

Two years later, on March 23, 1983, President Reagan announced his Strategic Defense Initiative (SDI) program for developing the technology to make ballistic missiles "impotent and obsolete," with its promise of ending the age of Mutually Assured Destruction. From that point on, many scientists opposed to the SDI have insisted that President Reagan's decision was based on the Livermore X-ray laser results. And many of these scientific opponents of the SDI, including those with access to top-secret nuclear data, insisted that the X-ray laser results were fraudulent. In fact, they adamantly insisted that the X-ray laser did not exist.

George Dooley/LLNL

Artist's illustration of nuclear-pumped X-ray laser beam hitting and destroying an enemy ICBM warhead high in space over the Earth.

Even more fervent than these domestic SDI critics were those in the Soviet Union. They stridently claimed that SDI defensive weapons were not possible, at the same time that they went all out specifically to stop the U.S. X-ray laser experimental effort. First, with Soviet encouragement, the nuclear freeze movement was accelerated in the West. Then the Soviets withdrew from the ongoing disarmament negotiations. Next they returned to the negotiating table and unilaterally initiated a total freeze on detectable nuclear tests, demanding that the United States put a freeze on its underground tests too.

The fervor of their effort against the SDI scaled perfectly with the intensity of their assertions that defensive weapons like the X-ray laser were not possible.

In the wake of the most recent controversy surrounding the X-ray laser and attacks on its chief scientific supporters, Drs. Edward Teller and Lowell Wood, the U.S. Government Accounting Office (GAO) issued a report in June 1988 titled "Strategic Defense Initiative Program: Accuracy of Statements Concerning DOE's X-ray Laser Research Program." In this report, the GAO declassifies a series of letters and reports from Lawrence Livermore researchers from 1983 through 1985 concerning the status and projections for their X-ray laser program. (See box, page 48.*) These official memoranda report the following:

(1) Based on a crash program, the H-bomb powered X-ray laser could be developed within a couple of years.

(2) It was conceivable that such a weapon could be eventually perfected to a point where *"a single X-ray laser module the size of an executive desk which applied this technology could potentially shoot down the entire Soviet land-based missile force. . . ."*

(3) The Soviet Union was at least seven years ahead of the West in X-ray laser development.

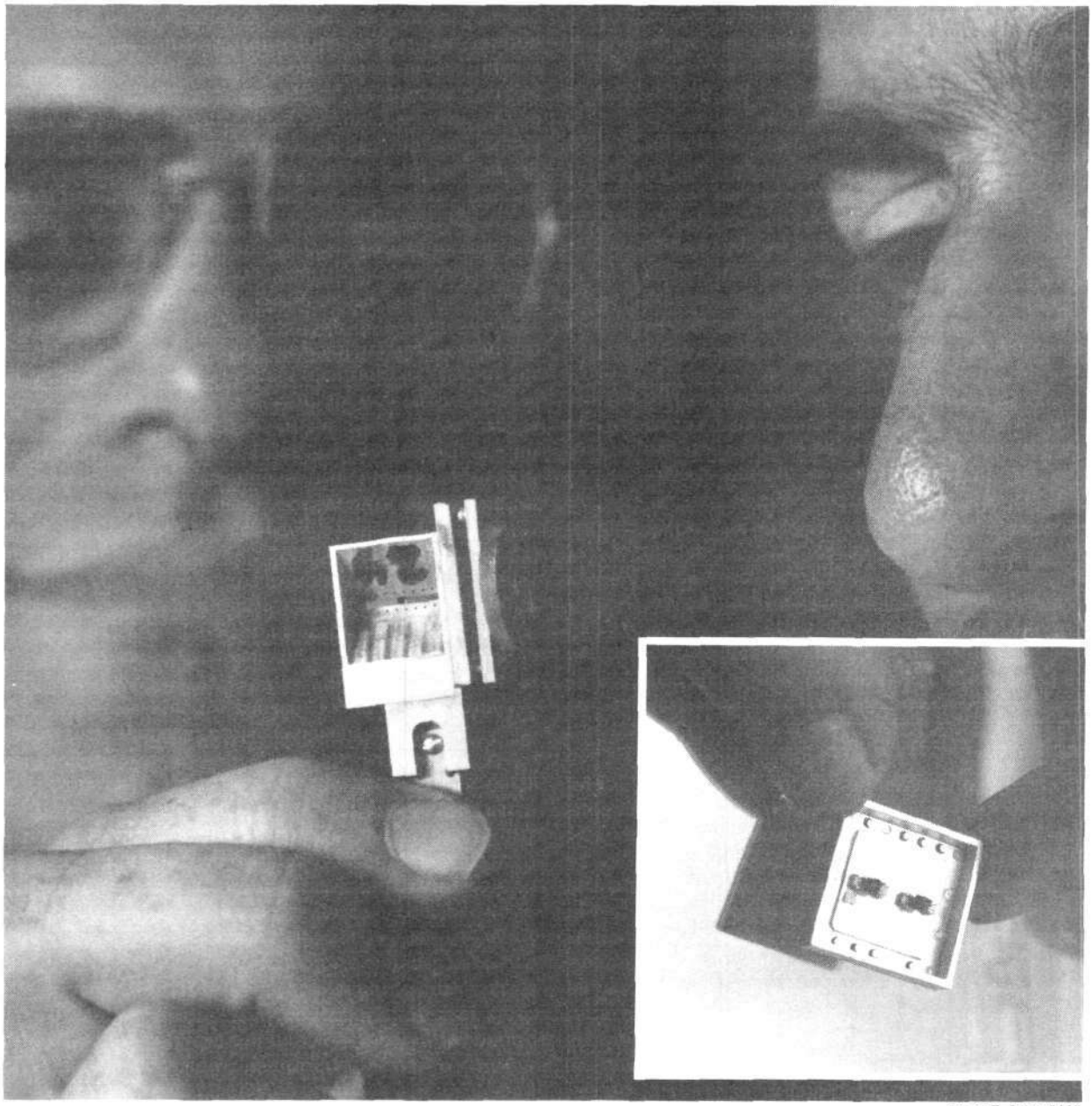
Fusion and the Potential of the X-ray laser

The fusion powered X-ray laser is not a solitary capability but is characteristic of an entire range of new directed-energy technologies that combine the inherently large energy densities of thermonuclear fusion processes with the coherence manifested by relativistic high-energy particle and laser beams. In fact, this combination provides the means for obtaining an entirely new capability for mastering the entire spectrum of electrodynamic action.

Nuclear-explosive directed-energy weapons are only the first working models for this new frontier of technology, and are apparently crude and overly cumbersome. For example, U.S. scientists have already been able to "miniaturize" the H-bomb by successfully igniting thermonuclear reactions in microscopic quantities of fusion fuel. Thus, the scientific principles for harnessing the virtually unlimited potentials of inertial confinement fusion (laser fusion) have been demonstrated. In this case a micropellet of fusion fuel is irradiated by either intense laser beams or particle beams. The action of the incident beams causes the fusion pellet to be compressed to the super densities and temperatures otherwise only found in the cores of stars. This generates the conditions for igniting thermonuclear fusion.

The resulting microscopic explosions can be readily contained and transformed into useful mechanical or electrical impulses. The process has been described as the internal combustion engine of the 21st century. But instead of burning gallons of oil, laser fusion burns just *micrograms* of readily available hydrogen. And instead of generating carbon dioxide and other potential pollutants, laser fusion generates the valuable element helium.

Inertial confinement fusion is not limited, however, to simply generating a cleaner and cheaper gross substitute for prevailing forms of energy consumption. The inherently high energy density of fusion processes also makes it pos-



James E. Stoots/LLNL

Figure 1
A LABORATORY X-RAY LASER

There are no photographs or diagrams of a defensive weapon X-ray laser in the public literature, because the research work is top secret. Pictured here is a "target" used to make soft X-rays in the unclassified X-ray laser research program at Lawrence Livermore National Laboratory. The aluminum target frame is about 1 inch by .5 inch, the size of a postage stamp. A metal-coated film is stretched across a gap in the frame that is 900 microns in length. Laser light is then focused to the central 150-200 microns of the film. (For comparison purposes, this coated film is about 60 times thinner than magnetic audio cassette tape.)

This photograph is a historic one, released in October 1984 when Livermore physicists Dennis Matthews and Mordecai Rosen announced that they had produced soft X-ray lasers from the vaporized gases of selenium and yttrium. The yttrium experiments produced amplified soft X-rays with a wavelength of 155 angstroms, the shortest wavelength at which significant amplication had ever been observed in a laboratory. The selenium laser had dual wavelengths of 209 and 206 angstroms. Inset is an enlarged view of the target.

sible to directly transform the energy output to useful forms—like electricity—at very high efficiencies, in some cases approaching 99 percent and better.

But as the X-ray laser demonstrates, this inherently high quality of energy deriving from intrinsically high energy densities is not limited to existing forms of coherent energy, like high-voltage electricity. The X-ray laser and other nuclear-explosive directed-energy weapons demonstrate that it is possible to achieve coherent pulses capable of being focused to even higher energy densities then those originally found in the generating thermonuclear process. And as Leibniz first showed, energy density correlates with productivity.

How the X-ray Laser Works

In principle, the workings of an X-ray laser are quite simple. An H-bomb primarily generates a burst of intense, incoherent X-rays. If this intense X-ray output is properly tailored, it will generate X-ray lasing action when the beams hit material containing the appropriate chemical elements. The appropriate chemical elements are enclosed in rods or cylinders that are geometrically arranged to properly receive the pulse of X-rays that comes from the detonation of the H-bomb's primary fusion fuel.

Within a few trillionths of a second, the incident X-rays convert the rods into plasmas; that is, the incident X-rays ionize the atoms of the rod. The X-ray output from the H-bomb thermonuclear plasma is not totally incoherent. It is possible to tailor this X-ray output both in terms of intensity and wavelength by the proper placement of intervening jackets (technically called *tampers*) around the thermonuclear fuel. The essential requirements are that the incident X-ray pulse be tailored such that it generates a uniform plasma column and uniform distribution of the desired ionization states in the atoms making up the plasma.

To describe the problem another way: A plasma has to be generated in which the atomic and electron elements are as well organized as those found in a perfect crystal. This must be done while the energy flux of a hydrogen bomb explosion passes through the plasma. The timespans involved are very short; the configuration must be achieved for durations lasting from only trillionths of a second to possibly a billionth of a second. Yet all of the conditions must match up during this short timespan. If not, the plasma will not generate the desired X-ray laser pulse. Furthermore, any nonuniformities could prevent the pulse, once generated, from escaping or from being directed along the path desired.

Such tailoring calls for a very advanced comprehension of energy-dense plasmas and their nonlinear interaction with electrodynamic radiation.

A more detailed analysis shows that most other laser defense systems must deliver *millions of joules* of energy if they are to assure the destruction of hardened warheads. Because of its high energy density, the X-ray laser can achieve the same result with as little as a *couple of joules* of incident energy. In the simplest terms, this is because when a sufficiently intense X-ray laser pulse hits the surface of a target, the interaction generates highly focused particle beams. The resulting high-energy particle beam will then penetrate to the interior of the target and will further focus the energy pulse during the process of absorption within the interior of the target.

This internal, high-energy particle deposition of energy is of such a form that it guarantees the destruction of all electronic elements and circuits when it achieves an energy level deposited of just a few joules per gram of target. Furthermore, the nuclear-explosive-powered X-ray laser can generate laser pulses in excess of billions of joules. This provides an accurate picture of the ultimate potential firepower of the X-ray laser against nuclear warheads—billions of warheads in principle. The essential determinant in this example is the ability to achieve the required initial level of X-ray laser beam focusing.

Benefits for the Civilian Economy

In stark military terms, it is clear that the X-ray laser and other nuclear-powered directed-energy weapons represent a transfinite transformation in the meaning and performance of firepower. The task is to apply this jump in firepower to make it possible to increase productivity in the civilian economy.

The same self-focusing properties of the X-ray laser and other nuclear-explosive directed-energy weapons that make them such powerful potential weapons also give some indication of how vast the increases in productivity will be by applying these techniques more broadly within the economy. For example, the X-ray laser is currently being perfected in a laboratory system at Lawrence Livermore in California for making atomic scale microholograms—three-dimensional pictures—of living cells. These microholograms promise to revolutionize every aspect of biological,

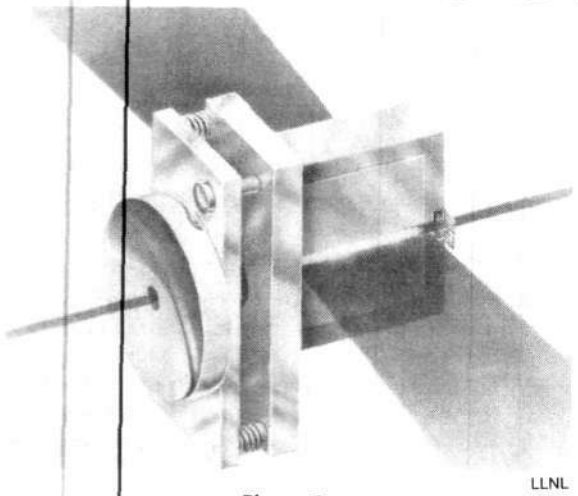


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Figure 2
X-RAY LASER TARGET

This artist's illustration shows the X-ray laser target. Two beams of the Novette laser are focused with cylindrical lenses to a line. The irradiation explodes and ionizes a foil of selenium or yttrium. The plasma gain channel, where stimulated X-ray emission takes place, forms in the exploding metallic vapor along a line between the output pinholes.

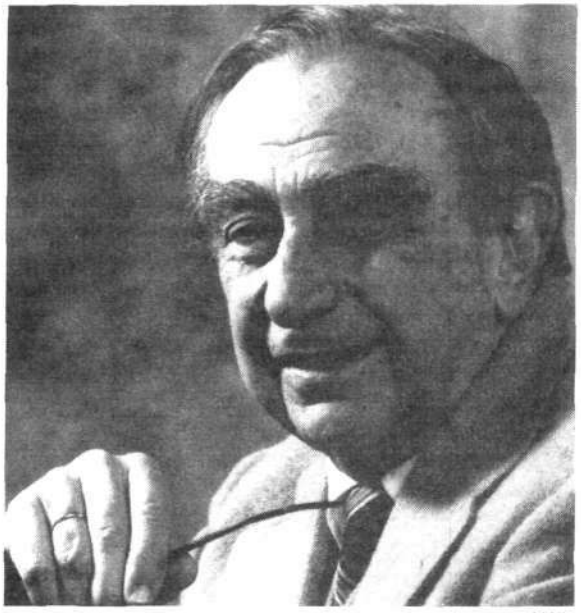
medical, and chemical science and technology.

In the simplest case, for example, atomic-scale microholograms taken with a time resolution measured in billionths or trillionths of seconds could provide in effect a "motion picture" of the way catalysis works in living biochemical processes. Insight gained from this alone could increase the productivity of the chemical industry many orders of magnitude.

On the broader horizon, the mastery of microscopic plasma and electrodynamic processes implicit in the technology of X-ray laser development can provide the essential means for generating vast leaps on the frontiers of science itself. For example, some X-ray laser experimental results on the interaction of intense X-ray laser beams with "perfect" crystals indicate that this may be a direct observation of the relative curvature of space-time, in the sense that Bernhard Riemann first called for making such measurements in his 1854 paper "The Hypotheses Which Underlie Geometry."

Mastering such measurements could lead to a new fun-

GAO Report Vindicates Drs. Teller And Wood



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United States General Accounting Office

GAO Briefing Report to the Honorable George E. Brown, Jr., House of Representatives

June 1988

STRATEGIC DEFENSE INITIATIVE PROGRAM

Accuracy of Statements Concerning DOE's X-Ray Laser Research Program

GAO/NSIAD-88-181BR

The June 1988 report that declassified the truth about the X-ray laser.

Teller: "This advance is comparable in magnitude to that involved in moving from chemical to nuclear explosives."

The June 1988 GAO report, "Accuracy of Statements Concerning DOE's X-ray Laser Research Program," presented the following summary of findings on charges that Drs. Edward Teller and Lowell Wood had exaggerated the potential of the X-ray laser (p. 3):

"We found that the LLNL official channel, which included Mr. Woodruff, had made statements about the status and potential of the X-ray laser, which were similar to most of the statements identified by Mr. Woodruff as being 'overly optimistic and technically incorrect.'

"Mr. Woodruff prepared letters to send to Dr. Keyworth and Ambassador Nitze clarifying the statements made by Dr. Teller. However, Dr. Batzel said that he preferred that Mr. Woodruff's clarifying letters not be sent [because Woodruff's letters included funding projections which Batzel did not think it proper to present to Keyworth and Nitze before sending these funding proposals through proper channels, as later detailed in the GAO report], and they were not. We found that Mr. Woodruff presented his opinions on information that had been provided by Dr. Teller to Dr. Keyworth and Ambassador Nitze. Mr. Woodruff told us he did not have opportunities to present his views to Mr. McFarlane and Mr. Casey.

"In addition, we asked selected LLNL scientists, who had specific knowledge about the X-ray laser program, for their opinions as to the accuracy of the statements challenged by Mr. Woodruff. From these interviews, we concluded there was no general agreement among these scientists regarding the accuracy of the statements. . . ."

What Teller Said in 1983

What did Teller actually tell the administration about the X-ray laser potential? The GAO report notes the following contents of a Dec. 22, 1983 letter from Teller to Presidential Science Adviser Dr. George Keyworth (pp. 3–4):

"Dr. Teller discussed the status of the X-ray laser program. . . . [He reported that] (1) three factors measured in a nuclear test were in 'essentially quantitative agreement' with predictions and (2) the X-ray laser program was, in his opinion, ready for engineering. . . . Accord-

damental comprehension of what matter represents in terms of electrodynamical physical processes—understanding the electrodynamics of subnuclear processes, for example. Although currently highly speculative, it might be possible to construct new types of crystalline states of matter such that controlled thermonuclear fusion between the lattice nuclei would result from the simple introduction of the appropriate sound wave. The resulting fusion energy output would appear as a pulse of electricity or other desired coherent energy form. In principle, this would give us a new type of battery, as small or as large as desired, which would be millions of times more powerful by weight as well as thousands of times cheaper, and it would be capable of operating for years or decades, depending on the application.

X-ray Laser Research

The first unambiguous demonstration of an X-ray laser in the United States took place in 1980 in an underground Nevada nuclear test. The experiment was highly speculative at the time and surprised most scientists, including Edward

ing to Dr. Teller, the purpose of his letter to Dr. Keyworth was to inform him that LLNL had successfully demonstrated X-ray lasing. In addition, Dr. Teller, being a theoretical physicist, felt the basic scientific question, can an X-ray laser be demonstrated, had been answered. Therefore, in his opinion, all that remained to be accomplished was 'engineering.' "

Teller's letter, now declassified, stated further:

". . . I agree that science cannot be sped up by throwing money at it. But we are now entering the engineering phase of X-ray lasers. . . . We have also developed the diagnostics by which to judge every stage of engineering progress. . . . Since there is evidence that the Soviets have started sooner and in fact may have anticipated the President's speech of March 23 by a few years, it seems to me that we are facing a potentially dangerous situation."[1]

Teller wrote in a letter to Ambassador Paul Nitze, Dec. 12, 1984 on the X-ray laser tests:

"The technology employed in this demonstration appeared to be capable of generating a beam of X-rays which, at great distances, would be as much [deleted] bright as the bomb itself. One example of its utility would be the ability to kill a target at a distance of 10,000 km which would not be killed unless it were no more than 10 km from the bomb itself; another would be the ability to kill 100 such targets at distances of 1,000 km. This advance is thus comparable in magnitude to that involved in moving from chemical to nuclear explosives. . . . As a result of work done by Lowell's team during the past two years, there appears to be a real prospect of increasing the brightness . . . of X-ray lasers relative to the hydrogen bombs which energize them . . . as large as a trillion, when directed against sharply defined targets. . . . This technology might be devastatingly effective in the midcourse and terminal phases of strategic defense, as it might be possible to generate as many as 100,000 independently aimable beams from a single X-ray laser module, each of which could be quite lethal even to a distant hardened object in flight. . . ."[2]

What the Department of Energy Said

The GAO reported the following in June 1986, in response to a May 14, 1986 request from Representatives Edward Markey and Bill Green concerning questions raised by the *Los Angeles Times* in a Nov. 12, 1985 article:[3]

"Essentially, we found the X-ray laser program is a research program with many unresolved issues. In our opinion, there was no 'design flaw' in the diagnostic instrumentation as mentioned in the Los Angeles Times article. . . . In our opinion, there was no need to delay the latest X-ray laser nuclear test. We also found that the X-ray laser program was not being arbitrarily accelerated. . . .

"Question 9: The attached Los Angeles Times article indicates that several classified reviews of the X-ray laser program have called into question earlier claims for the weapon's success. The first of these critiques was issued as far back as August of 1984. According to the article, by last summer scientists from the Los Alamos Laboratory, the Livermore Laboratory, and the Jason group had all identified serious technical problems with this program. Please examine these internal reports and interview the individuals who prepared them. Provide an assessment of these critiques and their implication for further research on the X-ray laser program. Examine whether the officials responsible for managing the X-ray laser program took these criticisms fully into account in their planning for future research and testing of this device."

The GAO reported that the Department of Energy replied to this:

"In all the classified reviews held to date, there has been unanimous opinion that X-ray lasing has been demonstrated. . . . Most of the scientific reviews have, in fact, been requested by LLNL in order to provide independent peer review of the results and progress. In all cases, we have accurately conveyed the current status of the X-ray laser program to all levels of government and the scientific community. No major disagreements with LLNL's presentation have been expressed. The outcome of the reviews have, in general, been enthusiastic support for the program as laid out by LLNL. . . ."

Notes

1. This letter appears in *Executive Intelligence Review*, Sept. 9, 1988, p. 17. It is not included in the GAO report.
2. The letter to Nitze appears in *Executive Intelligence Review*, Sept. 9, 1988, p. 19.
3. SDI Program: *Evaluation of DOE's Answers to Questions on X-Ray Laser Experiment* (GAO/NSIAD-86-140BR).

Teller, with its success. The initial weapon specifications deriving from this first-generation theoretical demonstration of X-ray lasing projected a crude device. It was thought that this device would develop a few X-ray laser beams whose poor optical quality and low efficiency in converting H-bomb energy into X-ray laser beam energy limited them to relatively short ranges (less than 500 kilometers) against relatively soft targets (like thin-skinned rockets during their boost phase, or satellites).

However, further tests demonstrated that scientists had underestimated the rate at which the nuclear X-ray laser could be improved. The areas of improvement developed along two lines. First, the dynamics of the X-ray laser lasing medium proved to be highly nonlinear. Much higher efficiencies and laser-beam optical quality levels were achieved than those originally expected. Second, innovative techniques were discovered for developing X-ray laser optics. Many scientifically esteemed critics of the SDI made the projection that such optics—the mirrors and lenses that are used to direct and focus ordinary light—for intense X-ray laser beams would be technically impossible to realize. But experiments quickly demonstrated that the opposite was the case.

Once these new potential improvements were demonstrated, as the GAO report documents, Teller and his colleagues began to radically *increase* their projections for the firepower of the X-ray laser and *decrease* the estimated timespan required to perfect the system. Then, in 1985, a Nevada test demonstrated the effectiveness of a plasma lens for focusing and directing X-ray laser beams. This test took the lid off of even the previously most optimistic projection. And although there is still a significant scientific debate on the interpretation of these 1985 results, the fact is that Teller stands by the projections he made at that time. There are also indications that new information will be released shortly concerning these experimental results.

In any case, the projection for the X-ray laser improved such that instead of projecting the development of a system capable only of intercepting slower submarine-launched ballistic and intermediate-range missiles in their boost phase, the accepted estimate was that *a single X-ray laser module could generate upwards of 100,000 individual beams, each capable of functionally disabling—if not physically destroying—the hardest targets, like reentry vehicles and warheads.*

The Opposition Strikes

Ironically, it was at the request of two anti-SDI congressmen, Edward J. Markey of Massachusetts and George E. Brown of California, that the GAO issued its report on the X-ray laser. In carrying out their campaign of slander against the SDI, Markey and Brown thought they were safe from serious retaliation because security classifications would effectively muzzle the scientific supporters of the X-ray laser. The most recent effort launched against Teller and his colleagues around the X-ray laser was supposed to spearhead the Dukakis campaign's mobilization to bury the SDI missile defense program. A secondary flank in this campaign was the proposal by Senator Nunn to replace the SDI with what he calls an Accidental Launch Protection System

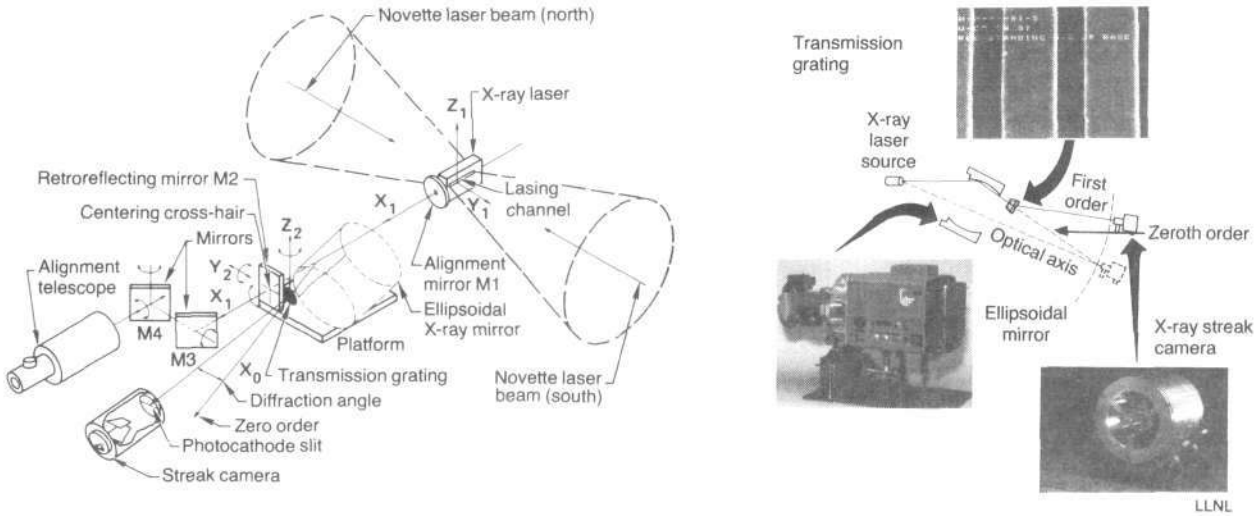


Figure 3
SCHEMATIC OF X-RAY LASER DIAGNOSTICS

These diagnostics are used to measure the output of the Livermore X-ray laser. Two beams of the Novette optical laser are shown irradiating the thin sheet of metal (shown in Figure 1) that generates the X-ray laser pulse along its length. At the front of the X-ray laser is an alignment mirror, M1, that aligns the X-ray laser with the diagnostics. Other mirrors and the alignment telescope are shown for the alignment system. Also shown at right are photos of the transmission grating that diffracts the X-ray laser pulse and the ellipsoidal X-ray mirror that permits the comparison of an undiffracted portion of the X-ray laser pulse with the diffracted portion when both arrive at the streak camera. Inset are photos of the X-ray streak camera, the transmission grating, and the ellipsoidal mirror.

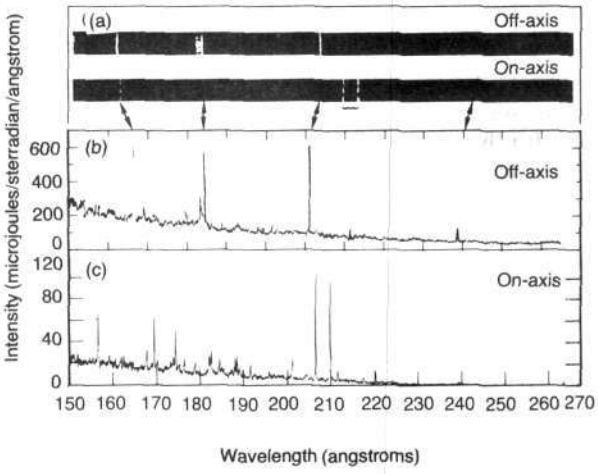


Figure 4
SPECTRAL DATA RECORDED FROM X-RAY LASER EXPERIMENTS

Spectral data from the streak camera are used to measure the X-ray laser output. The actual streak camera film data both off-axis (top line) and on-axis (second line) are shown in (a). The off-axis data are taken along a line other than the line defined by the X-ray laser beam, while the on-axis data are taken when the camera is receiving the signal along the line defined by the X-ray laser beam. The data from the off-axis film are graphically represented in (b) while the data from the on-axis film are represented in (c).

Note that there are two very large lines at 206 and 209 angstroms, which indicates a laser that has two output wavelengths. If laser action were not taking place, there would not be such a large difference between on-axis and off-axis measurements.

These X-ray laser diagnostics are systems on the frontiers of scientific theory and technological capabilities, making measurements on a spatial scale of angstroms—less than atomic radii—and timespans measured in picoseconds—trillionths of a second. These measurement resolutions also define the required tolerances for the manufacture of these diagnostics.

(ALPS), in effect a limited missile defense for Washington, D.C.

From the beginning, the critics of the SDI have zeroed in on the most secret element of the SDI, the X-ray laser. They believed that the administration would never release a sufficient amount of hard data on this most secret program to rebuff their attacks. Without explaining in any substantial way the actual potentials of the X-ray laser or the fact that the Soviets had almost a 10-year lead in developing the system, these critics simply said what the Soviets said: The X-ray laser won't work; it is a figment of some mad scientists' imagination.

This line of attack became difficult to maintain as unclassified laboratory versions of the X-ray laser were demonstrated (see Figure 1, for example). Then Dr. Roy Woodruff entered the fray. Woodruff became the source of the anti-SDI faction's supposedly hard information on how Teller and his colleagues had "misrepresented" the X-ray laser. Every statement Woodruff made was accompanied by a burst of media coverage about the Livermore turncoat who was exposing the X-ray laser "hoax." The *Los Angeles Times* gleefully titled its article on Woodruff, "The Man Who Blew the Whistle on Star Wars" (by Robert Scheer, July 17, 1988).

Woodruff was a relatively competent technician and weapons designer who rose to highest management ranks at Lawrence Livermore National Laboratory on the basis of his clever design work since the late 1960s. His wife, Mary, had been a top assistant to former Secretary of Defense James R. Schlesinger. Woodruff himself pointed out that when he saw that Teller was serious about replacing the more "traditional" mutually assured destruction policy with the SDI's mutually assured survival concept, "That's where everything . . . turned sour."

Despite the media hoopla on Woodruff's disparaging remarks about the X-ray laser, the GAO report "found that the LLNL official channel, which included Mr. Woodruff, had made statements about the status and potential of the X-ray laser, which were similar to most of the statements identified by Mr. Woodruff as being 'overly optimistic and technically incorrect.' "

Both the declassified Teller and Woodruff memoranda reveal that the X-ray laser was indeed demonstrated. Further, they reveal that with sufficient resources, starting in 1985, a system with tremendous firepower capabilities could be realized within 5 to 10 years and that the Soviets were as much as 7 years ahead of the U.S. in developing this capability.

From a military standpoint, the X-ray laser would appear to fulfill President Reagan's objective of making ballistic missiles "impotent and obsolete." In any case, the very existence of the X-ray laser as a viable potential completely and uniquely undermines the military certainty of a massive first strike with ICBMs. Given that the West has no interest in such a first strike policy, then it is not undesirable to have both the United States and the Soviet Union possess the X-ray laser capability.

In this context, it is idiotic for the anti-SDI congressmen to persist in emasculating the X-ray laser by chopping its research budget. Congress has cut the fiscal year 1989 budget request for X-ray laser R&D to $255 million, well under half the level of funding—$707 million—that was projected two years ago for 1989. Meanwhile, the same anti-SDI congressmen have absolutely not one word to say about the $20 billion Soviet SDI research program.

Charles B. Stevens, an associate editor of 21st Century *magazine, writes frequently on the SDI and related technologies.*

Note

*For a detailed account of these letters, the GAO report, and the history of the controversy around the X-ray laser, see the author's three-part series in the *Executive Intelligence Review*, Sept. 2, 1988, p. 24, Sept. 9, 1988, p. 16, and Sept. 16, 1988, p. 20.

1988 Index

21st CENTURY
SCIENCE & TECHNOLOGY
Volume 1

Editor's Note: Books reviewed will be indexed separately. Abbreviations used are *NB* for News Briefs and *E* for Editorial.

Authors

Subjects

Argonne National Laboratory

Dr. Eliezer Huberman, director of Argonne's biological and environmental research division, examines a protein map that reveals the individual proteins in blood. Huberman's work showed that active ingredients in marijuana keep blood cells from maturing, thereby reducing the body's ability to fight disease.

How Marijuana Destroys The Immune System

by John Grauerholz, M.D.

For all the pleadings of the decriminalization advocates that marijuana is a harmless "recreational substance," the fact remains that the principal active chemical in marijuana, tetrahydrocannabinol (THC), is a highly toxic substance with a number of serious side effects. Although this compound is now being touted as a treatment for glaucoma and as a painkiller, among its effects is suppression of the body's immune defenses, making marijuana smokers more susceptible to disease.

How this suppression occurred was unknown until recently. Now scientists at Argonne National Laboratory have shown that THC, and a number of related chemicals called cannabinoids, arrest the development of at least one group of white blood cells. These white blood cells, known as monocytes, are a key part of the body's immune defense system. When these cells fail to mature properly they cannot perform their necessary disease-fighting functions. The technical name for this condition is *maturation arrest,* which literally means a failure to grow up and function normally.

The Experiments

A research team headed by Dr. Eliezer Huberman used immature monocytes derived from human leukemia cells to study the effect of various cannabinoids on cell maturation. Leukemic cells were used because they represent a fairly uniform population of immature cells of a single type. In contrast, cells from normal human bone marrow represent an entire spectrum from primitive, undifferentiated forms to fully mature functional cells, making them useless for studying cell maturation.

By exposing the relatively uniform population of immature cells to the different cannabinoids and then studying changes in appearance and function, as well as a number of biochemical markers, the researchers were able precisely to evaluate the effect of the different chemicals on maturation of the cells. The three compounds evaluated were THC (the psychoactive ingredient in marijuana), and cannabinol (CBN) and cannabidiol (CBD), two other components of marijuana that closely resemble THC.

After inoculation with one of the three cannabinoids, the cells were cultured for from one to six days and then examined. Although the cannabinoid-treated cells showed several markers characteristic of maturing monocytes, three physical characteristics marked them as developmentally arrested. First, their size and shape were that of *promonocytes,* an immature, nonfunctional cell. Next, the cannabinoid-treated cells did not attach to glass as mature monocytes would do. Third, the treated cells continued to divide, unlike mature monocytes.

On the other hand, the treated cells did show biochemical and immunological evidence of maturation from more primitive forms. Thus, although THC appeared to initially stimulate development of the leukemic cells, this development was subsequently arrested before the cells became fully mature and functional. This, again, is the phenomenon known as *maturation arrest.*

These changes occurred at concentrations of THC that have been found in the blood plasma of humans who have smoked marijuana cigarettes.

There are two major consequences

of maturation arrest of white blood cells. The first, and most obvious, is that such arrested cells are nonfunctional and therefore ineffective in helping the body fight disease. In the case of monocytes, depressed function can cause a number of problems. In the bloodstream, mature monocytes ingest foreign organisms and present them to the T and B lymphocytes for further processing and antibody production. In addition, monocytes secrete a number of chemicals called *lymphokines*, which activate other immune cells.

The second consequence of maturation arrest relates to the fact that the arrested cells still possess the capacity to divide. When the body responds to an infection, for example, a number of substances are produced that stimulate the proliferation of different white blood cells from their primitive precursor cells in the bone marrow. If there is a lack of functional white blood cells because of maturation arrest, the body, sensing the lack of mature cells, will continue to stimulate the bone marrow to produce more cells.

As a result, there will be a buildup of large numbers of immature white blood cells in the circulation. If the maturation arrest is severe enough, this defines the condition of leukemia; that is, an excess of immature white blood cells in the circulating blood.

Society's 'Maturation Arrest'

These findings, along with studies that indicate that THC causes disturbances in both T and B lymphocytes, as well as reduced resistance to cancer growth and infections by viruses and bacteria, certainly call into question the judgment of those clamoring for decriminalization of marijuana.

Many of these same people are also the most vocal opponents of effective measures to control the spread of the AIDS HIV virus, another agent with profound effects on monocytes and T lymphocytes.

The human immune system is a marvelously designed mechanism for promoting human survival. However, it may have finally met its match in the systematic, suicidal stupidity of our society. Unless we deal with the "maturation arrest" of our present culture, the monocytes are not the only organisms that have a problem.

Crystals That Emit Energy

by David Cherry

Bey Wesley

Some nonconducting crystals, when squeezed, produce a small electrical current. This effect, known as piezoelectricity, was discovered by Pierre Curie in 1880, while he was investigating the properties of crystals. The current continues only as long as the stress on the crystal lattice is changing.

Piezoelectricity was exploited in developing the needle and cartridge that play long-playing records. As the needle moves along the groove and is forced to oscillate laterally as it moves, the oscillations increase and decrease the pressure on a crystal, whose varying emission of current is converted to a varying pitch.

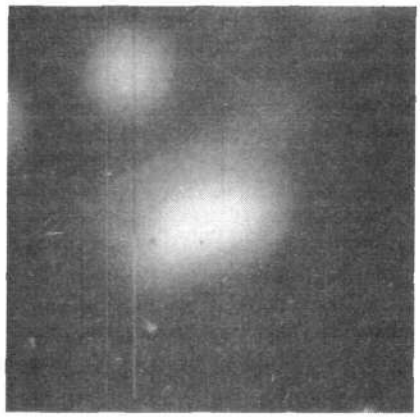
Some crystals have the less well known property of *emitting light* when they are fractured. This phenomenon may not have many practical applications, since the fracturing of crystals is not a reversible process like squeezing! But there is much to be learned about crystals, and this phenomenon, called *triboluminescence*, can be used to tell us something about the nature of crystals.

Bey Wesley of Loudoun County High School in Leesburg, Va., did a science fair project on piezoelectricity as a freshman, and in his sophomore year in 1987-1988 studied the relationship between the two kinds of energy emission—piezoelectricity and triboluminescence.

Wesley had read that piezoelectric crystals always belong to classes that lack a center of symmetry, and that triboluminescent crystals usually do. He adopted the hypothesis that strongly piezoelectric crystals would also be strongly triboluminescent.

The Experiment

The current emitted by the squeezed crystals is measured with an ammeter. But how can the amount of squeezing be controlled? Wesley's solution was an interesting one. Instead of applying a large, constant pressure—for example by pressing under a heavy weight—



PHOTOGRAPHIC CAPTURE OF TRIBOLUMINESCENCE

In his experiments, Wesley crushed single sucrose crystals as well as sucrose in the form of lifesavers. Here, the triboluminescence of a lifesaver is captured on film. Wesley says multiple blobs of light were sometimes generated by fragments landing on the film.

he crushed the crystals and read the maximum value on the ammeter. The crushing force was controlled by attaching the end of the hammer haft to a rotatable towel-rod, so that the hammer head could be lifted a standard 12 inches each time, and allowed to fall.

To measure the light emitted when crystals are crushed, Wesley developed the following darkroom procedure: He placed photographic film with an ASA speed of 400 beneath a piece of plexiglass, which then served as an anvil on which a single crystal was crushed with a hammer. The developed film was then compared to the Kodak Gray Scale to measure the intensity of the light emitted.

The crystals tested were Rochelle salt ($KNaC_4H_4O_6 \cdot 4H_2O$), quartz (SiO_2), and sucrose ($C_{12}H_{22}O_{11}$). Wesley's results were just the opposite of his hypothesis. "Sucrose, which has the lowest piezoelectricity of the crystals tested, gave the most intense light," he said, and "Rochelle salt, which has the greatest piezoelectricity, gave the least intense light." Quartz fell in the middle in both tests.

The Question of Crystal Size

One of the problems Wesley did not tackle was that the crystals in his trials were not all of the same size, and this may have influenced his results. Wesley commented that it is difficult to grow crystals to a uniform size.

It should be possible to take varying size into account by measuring the piezoelectric strength of each kind of crystal, for crystals of different weights. The result would be a curve of piezoelectric strength plotted against crystal weight. The same should then be done for triboluminescence.

Is triboluminescence really one phenomenon, or do similar-looking results arise from different causes, depending on the crystal chosen? Alan Walton, in his essay "Triboluminescence" cited below, contends the latter is true, and that should influence the design of the experiment.

Wesley sees his project as "a stepping-stone in the eventual classification of chemical bodies in their crystal forms . . . similar to the way the periodic table classifies nuclei by the number of protons." The keys to this classification, he says, are the amount of light generated and its spectroscopic variation.

In the Loudoun County (Va.) science fair Wesley took first prize in physics and won an invitation to compete for a Naval National Science Award.

Resources

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G. Walker, "A Home-made Spectrophotometer" (The Amateur Scientist), *Scientific American*, Jan. 1980, p. 150.

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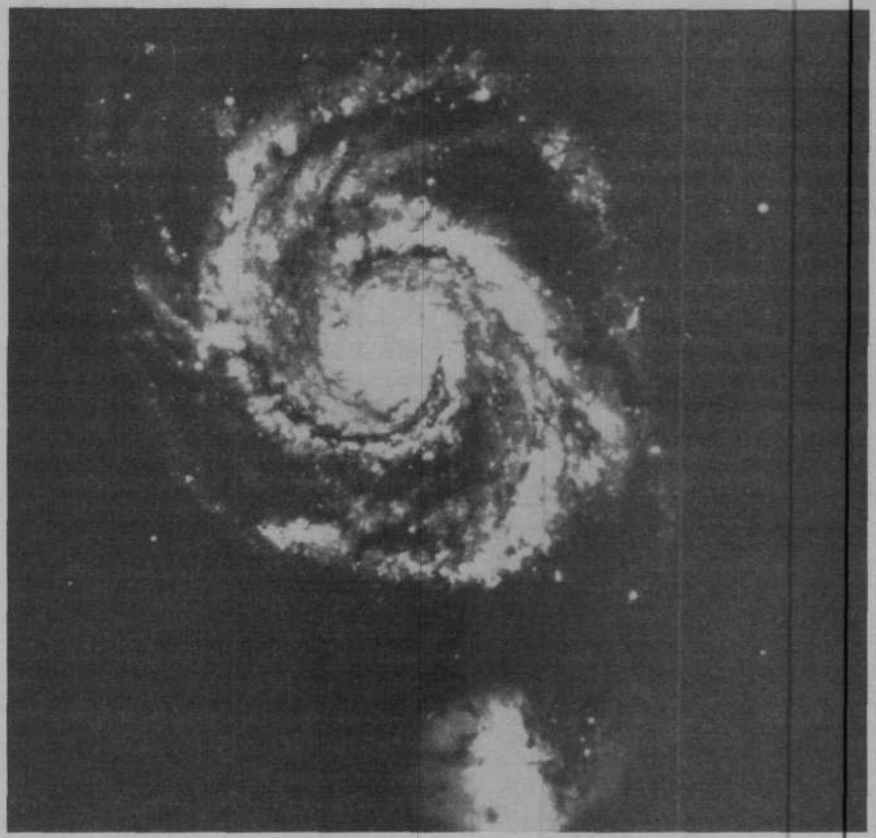
Alan J. Walton, "From Sweetness to Light," *Physics Bulletin* (Bristol, England) **29**:355–6 (1978).



A galaxy pair well known to amateur astronomers, M 51 in the constellation Canes Venatici.

How Can Astronomical Redshifts Be Quantized?

by David Cherry

If the redshifts of galaxies were found to be quantized, a great deal of what we think we know about astronomy would have to be reevaluated.

These redshifts are supposed to indicate the recessional velocities and also the distances of galaxies. If they were found to be quantized, some previously unrecognized principle—or principles—would have to be operating. Such a development should set off a burst of creativity as astronomers sought to devise tests to discover the causes and implications.

Now, with highly accurate radio-wavelength measurements, redshifts have indeed been found to show quantum behavior. Before reporting these results, the background deserves a review.

In 1912, the American astronomer Vesto Melvin Slipher discovered something special about the spectrum of the Andromeda spiral galaxy. Its spectral features (the hydrogen lines, for example) were somewhat shifted away from the wavelengths of those same features as seen in the laboratory, toward the blue end of the spectrum.

Over the next dozen years, Slipher measured such shifts in spectra of numerous other spiral galaxies. The shifts were thought to be the result of the Doppler effect: Light arriving on Earth from a receding galaxy must be shifted toward the red end (hence redshift) of the spectrum, and light from an approaching galaxy must be shifted toward the blue end.

This phenomenon was first known in the realm of sound. The sound from the whistle of an approaching train has a higher pitch until the train passes, when the same whistle, now receding, is heard at a lower pitch.

Hubble's Law

Another American, Edwin Hubble, extended Slipher's work and found in 1929 that the greater a galaxy's redshift, the greater its distance from us in linear proportion. This relation, originally based on the study of 46 galaxies, is known as Hubble's Law.

Hubble's Law had to mean that the more distant the object, the faster its recession. That was soon recognized as an essential characteristic of an expanding universe—a universe in which all galaxies are receding from each other. The same conclusion was implicit in Einstein's General Theory of Relativity.

The year 1989 marks the 60th anniversary of Hubble's discovery. A great deal of astrophysical work has been carried out since 1929, and not all of it supports the simple relationships laid down in Hubble's Law.

Tifft's Discovery

The discovery by William Tifft at the University of Arizona's Steward Observatory that the redshifts of galaxies are quantized is one of the most startling of the findings that complicate the simple picture implied by the Hubble Law. Tifft's discovery does not in itself rule out an expanding universe, but it does indicate that there are constraints on redshifts other than simple recessional velocity.

This is a conclusion that most astronomers prefer to ignore. They cannot explain it and it makes their observational work less tidy. While most astronomers simply disbelieve Tifft's conclusions, the accumulation of precision data and new kinds of tests have

only confirmed and strengthened these data.

The first indication in the early 1970s that redshifts were not behaving as expected came from studies of correlations between redshift, magnitude (brightness), and galaxy type. For the Coma cluster of more than a thousand bright galaxies, for example, a plot of redshift against magnitude disclosed an arrangement of the galaxies in sloping bands. Spiral galaxies also generally had higher redshifts than elliptical ones.

Then an entirely different kind of study led to a model involving quantized redshifts. Galaxies exhibit differential rotation—the inner portion making one full rotation more quickly than the outer. The only way to identify and measure these velocities is by means of redshifts.

In Tifft's studies of differential rotation, some galaxies showed a sharp break in rotational velocity at the nucleus or between spiral arms. The most remarkable result was that the difference at this break always appeared to be a multiple or simple submultiple of 72 kilometers per second.

(Redshifts can be expressed either as a percentage of shift with respect to the at-rest wavelength, or else as the velocity of a source that would produce that amount of shift. The latter form is used here.)

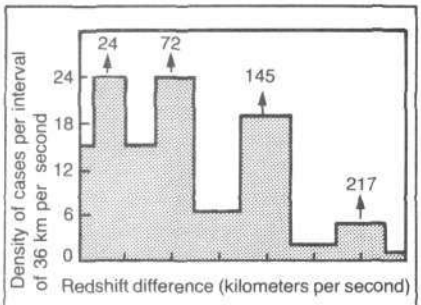
This raises the question, if actual rotational velocities are quantized, what determines their "tuning"? And again, when there are quantized nonvelocity redshifts, what is the "tuning" principle?

By 1976, Tifft had concluded that "galaxies are composites of specific redshift 'states' dominated by a characteristic redshift differential close to 72 kilometers per second."

Galaxy Pairs in Orbit

Tifft turned to the study of galaxy pairs—galaxies in orbit around each other. Because of their association, they are for all practical purposes at the same distance from Earth, with the same recessional velocity. Any difference in redshift should therefore be the result of different *orbital* velocity with respect to our line of sight.

Tifft recorded these redshift differences for many galaxy pairs. Every sort of variation in the pairs can be found.



Source: Figures are based on W.G. Tifft and W.J. Cocke, "Redshift Quantization—Many Lines of Evidence," poster paper for the June 1988 meeting of the American Astronomical Society in Kansas City, Mo.

Figure 1
QUANTIZED REDSHIFT DIFFERENCES FOR PAIRED GALAXIES

Redshift differences for paired galaxies are quantized. When a galaxy pair—two galaxies presumed to be in orbit about each other—is accurately measured for redshift using the neutral hydrogen 21-cm wavelength, the two component galaxies are found to differ. Despite the random variations in orbits and differences in inclinations of the orbital planes, the plotting of these differences does not produce the smooth curve that one would expect. Normal dynamics predicts a smoothly decreasing curve peaking at zero. Instead, the differences are bunched around multiples of about 72 km per second.

This bar diagram shows the number of cases falling in each individual interval scaled to convert observed numbers of data points to actual point density at a uniform effective bin width of 36 km per second. In this form, equal areas of the bar diagram enclose equal numbers of points. The peaks are as predicted in 1976, except that the expected peak at zero is displaced to 24 km per second. The bins are chosen to center on the peaks.

Some pairs are seen edge-on with respect to the plane in which they orbit each other. In other cases the orbital plane is seen face-on. Most cases are somewhere in between. The orbits also vary in size and ellipticity.

These redshift differences, when plotted against the frequency of their occurrence in the sample, should exhibit a smooth, downward-sloping curve. They do not. Instead, they are bunched around multiples of 72 kilometers per second. The optical spectra collected by Tifft in the later 1970s appeared to illustrate this phenomenon, but lacked the precision needed for certainty.

This state of affairs began to change in 1980 when Steven Peterson, then a graduate student at Cornell University, published a survey of radio emissions of galaxy pairs studied at the 21-centimeter wavelength emitted by their neutral (nonionized) hydrogen. This is a vastly longer wavelength than for visible light, permitting an accuracy sufficient to see a 72 km per second periodicity clearly.

Figure 1 is a composite diagram of redshift differences in galaxy pairs, using the best data currently available, both radio and optical. There are only a few chances in a thousand that this result would not be confirmed with a different sample of equal or larger size.

One Galaxy Type Globally

What if the redshifts of individual galaxies of a single type were compared globally—that is, from all over the sky? These galaxies would not be in any physical association with each other. Tifft chose the simplest kind of galaxy for the purpose of comparing redshifts—dwarf irregulars. They have high proportions of neutral hydrogen and hence can be measured accurately at the 21-cm wavelength, and they have little organized internal or rotational motion to complicate the redshift picture.

Using the Fisher-Tully survey of 21-cm redshifts of dwarf galaxies, and allowing for the motion of the solar system around the center of the galaxy, Tifft, now joined by his colleague John Cocke, found a strong periodicity at 24 km per second, one third of 72 (Figure 2). The Fisher-Tully redshifts are accurate to 5 km per second. There are only a few chances in a hundred-thousand that this pattern would occur by chance.

Dwarf galaxies from the Fisher-Tully survey with large internal and rotational motions turn out to show a similar

periodicity in multiples of 36 km per second.

Exclusion Principle

Why did the global sample of dwarf irregulars periodize at 24 km per second, while the pairs in the Peterson survey were periodic only at 72? Tifft asked. Since the latest, best data for pairs, seen in Figure 1, showed that the expected peak at zero was instead offset to 24, it seemed that identical redshifts (that is, redshifts with a difference of zero) do not occur in the limited volumes of space occupied by pairs. A pattern of such offsets could generate the global 24 km per second periodicity.

Was it possible that in limited volumes a quantum-mechanical exclusion principle was operating and that galaxies were forced to adopt redshift values offset by multiples of 24 or 72 km per second?

Tifft has devised a test using triplets of galaxies that appears to confirm this hypothesis. He has also returned to the Coma cluster of galaxies to test periodicity in a cluster. He predicted that to maintain periodicity and exclusion, redshifts would spread over a wider and wider range of 72 km-per-second steps. In regions of the cluster where the density of galaxies was low, periodicity might be expected to fade. The results are shown in Figure 3. Offset values did not appear in this test. Tifft reflects: "They may be there—buried in the 'noise,' or perhaps they aren't there. This is just an empirical first pass."

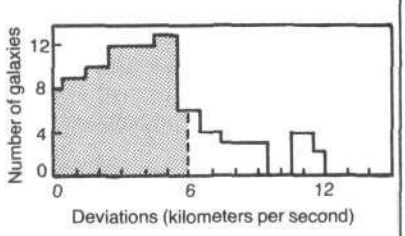


Figure 2
SMALL DEVIATIONS FROM PERIODICITY FOR DWARF IRREGULAR GALAXIES

With individual dwarf irregular galaxies from all over the sky as a sample, periodicity is strong, but the period is 24 km per second. Periodicity is demonstrated by the concentration of galaxies with only small deviations from that periodicity shown to the left of the dashed line. The individual redshifts, from the catalogue of dwarf galaxies compiled by J. Richard Fisher and R. Brent Tully (1975, 1981), were measured at the 21-cm radio wavelength and are accurate to about 5 km per second of redshift.

Astonishing Results

These results are nothing less than astonishing. Tifft emphasizes that the differences in redshift are small compared to the total redshift of the galaxies studied. Hence they do not *necessarily* rule out the total redshift as an indicator of recessional velocity or of distance.

Perhaps a galaxy's redshift is not a Doppler shift at all, but a fundamental property of the galaxy or of the matter of which it is composed. Perhaps the redshift *is* a function of velocity, but the velocity is constrained in a quantum-mechanical sense. There are other possibilities as well. In any case, there is at least one principle operating on the astrophysical scale that is unknown to the textbooks.

Some of Tifft's results have been replicated by British astronomers. A group led by William Napier at the Royal Observatory in Edinburgh reports that "Quantization does not seem to occur in close binaries and compact groups, but seems to be spectacularly present in the more widely spaced systems so far examined." The Edinburgh group believes that quantization is also a global phenomenon, not confined to dynamically coherent systems such as binaries.

Tifft says of the Edinburgh work: "The sample included quite a bit of low-quality data, insufficiently accurate to properly analyze the close pairs especially. If you have random error of more than about 20 km per second, it washes out any periodicity effects." He added, "Wherever periodicity has been found in a given sample—and when the sample was of sufficient quality—subsequent efforts to replicate the result have always been successful."

In considering the negative reaction of most astronomers and astrophysicists to the findings of Tifft and his collaborator in recent years, John Cocke, it is useful to recall the context within which Max Planck proposed the photon as a discontinuous quantum of energy in 1900. Sir James Jeans summed it up in *The Growth of Physical Science:*

"Such an assumption was in flagrant opposition to Maxwell's electromagnetic laws and to the Newtonian mechanics; it dismissed continuity from nature, and introduced a discontinuity for which there was so far no evidence." Within a few years, however, the door opened by Planck had led to important advances in understanding nature.

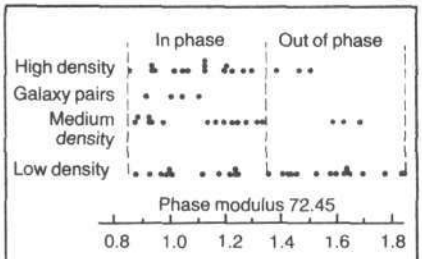


Figure 3
PHASE-DENSITY RELATIONSHIP FOR THE COMA REGION

Are the redshifts of galaxies in the galaxy-dense Coma region spaced at intervals of about 72 km per second? Here galaxies are plotted according to their relationship to the phase modulus (multiple) of 72.45 km per second. Any redshift that is an exact multiple of 72.45 appears here at 1.0, and deviations show up as a fractional remainder over or under 1.0. Tifft and Cocke consider redshifts in the range 0.84 to 1.33 to be in phase, and all others out of phase.

In low-density volumes of the region, periodicity fades. Galaxy pairs are a special case of high density.

For Further Reading

W.G. Tifft and W.J. Cocke, "Quantized Galaxy Redshifts," *Sky & Telescope*, Jan. 1987, pp. 19-21.

W.G. Tifft, "Quantization and Time Dependence in the Redshift," and W.M. Napier, B.N.G. Guthrie, and Bruce Napier, "Are Redshifts Really Quantized?" in *New Ideas in Astronomy—A Symposium Celebrating the 60th Birthday of Halton C. Arp*, F. Bertola, J. Sulentic, and B.F. Madore, eds., Cambridge University Press, 1988.

An Outdated History of Time

by Winston Bostick

A Brief History of Time:
From the Big Bang to Black Holes
by Stephen W. Hawking
New York: Bantam Books, 1988
$18.95, 240 pp., hardbound

In this book, Stephen Hawking sets forth admirably, succinctly, comprehensively, comprehendably, and anecdotally, with much wit and charm and clearly in layperson's language (only one equation!), the 1988 Papal Encyclical of the world's cosmological community. Hawking's contributions to the theory and his invaluable guidance to colleagues and students on the subject of cosmology in general, and black holes in particular, have rightfully enshrined him as the oracle and secular saint of modern-day cosmology.

He is also an intellectual citizen at large in the world of supergravity, superstrings, and the Big Bang. Not only is Hawking concerned with the mathematical and physical principles involved in the creation and evolution of this universe, but also he is fascinated with the role of the human race in the process of observing, hypothesizing, and comprehending this universe—with the ultimate goal being that of synthesizing the grand unification theories (GUTS) of the "four basic forces": electromagnetic, weak, strong, and gravitational.

Hawking follows the various inflations, clusterings and unclusterings, condensation and expansion explosions (supernovae), which are observed or hypothesized to have occurred during the 10 to 20 billion years since that (somewhat) singular boundary in time that was the commencement of the Big Bang. In many cases, he gives the "names and numbers" of the players who have labored in the vineyards in the assembling of this knowledge.

Not the least of the book's commendable features is the well-chosen brief history of the development of science up from the ancients through the Greeks, the Renaissance, Kepler, Newton, the 18th century, and the quantum theory, with special attention to Feynman's interpretation in terms of the "sums over all possible histories."

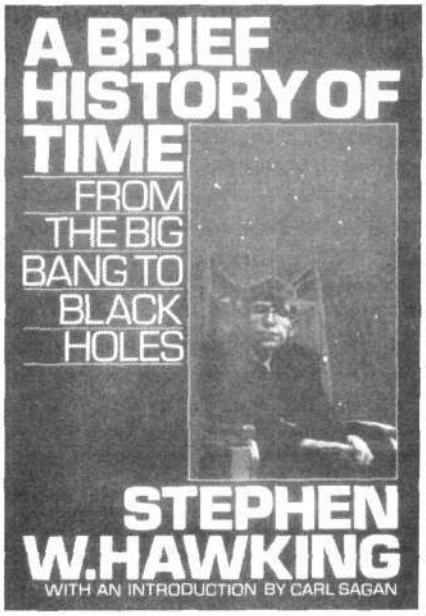
A Cosmic Omission

However, there is one valuable, fairly recent source of information that Hawking has failed to tap in the writing of his book. We do not wish to fault Hawking uncharitably for this omission. After all, no one person can be expected to play every instrument in the band. But to write a history of the cosmological processes without including what is now being called Alfvén's plasma universe would be like writing a history of Christianity without mentioning the Reformation.

Of course, the plasma universe is not the exclusive domain of Hannes Alfvén. Among others, it also belongs to the experimentalists in plasma physics who by design or luck in the laboratory have observed and documented magnetized plasma structures whose morphologies and development are unmistakably related to structures and processes observed in the cosmos.

Those experimentalists thereby obtain insights into processes that unfortunately are not available to the theoreticians who are ever obliged to generate their hypotheses on a basis of *a priori* guesses.

Fully electromagnetic, three-dimensional, particle-in-cell computer simulations of plasma processes are also providing confirmation to such laboratory-obtained insights and are generating new insights of their own. The fruit of these efforts lies in the following understandings that supplement, challenge, and in some cases surpass the conventional wisdom of the fraternity of cosmologists:



The Evidence

(1) Experiments (1956) with colliding plasma jets in a magnetic field produce barred-spiral morphologies that strongly suggest that the barred-spiral galaxy is a series-wound coherent homopolar generator that efficiently turns rotational energy into magnetic energy (Bostick 1986,1987).

(2) This constantly increasing magnetic energy of barred spirals can produce, by mutual magnetic induction, a repulsive force between neighboring galaxies that is greater than their attractive mutual gravitational force. This process can produce the Hubble expansion, thus obviating the Big Bang hypothesis (Bostick 1987).

(3) The "2.7° K blackbody" microwave background radiation ascribed to

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the Big Bang alternatively can be produced by electron synchrotron radiation from cosmical vortex filaments consisting of magnetized plasma. (Information from computer simulations by A. Peratt at Los Alamos National Laboratory, 1986.)

(4) Since 1965, laboratory experiments with the plasma focus show that nature's preferred modus for carrying electric current in a plasma is through slender, paired, force-free, minimum-free-energy plasma vortex filaments (Bostick 1986). This confirms the 1901 work by Kristian Birkeland and is corroborated (Peratt 1986) by computer simulation. This is also true in situations involving relativistic electron beams (V. Nardi 1980).

(5) The electromagnetic-ram action of the plasma focus is the laboratory paradigm for the cosmic processes generating gigantic galactic jets and cosmic rays (Nardi 1985).

(6) The self-densification of plasma and magnetic fields (~200 megagauss) in the plasma focus with the production of large clusters of ions is the paradigm of the cosmic process that transforms cosmic plasma into cosmic dust (Nardi 1986).

(7) Computer simulation (Peratt 1986) and experiments (1) and (2) above strongly suggest that a quasar is a magnetic cushion produced by two companion galaxies that are squeezing it from opposite sides. (Bostick 1957).

(8) The experiments mentioned in (1) and (2) are the laboratory paradigms for the formation of binary stars and companion galaxies, and strongly suggest that all rotations in the cosmos are initially formed by the gravitational attraction of plasma in a magnetic field. Computer simulations confirm these results.

(9) The ubiquitous plasma vortex filament noted in (4) suggests a string-like model of the electron (Bostick 1988). The de Broglie waves of the electron can readily be identified as waves on these electromagnetic strings. All mass can be shown to be electromagnetic in nature. The four basic forces can be shown to result from different morphologies of the electromagnetic strings. Photons, gravitons, and other onta can be modeled in terms of strings (Bostick 1986, 1988).

(10) It has been demonstrated (Nardi et al. 1988) that the nuclear fusion reactions of deuterium-carbon-12 and deuterium-carbon-14 can be easily produced in abundance in the plasma focus, which is the laboratory paradigm of the solar flare, thereby proving that nucleogenesis can occur in the atmospheres of the stars as well as in their interiors, in supernovae and in the Big Bang.

(11) The Titius-Bode numerical relationship that gives the approximate distances of the planets from the Sun can now be successfully replaced by an analytical relationship involving first- and second-order Bessel functions that describe the helical vectors of mass velocity, vorticity, magnetic field, and current density in a spontaneously arising, perfectly "relaxed" minimum-free-energy, force-free plasmoid. An ansatz involving hypothesized, virtual, relaxed plasmoids occupying the "vacuum" state is invoked to achieve GUTS by attributing all four forces to the magnus forces of these virtual plasmoids (Wells 1986, 1988).

(12) Lerner, with the help of Nardi, has applied plasma-focus-derived information on plasma vortex filaments to energy production in quasars, and has extended the concept of the vortex filament over the dimensional range of the classical radius of the electron to of the observable universe. He claims to be able thereby to calculate the value of the fine-structure constant to one part in 10^8 (Lerner 1986).

In addition to these contributions of plasma experimenters and computer simulators, we note the recent unmentioned work of Donald Conant and B.A. Soldano. Conant (1978) and Soldano (1985) have independently derived the correct value of the gravitational *G* and Soldano has derived the correct value of Planck's constant *h* by establishing that there is a small non-equivalence in gravitational and inertial mass.

With these quantum jumps in understanding, we should look forward to a renaissance in our ability to push on with the frontiers of science, and in our ability to communicate clearly and succinctly this improved knowledge to the common people who, in

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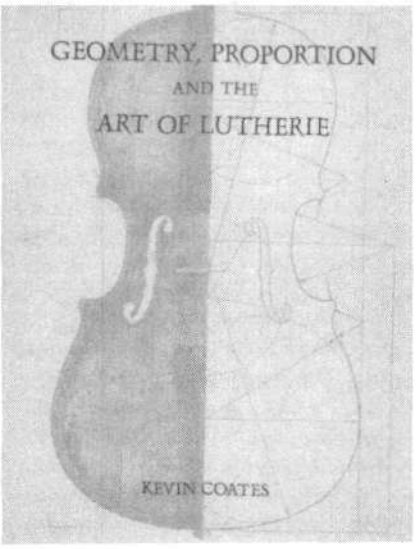
Stradivari's Golden Mean

by David Shavin

Geometry, Proportion, and the Art of Lutherie
by Kevin Coates
Oxford University Press, 1985
$69.00, hardcover, 178 pp.



Kevin Coates has compiled, in a very handsome book, a long overdue and straightforward case on the harmonic geometries that underlie the design and construction of string instruments.

In brief, Coates has mapped out the different types of proportion that account for the design features—both large-scale and rather minute—in string instruments. He examines a total of 32 representatives of 9 different string families from 1550 to 1762, and includes an analysis of a drawing of a lute that dates back to 1460.

Coates's empirical work is carefully done, well layed-out, and, taken as a first step in reclaiming the science and art of the Renaissance, an impressive and valuable contribution.

Coates calls himself a "believer" in Platonic proportion; that is, he says, in the idea that where one finds "design-interrelatedness," one also finds beauty. He pursued the origin of the design of the modern string instruments with the simple conviction that luthiers must have followed the same principles of harmonic proportions of design as did their "contemporary confederates, the architects and painters." In this regard, he explicitly references the analogous work in architecture of Rudolf Wittkower's 1949 *Architectural Principles in the Age of Humanism.*

Coates finds it time to explain to musicians some of the hidden origins of their instruments: "Imagine that this [geometric, proportional beauty] has long been suspected by many 'instrumentophiles' who, like, myself, have found just such a 'beauty' in the myriad forms of stringed musical instruments, and wondered at the strength and integrity of their shapes."

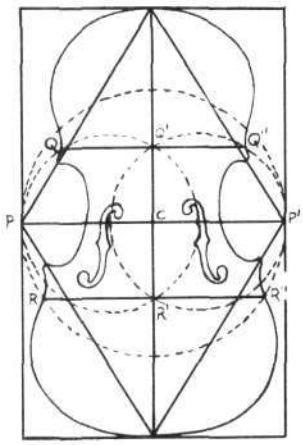
David Shavin is a professional violinist, currently working with the Schiller Institute on research into classical tuning.

An Empirical Study

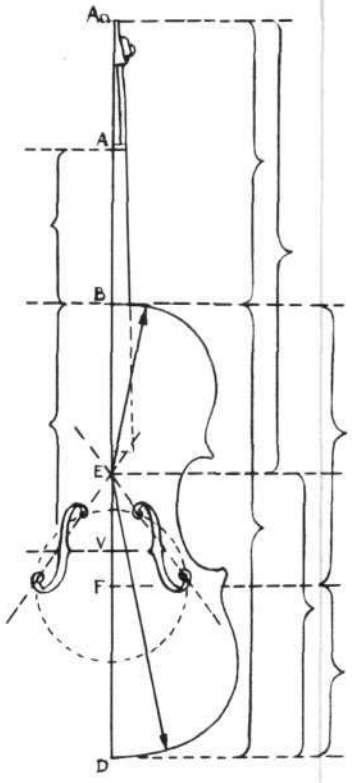
As an empirical study, the book is important and deserves much closer attention that it has received up to now. However, its critical omission is the lack of any examination, or even consideration, of the causal connections between golden-mean proportions and lased, acoustical phenomena.

Coates displays the inherent limitation of his work in his introductory section, a short history of geometry. As a "believer" in proportional beauty, he can only refer to the "mystical" qualities of the five Platonic solids, giving no intimation of the ability—or the necessity—to explore and investigate the causal connections behind them. Key leads in this respect are not followed up, nor—for that matter—even identified as key leads.

For example, Coates shows that there is a fundamental difference in the design layout of the 1666 Strad, from the 1564 Andreas Amati. Although both instruments incorporate



(a)



(b)

AMATI AND STRADIVARIUS VIOLINS COMPARED

Both violins are based on harmonic proportions, but the Amati violin (a) uses as a starting point the center of the main axis, while the Stradivarius (b) uses the golden mean point of the main axis.

harmonic proportions throughout, the Amati chooses its proportions based on the *center point* of the main axis of the instrument's body, while Stradivari initiates the primary focal point for the construction of his design at the golden-mean point of the main axis (see figure).

Such a strategic shift, although seemingly modest, can and will shift the internal ordering of the derivative proportionalities. Are there implications here that account for the unique Stradavari sound?

Now, as Coates, and many of his readers, would know, Stradivari studied under the first family of violin-making, the Amatis, who had built sweet-sounding violins for well over 100 years. However, Stradivari was able to create instruments with substantially greater power and projection and a fuller sound—one could say, the "bel canto" violin. How was this enhanced acoustical lasing capability created?

Coates views the body of the instrument as simply a piece of material upon which an interesting design is to be placed. Instead, if one views the body as the critical boundary conditions of an "acoustical laser" device, then such key design features as Stradivari's take on a wholly different significance.

Aesthetics Vs. Science

Coates does not claim to be addressing acoustical phenomena. In fact, he states in his introduction, "Above all, it is essential to understand that it will be a study of the *aesthetics of proportion* in musical instrument design, and, as such, *acoustical considerations will not arise*" (emphasis in original).

His choice of wording is the giveaway. First, nowhere else in the introduction does Coates feel compelled to give such emphasis. Second, his use of the words "as such" is even more telling. Why should Coates accept as a given that by limiting his study to "aesthetics of proportion," he *as such* has kept acoustical considerations out? Certainly, his interesting Stradivari example suggests otherwise.

One can imagine that those who wish to deny to themselves that beauty is an inherent quality of truth, and of science, will not be forcefully challenged by this work.

New Delhi Report

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dams in the upper reaches of the Brahmaputra. This plan was later discussed between India and Bangladesh but has so far borne no fruit.

An earlier proposal along the same lines had been made when Bangladesh was still a part of Pakistan. The Pakistani proposal called for building a large detention reservoir to channel the Brahmaputra all the way to the Ganges from the point where it enters Bangladesh. The total length of the channel, which is itself the detention reservoir, is 252 miles, with embankments on both sides. This plan included building a cross-dam on the Ganges and a barrage on the Padma river. But this, too, never got off the ground.

To prevent floods, it is obvious that in the long term, storage dams must be built and mountain slopes must be reforested. Dredging the beds and mouths of rivers so that they can carry the onrushing volume of water is a necessary adjunct to the more basic measures. At present, about $1.5 million is spent annually in dredging these rivers. However, the effort is too little, and as a result the investment is essentially wasted.

Ramtanu Maitra is editor of Fusion Asia *magazine.*

Research Communications

Continued from page 5

the ether can exist and have suppressed research along the lines now brought to the fore by Moon. Had it not been for such suppression we could be now enjoying use of technology controlling gravity today, without having to wait for the 21st century.

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Letters

Continued from page 4

havior of different fluids. The special usefulness of these works lies in their consistently pointing out the differences between theory and experiment. This allows the scientist to see what must be done to improve the science, and the designer to find avenues to which current theory is blind.

Hoerner was an aerodynamicist at Fieseler Corp. where, in the late 1930s, he helped develop the first STOL aircraft, the STORK. He was subsequently head of design aerodynamics at Junkers, and research aerodynamicist at Messerschmitt. After the war he worked at Wright-Patterson Air Force Base and was a consultant to the Navy on hydrofoils.

The two volumes are published by Hoerner Fluid Dynamics, 7528 Staunton Place N.W., Albuquerque, New Mexico 87120.

Robert McLaughlin
Alexandria, Va.

An Outdated History

Continued from page 61

the final analysis, support our efforts and pay the bill (and of whom Abraham Lincoln has said, "God must love them for he made so many of them").

This reviewer hopes that Stephen Hawking and his colleagues will welcome and contribute to the coming of this renaissance. We of the plasma physics trade are greatly in their debt for bringing the subject of cosmology to its present state of development.

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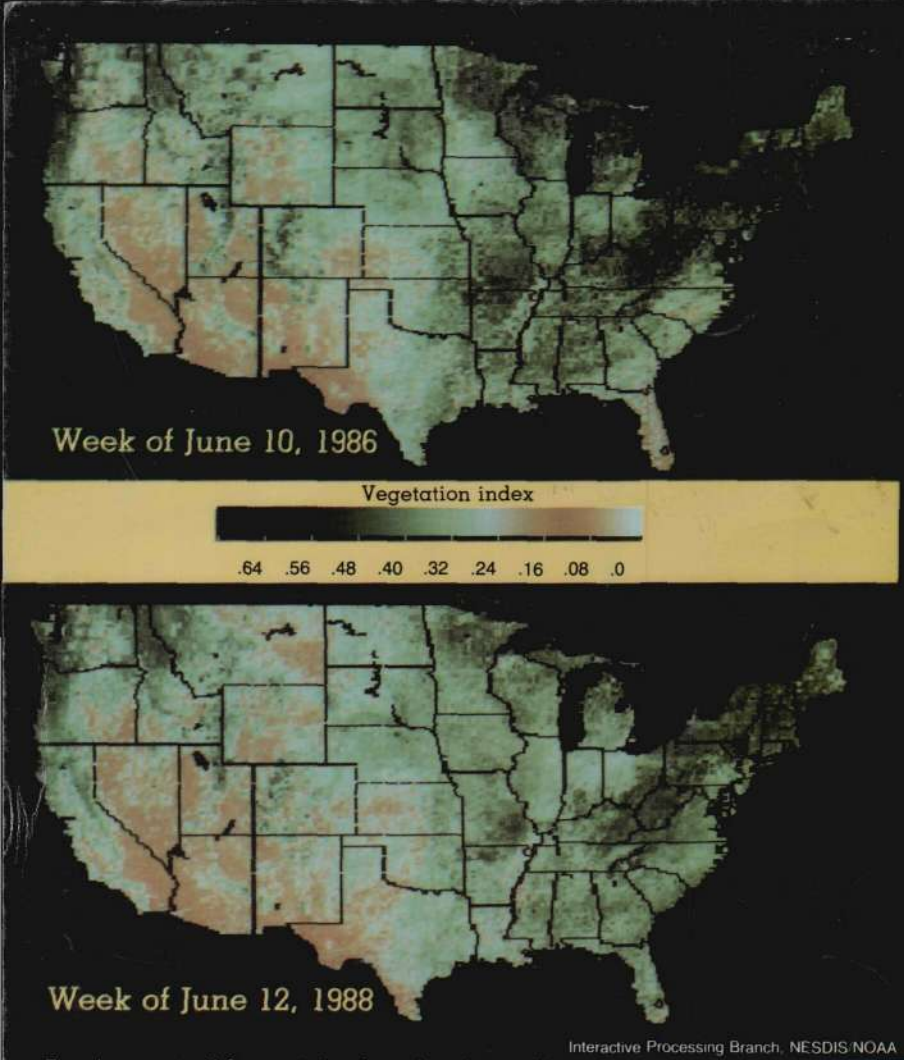


Interactive Processing Branch, NESDIS/NOAA

The damage to U.S. vegetation from drought conditions in 1988 can be seen in these computer-enhanced satellite images. Areas with a higher vegetation index are darker green; those with a lower index are lighter green to brown. For the comparison week, most of eastern Montana, North and South Dakota, and several other states are a lighter shade of green in 1988 than in 1986.

In This Issue

CAN WE IMPROVE THE WEATHER— AND AGRICULTURAL PRODUCTIVITY?

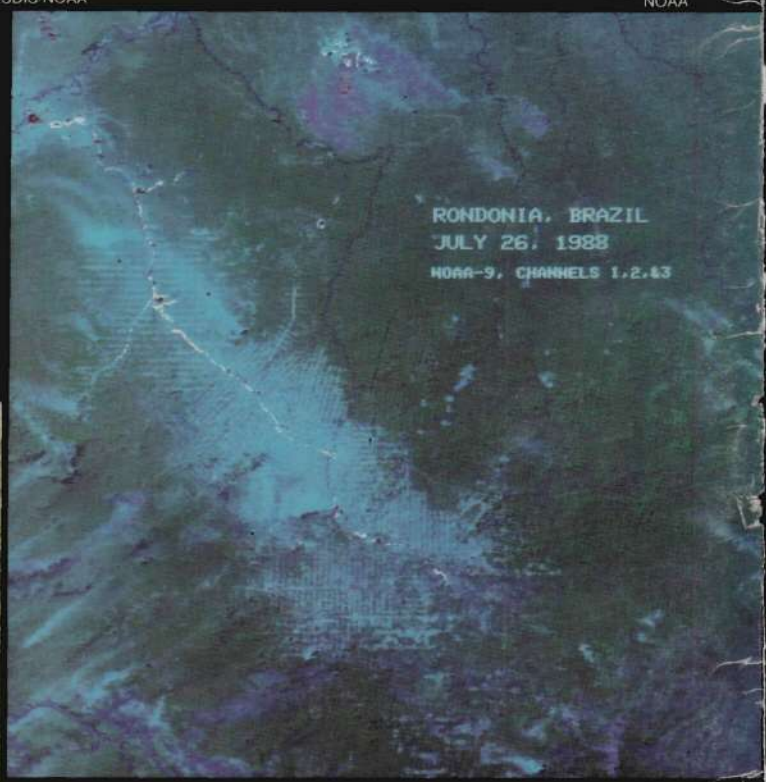
In this time of great weather extremes—from droughts and floods to the century's most severe hurricane—the obvious question is, can man improve the weather? The answer is yes, if we move the economy in the direction of advanced technology. Carol White reviews recent work in meteorology, which begins to explain the current extremes. And Rogelio Maduro makes clear that a top priority is to stop the wanton burning of the rain forests in Brazil, which is now responsible for spewing into the atmosphere almost as much in particulate emissions per year as the much maligned industries of the United States.

A related question is, can we produce enough food to end hunger? Again the answer is yes. Marsha Freeman reviews the many new and exciting technologies being developed to increase agricultural productivity.

Below: Red peppers growing aeroponically at Krafft Inc.'s exhibit, The Land, at Disney World. The peppers grow on hollow columns that move on ceiling tracks; a nutrient solution is sprayed on the roots inside the column.

Walt Disney Co. © 1988

NOAA



Computer-enhanced satellite image of forest clearing and fires in Rondonia, Brazil, July 26, 1988. The area shown is about 500 km long. The blue and white plumes are smoke, the red spots are fires, the grid patterns are cleared areas, and the white line running from upper left to lower right is a highway.